Physics CP Curriculum Maps

Grade: 11 and 12 **Subject:** Physics CP	**Unit 1: Physics Math and Measurements**
Big Idea/Rationale	• Physics is the science of understanding the movement and interaction of energy and matter in the world around us. Measurement is central to our ability to understand the world around us. The ability to carefully measure the phenomena we are studying, without mistakenly stating the accuracy of those measurements, the ability to clearly define the units we have used in making those measurements and the ability to convert to other units to compare measurements is central to our ability to do physics. • Much of Physics is about applying the concepts students have learned in algebra and geometry, from triangle math, algebraic manipulation. Reviewing these concepts is important in laying the foundation for the studies that are to come. • We innately understand images much more easily than we understand numbers. For this reason, graphing and other visualization tools play an important role in understanding physics. Understanding basic graphical relationships presents a great way to determine if a mathematical relationship exists between things we measure and to deduce the nature of that relationship. From that understanding comes the ability to make predictions about the behavior of the things we measure.
Enduring Understanding (Mastery Objective)	• Students will successfully carry out calculations to the correct number of significant figures. • Students will demonstrate an ability to carry out basic calculations with numbers in scientific notation and to translate numbers in and out of scientific notation. • Students will demonstrate proficiency with metric prefixes. • Students will use the factor-label method to convert between units • Students will demonstrate an understanding of base units vs. derived units and will define the base units of length mass and time in Physics. • Students will demonstrate an ability to define and use basic trigonometric functions to solve right triangle problems • Students will demonstrate an ability to define basic mathematical relationships (direct, inverse and exponential), describe the graphs of these relationships and how to calculate the best fit line of these relationships.
Essential Questions (Instructional Objective)	• Why is a fundamental understanding of how to properly take measurements in the world around us and make calculations based on those measurements useful in both Physics and everyday life? • How will an understanding of basic algebraic functions, order of operations, scientific notation and trigonometry help in understanding the motion of objects and Physics in general? • How can graphing relationships lead to an understanding of the nature of

	the relationship, what useful information can be drawn from graphical relationships and how can we use graphs to predict the behavior of things we measure? When is making such predictions appropriate or inappropriate? How confident can we be of those predictions?
Content (Subject Matter)	• Proper Use of Scientific Notation and Mathematical Operations with Sci. Not. • Determination and Use of Significant figures in measurements and calculations • Fundamental and derived units in Physics • Unit conversion and factor label method conversions • Basic Trigonometric Functions and Use of trigonometry to solve basic right triangle problems
Skills/ Benchmarks (CCSS Standards)	• 5.1.12.A.1 Refine interrelationships among concepts and patterns of evidence found in different central scientific explanations. • 5.1.12.A.2 Develop and use mathematical, physical, and computational tools to build evidence-based models and to pose theories. • 5.1.12.B.2 Build, refine, and represent evidence-based models using mathematical, physical, and computational tools. • 5.1.12.B.3 Revise predictions and explanations using evidence, and connect explanations/arguments to established scientific knowledge, models, and theories. • 5.1.12.B.4 Develop quality controls to examine data sets and to examine evidence as a means of generating and reviewing explanations.
Materials and Resources	• Scientific Calculators/Trig Tables • Inclinometers from Amusement Park Physics Kits (Height of Tel. Pole Lab) • Metric Rulers/ Meter Sticks • Metric Prefix and Metric Conversion Tables • Microsoft Excel for Graphing/Curve fitting
Notes	**Common Misconceptions:** • Mixing up metric prefixes • Entering numbers in scientific notation in a calculator • Order of operations in basic algebraic functions • Using trigonometric functions backwards or in situations where a right triangle isn't in normal orientations **Key Terms:** Significant Figures, Scientific Notation, System Internationale (SI) units, mks units, Factor-label method, Linear Regression, Coefficient of Correlation (R^2), Order of Magnitude Estimation

Grade: 11 and 12 Subject: Physics CP	Unit 2: Motion in One Dimension
Big Idea/Rationale	Modern Physics began with Galileo formally studying the rules that governed how and why things move. To understand his work, we need to begin by defining what it is to be moving, and how that motion can be measured. There is more substance to these concepts than students initially give credit for. By questioning their assumptions regarding frames of reference and the relativity of motion, the difference between scalar and vector measurements of motion, and what it means to be changing our motion (accelerating), we can build a deeper foundation on which to build Newton's laws, as well as build toward an understanding of two dimensional motions. We will also derive and begin using the kinematics equations that form the computational basis for quantitative work in Physics.
Enduring Understanding (Mastery Objective)	• Choose coordinate systems for motion problems. • Recognize that all motion is described relative to a frame of reference and describe how relative changes as that reference frame changes motion. • Define and differentiate between the scalar and vector measures of motion – distance vs. displacement, speed vs. velocity. • Define the difference between initial, final, average and instantaneous measurements of these quantities. • Define acceleration and represent it graphically and mathematically. • Define the acceleration due to gravity and free fall. • Derive and use basic kinematics equations to solve motion problems.
Essential Questions (Instructional Objective)	• How do we know whether something is moving? How can motion be measured? How is the motion of an object affected by the vantage point (reference frame) of the observer? How does an understanding of the seeming paradoxes of motion aid us in gaining a deeper understanding of the universe around us? • What is the difference between distance and displacement and how can each measurement be significant in its own way? • How can motion be visualized and analyzed graphically, whether measuring distance, displacement, speed, velocity or acceleration? How does visualizing change of any short graphically aid our understanding of measureable phenomena? • What kinds of useful information can be drawn from graphical relationships, and how can we use graphs to predict the behavior of things we measure? When is making such predictions appropriate or inappropriate? How confident can we be of those predictions? • Wheat is speed? What is velocity? How are they similar and how are they different? When will the bye equal and when will the by different? • What are the clues that the quantity being measured is with a vector on scalar one, and why does that distinction matter?

	• How do vector and scalar quantities differ from each other, and in what way do calculations with each quantity differ from each other? • What does it mean to be accelerating, and how can acceleration be measured or calculated? • What are the characteristics of free fall motion? Is everything that is falling in free fall? Is free fall the same for all objects?
Content (Subject Matter)	• Define Coordinate Systems and Frames of Reference. • Define and differentiate descriptions of motion(Distance vs. Displacement, Speed vs. Velocity) • Define Acceleration, and change in velocity. • Define Free fall. • Derive and Use Kinematics Equations and solving basic Motion Problems • Solve problems with accelerated Motion • Demonstrate an ability to draw and Interpret Motion Graphs
Skills/ Benchmarks (CCSS Standards)	• 5.1.12.A.1 Refine interrelationships among concepts and patterns of evidence found in different central scientific explanations. • 5.1.12.A.2 Develop and use mathematical, physical, and computational tools to build evidence-based models and to pose theories. • 5.1.12.A.3 Use scientific principles and theories to build and refine standards for data collection, posing controls, and presenting evidence. • 5.1.12.B.1 Design investigations, collect evidence, analyze data, and evaluate evidence to determine measures of central tendencies, causal/correlational relationships, and anomalous data. • 5.1.12.B.2 Build, refine, and represent evidence-based models using mathematical, physical, and computational tools. • 5.1.12.B.1 Design investigations, collect evidence, analyze data, and evaluate evidence to determine measures of central tendencies, causal/correlational relationships, and anomalous data. • 5.1.12.B.2 Build, refine, and represent evidence-based models using mathematical, physical, and computational tools. • 5.1.12.B.3 Revise predictions and explanations using evidence, and connect explanations/arguments to established scientific knowledge, models, and theories. • 5.1.12.B.4 Develop quality controls to examine data sets and to examine evidence as a means of generating and reviewing explanations. • 5.1.12.C.1 Reflect on and revise understandings as new evidence emerges. • 5.1.12.C.2 Use data representations and new models to revise predictions and explanations. • 5.1.12.C.3 Consider alternative theories to interpret and evaluate evidence-based arguments. • 5.1.12.C.2 Use data representations and new models to revise

	predictions and explanations. • 5.1.12.D.1 Engage in multiple forms of discussion in order to process, make sense of, and learn from others' ideas, observations, and experiences. • 5.1.12.D.2 Represent ideas using literal representations, such as graphs, tables, journals, concept maps, and diagrams. • 5.2.12.E.1 Compare the calculated and measured speed, average speed, and acceleration of an object in motion, and account for differences that may exist between calculated and measured values.
Materials and Resources	• Scientific Calculators • Metric Rulers/ Meter Sticks • Microsoft Excel for Graphing/Curve fitting • Tracker Video Analysis Software • PASCO Motion Detector probes and Data-Studio Software
Notes	**Common Misconceptions:** • Position, velocity and acceleration are absolute measurements independent of the observer • Heavier objects fall faster than light ones. • Acceleration is the same as velocity. • The acceleration of a falling object depends on its mass. • Since all objects fall with the same acceleration, the earth pulls on them with the same amount of force. • Inertia is speed, or momentum • Free fall means downward motion • Gravity only acts on objects when they are falling • Velocity must be positive (or that negative velocity means slowing down). • Two objects with the same position have the same speed, the leading object must be moving at a faster speed, or that a larger velocity means a larger acceleration.

Grade: 11 and 12 **Subject:** Physics CP	**Unit 3: Motion in Two Dimensions**
Big Idea/Rationale	• Students have been working with mostly scalar measurements in math class since kindergarten. However, many things we measure are actually vector quantities, which have a definite direction. The mathematics of vectors is fundamentally different from scalar math, and a basic understanding of how vector quantities may be added is fundamental to understanding the effect of forces on objects and how objects move. • Motion in any one dimension is independent of motion in the others. So, if an object is moving in an arc (two dimensions) its horizontal motion is independent of its vertical motion. For that reason, seemingly complex two (or even three) dimensional problems can be broken down into a series of one dimensional problem. The overall motion of an object than then be found by analyzing and summing (using vector mathematics) the result of these one dimensional motions. • These techniques can be used to solve the motion of projectiles acting under the conditions of free fall, but also any system undergoing multiple forces. By breaking the forces into one dimensional components, the net force in each dimension may be determined. The resultant force and acceleration may then be calculated based on this information.
Enduring Understanding (Mastery Objective)	• Students can clearly define vectors as quantities that are described by specifying both magnitude and direction. • Students can successfully predict the effects of two or more vectors acting simultaneously on an object can be determined by combining the vectors mathematically. • Students will demonstrate an understanding of Newton's First Law: Forces change the state of motion of an object, and no change in motion can occur in the absence of such forces. • Construct vectors and discuss methods of adding vectors to find vector sums. • Show that all vectors may be broken down into perpendicular components. • Demonstrate that vector components may be added to determine resultant vectors. • Define frictional forces and use Newton's Second Law to solve problems including friction in two dimensions. • Define Newton's Third Law of Motion and Differentiate and Define objects according to the Forces acting upon them, as opposed to the forces they are placing on other objects. • Describe the fundamental characteristics of projectile motion. • Use basic motion equations to solve projectile motion problems.

Essential Questions (Instructional Objective)	• What are vectors, and how can they be represented graphically and mathematically? • How do vector quantities add (graphically and mathematically). • How can we use vector mathematics to determine the net force, acceleration and resulting motion of an object according to Newton's First and Second Laws of Motion in two dimensions, especially with respect to projectile motion?
Content (Subject Matter)	• Construct vectors and discuss graphical methods of adding vectors to find vector sums • Show that vectors may be handled easily mathematically be breaking them down into perpendicular components. • Demonstrate that vectors may be added to determine the resultant vectors. • Practice some basic vector math problems involving independent motions on horizontal and vertical planes. • Use vector mathematics to solve problems involving forces in two dimensions and projectile motion problems
Skills/ Benchmarks (CCSS Standards)	• 5.1.12.B.2 Build, refine, and represent evidence-based models using mathematical, physical, and computational tools. • 5.1.12.B.1 Design investigations, collect evidence, analyze data, and evaluate evidence to determine measures of central tendencies, causal/correlational relationships, and anomalous data. • 5.1.12.C.2 Use data representations and new models to revise predictions and explanations. • 5.1.12.D.1 Engage in multiple forms of discussion in order to process, make sense of, and learn from others' ideas, observations, and experiences. • 5.1.12.D.2 Represent ideas using literal representations, such as graphs, tables, journals, concept maps, and diagrams. • 5.2.12.E.1 Compare the calculated and measured speed, average speed, and acceleration of an object in motion, and account for differences that may exist between calculated and measured values. • 5.2.12.E.2 Compare the translational and rotational motions of a thrown object and potential applications of this understanding. • 5.2.12.E.4 Measure and describe the relationship between the force acting on an object and the resulting acceleration.
Materials and Resources	• Scientific Calculators • Metric Rulers/ Meter Sticks • Microsoft Excel for Graphing/Curve fitting • Tracker Video Analysis Software • PASCO Motion Detector probes and Data-Studio Software

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<td>Notes</td>
<td>Common Misconceptions

Acceleration always occurs in the same direction as an object is moving.
Only animate objects can exert a force. Thus, if an object is at rest on a table, no forces are acting on it.
An object dropped from a given height will hit the ground before an object shot horizontally from the same height (independence of motion along coordinate axes).

Key Vocabulary

coefficient of kinetic friction, coefficient of static friction, components, equilibrant, kinetic friction, static friction

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Grade: 11 and 12 **Subject:** Physics CP	**Unit 4: Forces and Newton's Laws**
Big Idea/Rationale	Acceleration is caused by force. All forces come in pairs because they arise in the interaction of two objects — you can't hit without being hit back! The more force applied, the greater the acceleration that is produced. Objects with high masses are difficult to accelerate without a large force. In the absence of applied forces, objects simply keep moving at whatever speed they are already going. In formal language1: • Newton's 1st Law: Everybody continues in its state of rest, or of uniform motion in a right (straight) line, unless it is compelled to change that state by forces impressed upon it. • Newton's 2nd Law: The change of motion is proportional to the motive force impressed; and is made in the direction of the right (straight) line in which that force is impressed. • Newton's 3rd Law: To every action there is always opposed an equal reaction: or, the mutual actions of two bodies upon each other are always equal, and directed to contrary parts.
Enduring Understanding (Mastery Objective)	• Students can successfully predict the effects of two or more vectors acting simultaneously on an object can be determined by combining the vectors mathematically • Students will demonstrate an understanding of Newton's First Law: Forces change the state of motion of an object and no change in motion can occur in the absence of such forces. • Students will demonstrate the ability to complete clear force diagrams when multiple forces are present on an object, including normal forces and friction • Students will define and use Newton's Second Law (F = ma) to successfully predict the results of both single and multiple forces on an object in both one dimension and two dimensions. • Students will demonstrate a clear understanding of Newton's third law of motion (action/reaction forces) and the implications of this law on our daily lives. • Students will work with normal forces, tensions and friction forces in solving problems in one and two dimensions.
Essential Questions (Instructional Objective)	• Define a force and differentiate between forces which arise out of physical contact and forces which may act across empty space. • Describe the relationship between forces and motion and define Newton's first Law of Motion. • Define equilibrium as a state of zero net force, and describe the possible motions of an object at equilibrium. • Define and describe the four fundamental forces. • Describe how net (resultant) force is related to an object's acceleration (Newton's second law of motion).

	• Describe how the weight and mass of an object are related. • Differentiate between the force the Earth places on objects (weight) and the net upward force placed on objects that are accelerating (apparent weight). • Your mass does not change when you move to other planets, because mass is a measure of how much matter your body contains, and not how much gravitational force you feel. • To calculate the net force on an object, you need to calculate all the individual forces acting on the object and then add them as vectors. • Newton's 3rd Law states for every force there is an equal but opposite reaction force. To distinguish a third law pair from merely oppositely directed pairs is difficult but very important. • Third law pairs must obey three rules: they must be of the same type of force, they are exerted on two different objects and they are equal in magnitude and oppositely directed.
Content (Subject Matter)	Students will be able to: • Construct vectors and discuss graphical methods of adding vectors to find vector sums • Show that all vectors may be broken down into perpendicular components • Demonstrate that vector components may be added to determine resultant vectors • Practice some basic vector math problems involving independent motions on horizontal and vertical planes • Describe how vector mathematics can be used to solve problems involving forces in two dimensions. • Demonstrate an ability to use force vectors to calculate resultant and equilibrant forces. • Define a force and differentiate between forces which arise out of physical contact and forces which may act across empty space • Describe the relationship between forces and motion and define Newton's first law of motion • Define equilibrium as a state of zero net force and describe the possible motions of an object at equilibrium • Define and describe the four fundamental forces • Describe how net (resultant) force is related to an objects acceleration (Newton's second Law of Motion) • Describe how the weight and mass of an object are related. • Differentiate between gravitational force weight and what is experienced as apparent weight. • Define frictional forces and use Newton's second law to solve problems including friction in one dimension. • Use Newton's Second Law to solve problems involving forces in one and two dimensions

	• Define Newton's third law of motion and differentiate and define objects according to the forces acting upon them as opposed to the forces they are placing on other objects
Skills/ Benchmarks (CCSS Standards)	• 5.1.12.B.2 Build, refine, and represent evidence-based models using mathematical, physical, and computational tools. • 5.1.12.B.1 Design investigations, collect evidence, analyze data, and evaluate evidence to determine measures of central tendencies, causal/correlation relationships, and anomalous data. • 5.1.12.C.2 Use data representations and new models to revise predictions and explanations. • 5.1.12.D.1 Engage in multiple forms of discussion in order to process, make sense of, and learn from others' ideas, observations, and experiences. • 5.1.12.D.2 Represent ideas using literal representations, such as graphs, tables, journals, concept maps, and diagrams. • 5.2.12.E.1 Compare the calculated and measured speed, average speed, and acceleration of an object in motion, and account for differences that may exist between calculated and measured values. • 5.2.12.E.1 Compare the calculated and measured speed, average speed, and acceleration of an object in motion, and account for differences that may exist between calculated and measured values. • 5.2.12.E.2 Compare the translational and rotational motions of a thrown object and potential applications of this understanding. • 5.2.12.E.4 Measure and describe the relationship between the force acting on an object and the resulting acceleration.
Materials and Resources	• PASCO Data Logger, Probe ware and Data Studio Software • Microsoft Excel for tabulation, graphing and analysis of lab data • phET Physics Applets from the University of Chicago (Vector Addition Applet) • Scratch Programming Environment from MIT • Tracker Video Analysis Software • iClicker Classroom Response System • SMART board • A variety of lab equipment including mass sets, pulleys, string, friction carts, and force tables.
Notes	

Grade: 11 and 12 **Subject:** Physics	**Unit 5: Torque and Rotational Motion**
Big Idea/Rationale	• Students have now developed a means to model and analyze the linear motion of objects, as well as how they will behave under applied linear forces, but we have not discussed rotational motion, which is an everyday phenomenon and an integral part of understanding the physics of sports, dance, driving, and most other physical activities. We will now introduce the topic of Torque – the rotational analogue of Force, and develop an understating of how a net Torque can produce a rotational acceleration in objects. • We will also explore how true equilibrium in objects is not merely the result of all the concurrent forces cancelling each other, but also the torques. Understanding these concepts will let us explore some basic statics and dynamics problems, which will allow us to perform the type of analyses which underlie many basic engineering and architectural activities.
Enduring Understanding (Mastery Objective)	• Students will describe rotational motion around a pivot point and define angular velocity, acceleration and moment of inertia as rotational analogues to linear motion. • Students will define torque, and its relationship to change in rotational motion (angular acceleration). Students will apply Newton's Second Law to Rotation problems. • Students will understand that true equilibrium is the result of balancing translational and rotational forces and solve statics problems involving balancing both linear forces and torques to produce equilibrium.
Essential Questions (Instructional Objective)	• How and why does true equilibrium occur in real world systems? • What factors influence the amount of torque on a system, and the change in rotational motion such systems can experience? • How can we calculate forces and torques in systems to ensure that equilibrium occurs, or how the rotational motion of a system will change under the influence of torques?
Content (Subject Matter)	• What is rotational motion and how do we measure it (rotational position and rotational speed)? • When do forces produce rotational motion, and when don't they? • Define Torque mathematically. • Define true equilibrium as a state of zero net force and torque. • Solve problems with systems under forces causing a torque when those forces are applied perpendicular to the moment arm.
Skills/ Benchmarks (CCSS Standards)	• 5.1.12.B.2 Build, refine, and represent evidence-based models using mathematical, physical, and computational tools. • 5.1.12.B.1 Design investigations, collect evidence, analyze data, and evaluate evidence to determine measures of central tendencies,

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5.1.12.C.2 Use data representations and new models to revise predictions and explanations.
5.1.12.D.1 Engage in multiple forms of discussion in order to process, make sense of, and learn from others' ideas, observations, and experiences.
5.1.12.D.2 Represent ideas using literal representations, such as graphs, tables, journals, concept maps, and diagrams.
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5.2.12.E.4 Measure and describe the relationship between the force acting on an object and the resulting acceleration.</td></tr>
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Microsoft Excel for tabulation, graphing and analysis of lab data
phET Physics Applets from the University of Chicago (Vector Addition Applet)
Scratch Programming Environment from MIT
Tracker Video Analysis Software
iClicker Classroom Response System
SMART board
A variety of lab equipment including mass sets, pulleys, string, friction carts, and force tables.</td></tr>
<tr><td>Notes</td><td>Common Misconceptions
The center of mass of an object must reside inside that object.
Center of mass is always the same as the center of gravity.
Momentum is not a vector.
Any force acting on an object will produce a torque.
Objects moving in a straight line cannot have angular momentum.
Torque is the same as force and acts in the same direction.
Key Vocabulary
rotational position, rotational speed, rotational acceleration, axis, fulcrum, center of gravity, torque, revolution vs. rotation, rotational inertia</td></tr>
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Grade: 11 and 12 **Subject:** Physics CP	**Unit 6: Circular Motion**
Big Idea/Rationale	• Our misunderstanding of the fundamental nature of circular motion has lead to all sorts of common misconceptions – e.g. the centrifugal force, and contributed to the fact that, before we understood centripetal force and acceleration, it was considered impossible for the Earth to be in motion. One Newton had describe the details of circular motion, many everyday phenomena were able to be explained, the motion of the planets was able to be modeled more accurately than ever before, and the engineering of such things as safely curved roadways, or roller coasters, satellites, and space stations became possible. • Students should develop a fundamental understanding of how and why objects move in circular patterns, and be able to apply these principles to solve everyday problems, such as the maximum safe speed for cars to take turns, or the minimum speed of a roller coaster loop, or the maximum speed when going over the top of a hill. • This unit also reinforces the central idea of mechanics – Newton's Second Law, that a body not subject to a net force cannot change its motion, but that a net force that is constant in magnitude but changing direction so that it is always directed towards a central point results in circular motion. • How does an understanding of circular periodic motion, allow us to predict other harmonic motions – such as pendulums and springs. How do these understandings lead us to be able to measure time?
Enduring Understanding (Mastery Objective)	• Explain the acceleration of an object moving in a circle at a constant speed. • Describe how centripetal acceleration depends on both the object's speed and the radius of the circle. • Recognize the direction of the forces that cause centripetal acceleration and differentiate that from direction of motion and velocity. • Solve basic centripetal motion problems on a plane. • Solve more advanced centripetal motion problems for forces in two dimensions – such as carnival swing rides. • Define Period of Motion, frequency of Motion, and simple harmonic motion.
Essential Questions (Instructional Objective)	• What causes objects to move in a circle? • How can we mathematically model circular motion? • How can we apply the problem solving strategies used in previous units – including drawing free body diagrams and applying Newton's Laws of Motion, to solve problems involving circular motion? • Define Period of Motion, frequency, simple harmonic motion and show how an understanding of circular motion can be extended to understand the periodic motion of pendulums and springs.

Content (Subject Matter)	• Define Circular Motion and debunk misconceptions about how and why objects move in circles. • Define centripetal force and differentiate it from centrifugal force • Graphically represent the velocity, force and acceleration of objects in circular motion • Derive the basic mathematical equations describing centripetal acceleration and force. • Use these equations to solve basic circular motion problems. • Use circular motion to describe periodic motions in general, and define Period of Motion, and frequency. • Derive and use the equations of motion that model the behavior of pendulums and springs.
Skills/ Benchmarks (CCSS Standards)	• 5.1.12.B.2 Build, refine, and represent evidence-based models using mathematical, physical, and computational tools. • 5.1.12.B.1 Design investigations, collect evidence, analyze data, and evaluate evidence to determine measures of central tendencies, causal/correlation relationships, and anomalous data. • 5.1.12.C.2 Use data representations and new models to revise predictions and explanations. • 5.1.12.D.1 Engage in multiple forms of discussion in order to process, make sense of, and learn from others' ideas, observations, and experiences. • 5.1.12.D.2 Represent ideas using literal representations, such as graphs, tables, journals, concept maps, and diagrams. • 5.2.12.E.1 Compare the calculated and measured speed, average speed, and acceleration of an object in motion, and account for differences that may exist between calculated and measured values. • 5.2.12.E.2 Compare the translational and rotational motions of a thrown object and potential applications of this understanding. • 5.2.12.E. Create simple models to demonstrate the benefits of seatbelts using Newton's first law of motion. • 5.2.12.E.4 Measure and describe the relationship between the force acting on an object and the resulting acceleration.
Materials and Resources	• PASCO Data Logger, Probe ware and Data Studio Software • Microsoft Excel for tabulation, graphing and analysis of lab data • phET Physics Applets from the University of Chicago (Vector Addition Applet) • Scratch Programming Environment from MIT • Tracker Video Analysis Software • iClicker Classroom Response System • SMART board • A variety of lab equipment including mass sets, pulleys, string, friction carts, and force tables.

Notes	**Common Misconceptions** • Circular motion does not require a force. • Centrifugal forces are real (in traditional stationary reference frames) • An object moving in a circle with a constant speed has no acceleration. • An object moving in a circle will continue in circular motion when released. • An object in circular motion will either continue its circular motion, or fly out in the radial direction when released. • Centripetal force is a real physical force – like gravity or friction that acts on an object, instead of a mathematical "bill" that the existing forces must pay. • Whatever force is acting towards the center of a turn will equal the centripetal force as opposed to understanding that the sum of all forces (net force) must act towards the center of the circle and equal the centripetal force calculation. **Key Vocabulary** • Centrifugal force, centripetal force, centripetal acceleration, Period of motion, revolution, tangent, Uniform circular Motion, frequency

Grade: 11 and 12 **Subject:** Physics CP	**Unit 7: Universal Gravitation and Orbits**
Big Idea/Rationale	• The story of the evolution of Western European perceptions of the universe is a fascinating story in and of itself, and the debate over the geocentric vs. heliocentric theories in many ways lead to the rise of modern science, secular humanism, the renaissance and our modern world. Students should be exposed to this story in a deeper manner than merely giving them the equations that represent the end result of this saga. • Students should also gain an appreciation for Gravity as one of the fundamental forces that hold our Universe together, make life on Earth possible (and on other planets impossible).
Enduring Understanding (Mastery Objective)	• Students will demonstrate an ability to use Newton's Law of Universal Gravitation to solve for forces between objects • They also should develop proficiency calculating gravitational forces and accelerations and understanding the direct relationship between gravity and mass and the inverse relationship between gravity and distance. • Students should develop an appreciation of orbits as a form of objects falling around each other, and that it represents equilibrium between the gravitational force between the orbiting objects, and the centripetal force "bill" necessary to stay moving in a stable circular orbit. Students should therefore be able to calculate stable orbital speeds, radii and orbital periods.
Essential Questions (Instructional Objective)	• What is the evidence that the Earth revolves around the sun and why did our ancestors believe that it was the sun that moved? • What historical developments lead to a change in thinking, and how did those changes shape our modern world? • How do Kepler's laws support the heliocentric model of the solar system? • What is the Universal Law of Gravitation and how did Isaac Newton deduce it? • How did Henry Cavendish deduce the Universal Gravitational Constant? • How can the Universal Law of gravitation be used to determine gravitational forces between any two objects, and how can it be used to determine orbital motions of planets and moons and satellites?
Content (Subject Matter)	Students will be able to: • Discuss Heliocentric and Geocentric theories of the solar system and the historical problems with each. • Discuss the contributions of Galileo, Copernicus, Kepler, Brahe and Newton to the heliocentric theory. • Relate Kepler's laws of planetary motion to Newton's law of universal

	gravitation. • Calculate the periods and speeds of orbiting objects. • Define the Universal Law of Gravitation • Use the Law of Gravitation to calculate some forces between objects of a given mass separated by a distance • Solve problems involving orbital speed and period using the universal law of gravitation. • Describe Cavendish's experiment to find the universal gravitational constant (G) and the results of having obtained an accurate value for G. • Describe gravitational fields. • Discuss true weightlessness vs. free-fall experienced by orbiting objects. • Distinguish between inertial mass and gravitational mass.
Skills/ Benchmarks (CCSS Standards)	• 5.4.8.A.3 Predict how the gravitational force between two bodies would differ for bodies of different masses or bodies that are different distances apart. • 5.4.8.A.4 Analyze data regarding the motion of comets, planets, and moons to find general patterns of orbital motion. • 5.1.12.B.2 Build, refine, and represent evidence-based models using mathematical, physical, and computational tools. • 5.1.12.B.1 Design investigations, collect evidence, analyze data, and evaluate evidence to determine measures of central tendencies, causal/correlation relationships, and anomalous data. • 5.1.12.C.2 Use data representations and new models to revise predictions and explanations. • 5.1.12.D.1 Engage in multiple forms of discussion in order to process, make sense of, and learn from others' ideas, observations, and experiences. • 5.1.12.D.2 Represent ideas using literal representations, such as graphs, tables, journals, concept maps, and diagrams. • 5.2.12.E.1 Compare the calculated and measured speed, average speed, and acceleration of an object in motion, and account for differences that may exist between calculated and measured values. • 5.2.12.E.4 Measure and describe the relationship between the force acting on an object and the resulting acceleration. • 5.4.12.A.1 Explain how new evidence obtained using telescopes (e.g., the phases of Venus or the moons of Jupiter) allowed 17th-century astronomers to displace the geocentric model of the universe. • 5.4.12.A.2 Collect, analyze, and critique evidence that supports the theory that Earth and the rest of the solar system formed from a nebular cloud of dust and gas 4.6 billion years ago. • 5.4.12.A.3 Analyze an H-R diagram and explain the life cycle of stars of different masses using simple stellar models. • 5.4.12.A.5 Critique evidence for the theory that the universe evolved as it expanded from a single point 13.7 billion years ago.

	• 5.4.12.A.6 Argue, citing evidence (e.g., Hubble Diagram), the theory of an expanding universe.
Materials and Resources	• Selected text and activity resources from Physics Union Mathematics (PUM), c 2009, Rutgers University, Light and Matter & The Peoples Physics Book, Santa Cruz Institute of Particle Physics, J. Kovalcin, c 2001, and Glencoe Physics: Principles and Problems, c 2001. Lab activities utilize a variety of common lab equipment as well as PASCO probe ware and PhET computer based simulations, University of Colorado, 2013. • Latex quilting hoop orbital motion simulator.
Notes	**Common Misconceptions** • The Moon is not in free fall. • The force that acts on apple is not the same type of force as the force that acts on the Moon. • The gravitational force is the same on all falling bodies. • There are no gravitational forces in space. • The gravitational force acting on the Space Shuttle and orbiting objects is zero. • The gravitational force acts on one mass at a time. • Moon stays in orbit because the gravitational force on it is balanced by the centrifugal force acting on it. • Astronauts in orbit are weightless (true weightlessness vs. apparent weightlessness) • Weight is the force of gravity acting on an object. • “g” represents the acceleration due to gravity or the strength of the gravitational field, not the force of gravity. **Key Vocabulary** • Aristotle - Greek philosopher. • Ptolemy – modeled the geocentric universe • Cavendish, Henry – scientist who deduced the Universal Gravitational Constant. • Copernicus, Nicolaus - polish astronomer • Galileo, Galilei - Italian physicist and astronomer. • Geocentric Model – Earth Centered Solar system • Heliocentric Model – Sun Centered Solar System • Retrograde motion - apparent reversal in the motion of some planets as they move across the ecliptic plane. • Parallax – The apparent motion of stars against the background universe caused by the Earth’s motion around the sun. • Gravity - universal force of the attraction of the mass of an object. • Kepler, Johannes - German astronomer and mathematician.

- Newton, Sir Isaac - English physicist, mathematician, and philosopher.
- Rate of acceleration “g” - the change in the velocity of the motion of an object.
- Kepler's Laws
- Planets all move in elliptical orbits about a sun, which located at one focus of the ellipse
- An imaginary line drawn from the sun to any planet moves through equal areas in equal intervals of time
- If T is the amount of time of a period and r is the average radius of the orbit then T^2/r^3 is the same for all known planets
- Period: time to complete a full orbit around the sun. On earth, a year.
- Newton's Law of Universal Gravitation $F=Gm_1m_2/r^2$
- G: Universal Gravitational Constant=6.6710^{-11} Nm^2/kg^2
- Revolution – the circular or elliptical movement of a body around a point outside of that body.

Key Equations

$F_g = \frac{m^1 m^2}{d^2}$ *where* $G=6.67*10^{-11} N/m^2/kg^2$

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Grade: 11 and 12 **Subject:** Physics CP	**Unit 8: Impulse, Momentum and the Physics of Collisions**
Big Idea/Rationale	• This unit represents one of the most practical applications of physics to everyday life. Through the development of the concept of Impulse and momentum out of Newton's Second Law, we can examine how and why objects change their motion during impacts, explosions or any situation involving forces placed on an object. The implications of these concepts in everyday situations such as car crashes, or playing sports will be explored, and students can come away with a better defined explanation of how impacts and collisions occur and how object's motions will be affected. • This unit introduces students to one of the great conservation laws of physics as well; the law of conservation of momentum, which on its own explains so much about the behavior of isolated systems, with implications on everything from accident investigating, to billiards to the motion of planets in our solar system. When this concept is combined with the concept of kinetic energy in our next unit, students will have a very complete and powerful tool to fully analyze collisions.
Enduring Understanding (Mastery Objective)	• Students will demonstrate an understanding that momentum is a measure of the amount of motion and is relative to an objects speed and mass and that it can be changed by providing an impulse to an object (Impulse-Momentum Law). • Students will know that momentum is conserved in all interactions between objects and will use the law of conservation of momentum to solve collision problems in 1-dimension and 2-dimensions.
Essential Questions (Instructional Objective)	• How does Newton's third law lead to the impulse- change in momentum equation? • What is momentum, and how is it useful in describing the motion of objects? • How can impacts be manipulated to maximize or minimize forces or changes in velocity? • How does the impulse momentum equation lead to the law of conservation of momentum? • How can the law of conservation of momentum be used in both one and two dimensional problems to predict the motion of objects either before or after collisions? • How does the law of conservation of momentum apply to rotating systems?
Content (Subject Matter)	Students will be able to: • Define the momentum of an object • Determine the impulse given to an object • Recognize and use the Impulse-Change in Momentum theorem to solve

	problems. • Students will be able to: • Compare the system before and after an event in momentum problems • Show how application of Newton's third law of motion to the Impulse-Momentum Theorem leads to the law of Conservation of Momentum • Discuss rotational momentum and show that the law works equally well for systems that are moving linearly or rotating. • Apply Conservation of momentum to basic problems in one dimension
Skills/ Benchmarks (CCSS Standards)	• 5.1.12.B.2 Build, refine, and represent evidence-based models using mathematical, physical, and computational tools. • 5.1.12.B.1 Design investigations, collect evidence, analyze data, and evaluate evidence to determine measures of central tendencies, causal/correlation relationships, and anomalous data. • 5.1.12.C.2 Use data representations and new models to revise predictions and explanations. • 5.1.12.D.1 Engage in multiple forms of discussion in order to process, make sense of, and learn from others' ideas, observations, and experiences. • 5.1.12.D.2 Represent ideas using literal representations, such as graphs, tables, journals, concept maps, and diagrams. • 5.2.12.E.1 Compare the calculated and measured speed, average speed, and acceleration of an object in motion, and account for differences that may exist between calculated and measured values. • 5.2.12.E.3 Create simple models to demonstrate the benefits of seat-belts using Newton's first law of motion. • 5.2.12.E.4 Measure and describe the relationship between the force acting on an object and the resulting acceleration.
Materials and Resources	• Selected text and activity resources from Physics Union Mathematics (PUM), c 2009, Rutgers University, Light and Matter & The Peoples Physics Book, Santa Cruz Institute of Particle Physics, J. Kovalcin, c 2001, and Glencoe Physics: Principles and Problems, c 2001. Lab activities utilize a variety of common lab equipment as well as PASCO probe ware and PhET computer based simulations, University of Colorado, 2013. • Air track and carts • Floor curling stones from physical education
Notes	**Common Misconceptions:** • Momentum is not a vector. • Conservation of momentum applies only to collisions and not phenomena like explosions, as well as everyday activities like riding bikes. • Momentum is the same thing as force or velocity.

	• Momentum is not conserved in collisions with "immovable" objects like walls.
	• Momentum and kinetic energy are the same thing.
	• Conservation of momentum does not mean conservation of velocity or force.
	• The law of conservation of momentum does not mean that the momentum of systems always adds up to zero.
	Key Vocabulary
	• **Momentum** - a measure of how hard it is to stop a moving object; dependent on the object's size and velocity
	• **Law of conservation of momentum -** the total momentum of objects that collide with each other is the same before and after the collision
	• **Impulse** – the product of both force and time that force is placed on an object. The greater the impulse the greater a change in momentum will be for an object.
	• **Rotational momentum** – the product of an object's rotational speed and moment of inertia (rotational mass).
	Key Equations
	• **Impulse/Momentum Law**
	  ○ Impulse = change in momentum
	• **Law of Conservation of Momentum**
	  ○ $m_1v_1 + m_2v_2 = m_1v_1' + m_2v_2'$

Grade: 11 and 12 **Subject:** Physics CP	**Unit 9: Work, Energy and Simple Machines**
Big Idea/Rationale	• Energy is perhaps the most fundamental, and one of the most elusive concepts in all of Physics. We have followed the historical development of our study of motion through Galileo and Newton, but it was not for another 150 years that the concept of energy evolved. Yet, despite this, almost any phenomenon in physics, not to mention biology, chemistry, economics and even history can be viewed through the lens of energy flows. Giving students a solid understanding of the concept of work, energy, power and simple machines gives them a way to re-approach and simplify many of the problems we have already encountered (for example inclined plane problems) but also to see many of our current societal issues – such as global warming and fossil fuel use, the viability of alternative energy sources, and the geopolitics of energy with a greater level of sophistication. • On a more practical level, students will learn how the concepts of work, energy, power, efficiency and simple machines have helped us build the technologically advanced modern world, and that a basic understanding of these concepts can help with everyday tasks in surprising ways. • Students should also gain a firm mathematical foundation in these concepts that should give them tools to solve more complex problems, and will be introduced to another of the great conservation laws in science – conservation of energy.
Enduring Understanding (Mastery Objective)	• Students will demonstrate an understanding that energy exists in many forms (including kinetic and potential) and that an object with energy by definition can exert forces on other objects to transfer energy to them (work energy theorem). • Students will know that energy can be changed from one form to another, but cannot be destroyed or created. • Students will know that simple machines involve tradeoffs in force for distance and will demonstrate an ability to calculate the mechanical advantage of a simple machine and compound machines as a ratio of that trade. • Students will know that all energy transfers involve transformation of some energy to heat and will apply this principal to calculate real mechanical advantage and efficiencies for simple and compound machines • Students will know that power is the ability to expend energy (or do work) over time.
Essential Questions (Instructional Objective)	Students will be able to: • Describe the concept of work as force applied over distance • Describe the relationship between Work and Energy. • Differentiate between Work and Power and demonstrate an ability to

	calculate power outputs.
Content (Subject Matter)	Students will be able to: • Describe the concept of work as force applied over distance • Describe the relationship between Work and Energy. • Differentiate between Work and Power and demonstrate an ability to calculate power outputs • Demonstrate the use of simple machines in performing work. • Describe the concept of efficiency; calculate the efficiency of simple machines. • Describe the concept of mechanical advantage • Describe the concept of power and calculate power expended for objects acted on by forces. • Describe the many forms of energy and the concepts of kinetic and potential energy, calculate each type of energy for a variety of situations and demonstrate an ability to use the mathematical formulas for each to solve problems. • Recognize that base level for potential energy is arbitrary and calculate potential energy using different base levels • Describe the law of conservation of energy, the implications of this law in everyday life and apply this law to solving problems. • Discuss the implications of energy laws to our world economy and future challenges regarding energy supplies
Skills/ Benchmarks (CCSS Standards)	• 5.1.12.B.2 Build, refine, and represent evidence-based models using mathematical, physical, and computational tools. • 5.1.12.B.1 Design investigations, collect evidence, analyze data, and evaluate evidence to determine measures of central tendencies, causal/correlation relationships, and anomalous data. • 5.1.12.C.2 Use data representations and new models to revise predictions and explanations. • 5.1.12.D.1 Engage in multiple forms of discussion in order to process, make sense of, and learn from others' ideas, observations, and experiences. • 5.1.12.D.2 Represent ideas using literal representations, such as graphs, tables, journals, concept maps, and diagrams. • 5.2.12.E.1 Compare the calculated and measured speed, average speed, and acceleration of an object in motion, and account for differences that may exist between calculated and measured values. • 5.2.12.E.4 Measure and describe the relationship between the force acting on an object and the resulting acceleration.
Materials and Resources	Selected text and activity resources from Physics Union Mathematics (PUM), c 2009, Rutgers University, Light and Matter & The Peoples Physics Book, Santa Cruz Institute of Particle Physics, J. Kovalcin, c 2001, and Glencoe Physics:

	Principles and Problems, c 2001. Lab activities utilize a variety of common lab equipment as well as PASCO probe ware and PhET computer based simulations, University of Colorado, 2013.
Notes	**Common Misconceptions:** • Energy gets used up or runs out. • Something not moving can't have any energy. • A force acting on an object does work even if the objects does not move. • Energy is destroyed in transformations from one type to another. • Energy can be recycled. • Gravitational potential energy is the only type of potential energy. • When an object is released to fall, the gravitational potential energy immediately becomes all kinetic energy. • Energy is a force. **Key Vocabulary** • **work (physics)** - a manifestation of energy • **joule** - a unit of work equal to one newton-meter • **watt** - a unit of power equal to 1 joule per second • **kinetic energy** - energy of motion • **mechanical energy** - the total energy of motion and position of an object • **efficiency** - the ratio of the output to the input of any system • **potential energy** - Energy that is stored and held in readiness • **gravitational potential energy** - potential energy that depends on the height of an object • **conservation of energy -** a fundamental principle stating energy cannot be created nor destroyed but only changed from one form to another • **energy (physics)** - the capacity of a physical system to do work • **power (physics)** - the rate of doing work • **horsepower -** a common unit of power, equal to about 746 watts **Key Equations:** • **Work:** W=F*d • **Power:** P=W/t or P=E/t **RMA/IMA and Efficiency Of Simple Machines:** • $IMA=d_{in}/d_{out}$ • $RMA=F_{out}/F_{in}$ • efficiency (%) = W_{output}/W_{input} *100 or • RMA/IMA *100 **Potential Kinetic Energy :** • $KE=½mv^2$ • PE=mgh • SPE; $½kx^2$ (Spring PE)

	Laws of Conservation Energy • $KE_i + PE_i = KE_f + PE_f$ • $½mv_{i2} + mgh_i = ½mv_{f2} + mgh_f$

Grade: 11 and 12 **Subject:** Physics CP	**Unit 10: Special Relativity**
Big Idea/Rationale	At the beginning of the 20th century, the age of reason was at its zenith. The achievements of physicists, chemists and other scientists over the past 500 years had seemed to explain the entire universe. All that was left was to clean up the details. And yet, a few doubts, based on the frustrating observed behavior of light remained. Albert Einstein, in his "miracle year of 1905, explained the behavior of light by detaching time as an absolute scale in the universe and showing that our experience "space-time" is relative the speed of our frame of reference. We are still dealing with the implications of his theory of special relativity today, but its agreement with experimental results, and the technology developed because of it, is irrefutable.
Enduring Understanding (Mastery Objective)	• Students will demonstrate an ability to describe and calculate how Einstein's theory of special relativity governs the behavior of objects near the speed of light, in terms of time dilation, length contraction and rest vs. relativistic mass. Many everyday technologies – including GPS systems, would be impossible without taking relativity into account. • Students should understand the philosophical implications of Einstein's theory as well: that there is no fixed point from which to conduct measurements in our Universe. Even the passage of time is relative to our current frame of reference. The implications of this theory are still being wrestled with, but it has profoundly influenced 20th and 21st Century western culture.
Essential Questions (Instructional Objective)	Students will be able to: • Discuss problems with traditional Galilean (Newtonian) physics at the turn of the century. • Discuss the failure of Newton's Second Law of Motion at velocities near the speed of light (basic Relativity) * • Einstein's daring theory of how time mass and length can be warped by moving at high speed through space and its implications for our world* • Use the relativistic formulas for time, mass and length to solve some basic problems. • Discuss the possibility of time travel. • Briefly discuss how Einstein extended special relativity into his theory of general relativity and his most famous equation ($e = mc^2$). • Discuss current problems in Physics involving resolving conflicting theories (General Relativity and Quantum Mechanics) and the current theories proposed to bridge the gap (e.g. String Theory). • Discuss the possibility of future discoveries completely altering our current understanding of how our universe works.
Content (Subject Matter)	• Einstein's Big Idea DVD • The failure of light to obey traditional Galilean and Newtonian Rules.

	The Michelson-Morely experiment and the search for ether • The solution proposed by Einstein to train thought experiment. The behavior of objects moving at high rates of speed in terms of length, mass and time • Solving basic relativity problems involving time dilation.
Skills/ Benchmarks (CCSS Standards)	• 5.1.12.B.2 Build, refine, and represent evidence-based models using mathematical, physical, and computational tools. • 5.1.12.B.1 Design investigations, collect evidence, analyze data, and evaluate evidence to determine measures of central tendencies, causal/correlation relationships, and anomalous data. • 5.1.12.C.2 Use data representations and new models to revise predictions and explanations. • 5.1.12.D.1 Engage in multiple forms of discussion in order to process, make sense of, and learn from others' ideas, observations, and experiences. • 5.1.12.D.2 Represent ideas using literal representations, such as graphs, tables, journals, concept maps, and diagrams. • 5.2.12.E.1 Compare the calculated and measured speed, average speed, and acceleration of an object in motion, and account for differences that may exist between calculated and measured values. • 5.2.12.E.4 Measure and describe the relationship between the force acting on an object and the resulting acceleration. • 5.4.12.A.5 Critique evidence for the theory that the universe evolved as it expanded from a single point 13.7 billion years ago.
Materials and Resources	• Selected text and activity resources from Physics Union Mathematics (PUM), c 2009, Rutgers University, Light and Matter & The Peoples Physics Book, Santa Cruz Institute of Particle Physics, J. Kovalcin, c 2001, and Glencoe Physics: Principles and Problems, c 2001. Lab activities utilize a variety of common lab equipment as well as PASCO probe ware and PhET computer based simulations, University of Colorado, 2013. • Kovalcin # 111-116
Notes	**Common Misconceptions** • Length, mass, and time changes are just apparent. • Time is absolute. • Length and time only change for one observer. • There exists a preferred frame of reference in the universe. • Mass is absolute, that is, it has the same value in all reference frames. • Scientists used to say that there was a "sound barrier" that could never be exceeded, but they were obviously wrong about that. Maybe they're wrong about the "light barrier". • Accelerating to the speed of light makes your mass infinite. Not mass. Momentum. Momentum approaches infinity from the perspective of a

	stationary observer. • Why not mass? Because in SR, mass is an invariant. An invariant is a quantity that never changes for any observer. The best known invariant is the speed of light, c. • Accelerating to the speed of light requires infinite energy. • From the perspective of the stationary observer, your expended energy appears to increase asymptotically. However, ship-board energy consumption is linear. • 2) E=mc^2 --> atomic bombs. • No. In reality, nuclear chemistry --> atomic bombs. Although it was Einstein that persuaded President FDR to create a nuclear program, and although in his letter to the president he probably did reference the equation E=mc^2, it was only meant as a sort of ex-post-facto explanation for how so much energy can come from such a small bomb. In fact, E=mc^2 would not be at all helpful for anyone trying to build a bomb. • You can't go faster than the speed of light. • Actually, you can. There are just a few provisos. First, no one will ever observe you going faster than light. To all observers, even the stationary ones, you will only appear to be going, at best, slightly less than c. • Second, for the person actually in the spaceship, they must be content to measure their speed by counting landmarks as they pass by, like stars. If you see 3 stars go by in a year of travel, and you know that stars are (sans length contraction) about 5 light years apart, then you're EFFECTIVELY* going 15c. **Key Vocabulary** 1.Special theory of relativity: The theory describes how time is affected by motion in space at constant velocity, and how the mass and energy are related. 2.Space-time: The physical reality that exists within the four dimensional continuum.. 3.Time dilation: The slowing of time by moving a clock as observed by a stationary observer. 4.Length contraction: The contraction of space along the axis of motion, resulting in observers seeing objects length shorten as they move faster and faster. 5.Mass dilation: The increase in mass of an object moving near the speed of light as observed by a stationary observer. 6.First postulate of special relativity: All the laws of nature are the same in all uniformly moving frames of references. 7.Second postulate of special relativity: The speed of light in empty space will always have the same value regardless of the motion of the source or the motion of the observer. 8.Postulates: Something that is taken as self-evident or assumed without proof as making a basis for reasoning.

	9.Twins Paradox: A dramatic illustration of time dilation is afforded by the identical twins, one astronaut takes a high-speed round-trip journey while the other stays home on earth. **Key Equations:** • $t=T*\sqrt{(1-v^2/C^2)}$ • $l=L*\sqrt{(1-v^2/C^2)}$ • $m=M/\sqrt{(1-v^2/C^2)}$

Grade: 11 and 12 Subject: Physics CP	**Unit 11: Waves and Sounds**
Big Idea/Rationale	• Our world is saturated with waves transferring energy. Sound waves let us hear and create music, light waves let us see and create art, X-rays let us obtain opened a world of hidden internal body imagery to us, microwaves let us cook and radio waves allow us to communicate and make our modern technological world possible. Some understanding of how waves work is crucial to understanding how our world works. • Sound waves, in particular follow fascinating mathematical rules. These rules govern volume, pitch and whether or not a sound will resonate. The concept of resonance is particularly fascinating and widely applicable in music, medicine, radio applications and perhaps even cosmology. • Some other applications of waves, including the Doppler Effect, form the basis of the technology that allows police officers to track automobile speed, and to allow more accurate weather forecasts of hurricanes and tornadoes. It is also the basis for our understanding of the big-bang theory and the idea that the universe is expanding. • Some understanding of the relationship between sound wave amplitude (volume), energy, and the Decibel systems is also very valuable. Students in our sensory saturated world are in greater danger of hearing loss than they realize.
Enduring Understanding (Mastery Objective)	Mastery Objectives Covered: • Students will define the wavelength, frequency, amplitude, and period of waves. Light and sound are two familiar forms of energy that exhibit wave properties. • Students will understand that waves transfer energy, that waves can be reflected, refracted, and diffracted at boundaries and that waves can interfere constructively or destructively with other waves in passing and that this interference can result in resonance. • Students will describe the unique properties of electromagnetic waves, the types of waves making up the electromagnetic spectrum, how we perceive and use these waves.
Essential Questions (Instructional Objective)	• How do waves transfer energy from one place to another? • How does changing the amplitude, frequency, wavelength and velocity of a wave alter how we perceive it? • What happens to the energy contained in waves when they move from one medium into another? • How do waves passing through each other behave? • What are standing waves and resonance? What conditions have to be met for it to occur? How can we use these rules to create musical instruments? • What happens to waves when an object emitting those waves is in

	motion, and how can we use these changes to determine the velocity of motion? • How do we measure the intensity and volume of sound waves and how does volume change with distance from a source?
Content (Subject Matter)	Students will be able to: • Recognize that all waves follow the same general behavior patterns • Distinguish between mechanical and electromagnetic waves • Distinguish between longitudinal and transverse waves • Define wavelength, frequency, period, amplitude and phase. • Students will be able to: • Define the relationship between the speed of a wave and the medium through which it travels. • Understand the process by which waves transfer energy and the relationship between energy concentration and distance from source. • Describe how waves may be reflected and refracted at medium boundaries • Describe how waves may superimpose constructively or destructively • Recognize that sound waves are longitudinal but are commonly represented as transverse and that sound waves share common properties with other types of waves • Describe the generation of sound waves and explain the transfer of sound energy • Solve problems relating the frequency, wavelength and velocity of sound • Understand the Doppler effect and solve problems involving moving wave sources. • Understand and apply basic principles of resonance, timbre, and musical instruments* • Determine why beat frequencies occur. (Cross Curricular Link – Music)
Skills/ Benchmarks (CCSS Standards)	• 5.1.12.A.1 Refine interrelationships among concepts and patterns of evidence found in different central scientific explanations. • 5.1.12.A.2 Develop and use mathematical, physical, and computational tools to build evidence-based models and to pose theories. • 5.1.12.A.3 Use scientific principles and theories to build and refine standards for data collection, posing controls, and presenting evidence. • 5.1.12.B.1 Design investigations, collect evidence, analyze data, and evaluate evidence to determine measures of central tendencies, causal/correlational relationships, and anomalous data. • 5.1.12.B.2 Build, refine, and represent evidence-based models using mathematical, physical, and computational tools. • 5.1.12.B.3 Revise predictions and explanations using evidence, and connect explanations/arguments to established scientific knowledge, models, and theories.

	• 5.1.12.B.4 Develop quality controls to examine data sets and to examine evidence as a means of generating and reviewing explanations. • 5.1.12.C.1 Reflect on and revise understandings as new evidence emerges. • 5.1.12.C.2 Use data representations and new models to revise predictions and explanations. • 5.1.12.C.3 Consider alternative theories to interpret and evaluate evidence-based arguments. • 5.1.12.D.1 Engage in multiple forms of discussion in order to process, make sense of, and learn from others' ideas, observations, and experiences. • 5.1.12.D.2 Represent ideas using literal representations, such as graphs, tables, journals, concept maps, and diagrams. • 5.2.12.A.1 Use atomic models to predict the behaviors of atoms in interactions. • 5.2.12.C.1 Use the kinetic molecular theory to describe and explain the properties of solids, liquids, and gases. • 5.2.12.E.1 Compare the calculated and measured speed, average speed, and acceleration of an object in motion, and account for differences that may exist between calculated and measured values.
Materials and Resources	• Barrons Regents Review Sound and Waves Questions • Ingrum Topic 14 • Ingrum Topic 15 • People's Physics Waves and Sound
Notes	**Common Misconceptions:** • Waves transport matter. • Waves do not have energy. • Increasing the pitch of a sound wave will increase its volume. • Big waves travel faster than small waves in the same medium. • When an A note is played on a clarinet, one single frequency is being played. • A softball striking a bat on a ***<u>node</u>*** will make the bat hum painfully due to resonance • Sound travels faster in air than water or solid earth. • Sounds are not altered by the motion of the source of the sound or the listener **Key Vocabulary:** • **Basic Wave Definitions** • pulse • wave • medium • longitudinal wave • transverse wave

- electromechanical wave
- mechanical wave
- frequency
- period
- Crest
- trough
- amplitude
- wavelength
- refraction
- reflection
- transmission
- diffraction
- wave front
- ray
- Law of Reflection
- refraction
- diffraction
- constructive interference
- destructive interference
- standing wave
- nodes
- anti-nodes
- resonant frequency
- fundamental frequency
- harmonic frequency
- beat frequency
- open tube resonance series
- closed tube resonance series
- timbre
- Doppler Shift
- Intensity
- Decibel

Key Equations:

- V = λ*f
- Vsound in air = 331.5 + 0.6(T)
- Vsound in a string = sqrt (T/m/l)
- Closed Tube and Open Tube Resonance Series
- Doppler shift
- f' = f{(vsound-vlistener)/(vsound-vsource)}
- Decibel System
- I = P/4*pi*r^2
- dB = 10log(I/1x10-12)

Grade: 11 and 12 **Subject:** Physics CP	**Unit 12: Light and Optics**
Big Idea/Rationale	Our investigation of light waves, and discovery of the rules that govern their propagation, or more formally Electromagnetic waves, have transformed our world perhaps more than any other discovery in human history. Radio, television, fiber optics and wireless communication of all sorts depend on our understanding of wave properties. Laser technology has transformed the fields of medicine and information storage. X-rays have allowed us to peer inside the hidden recesses of our own bodies, and microwaves make great popcorn. Many older technologies, such as telescopes, microscopes and glasses also depend on our knowledge of the rules that govern light wave behavior.
Enduring Understanding (Mastery Objective)	Students will demonstrate an ability to describe the formation of images by mirrors and lenses and to use the mirror/lens equation to solve problems.
Essential Questions (Instructional Objective)	• What is light, and what are the characteristics of light? • What is a laser and what advantage do lasers have over other light sources? • How are colors related to light? • What affects the observed color of an object? • What factors affect the propagation and brightness of light? • What is the difference between specular and diffuse reflection? • What is an image, and how is it different from the object that is the source of light that creates it? • What is the Law of Reflection and how does it affect image formation in plane mirrors? • What is the Law of Refraction? • How is Snell's Law used to determine the angle of refraction when light passes between mediums? • How do we determine the focal point of a curved mirror using mathematical calculations and ray diagrams? • What is the difference between a real and virtual image? • How are the type, distance, orientation and size of image produced by curved mirrors determined using ray diagrams and mathematical methods? • What is diffraction and how can this phenomenon be used to determine the wavelength of light? • What is polarized light and what are the applications of polarization?
Content (Subject Matter)	• Students will be able to: • Recognize that light is the visible portion of an entire range of electromagnetic frequencies. • Describe the ray model of light

	• Solve basic problems involving the speed of light and review the rules of relativity as they relate to the speed of light. • Describe how brightness of light is affected by distance and the parallels between brightness the Decibel system for sound waves. • Explain the formation of color by light and by pigments or dyes. • Describe polarization, methods of production and uses of polarized light. • Describe and apply the law of reflection • Distinguish between diffuse and regular reflection and provide examples and uses of each type. • Calculate the index of refraction of a medium and solve basic index of refraction/speed of light problems • Define Snell's Law and show how the law may be applied to solve basic refraction problems • Define the critical angle and use Snell's law to determine the critical angle for a variety of media. • Explain how concave convex and plane mirrors form images. • Locate images using ray diagrams and define images as real or virtual • Use mirror/lens laws to calculate image locations, magnifications and orientations for converging and diverging lenses
Skills/ Benchmarks (CCSS Standards)	• 5.1.12.A.1 Refine interrelationships among concepts and patterns of evidence found in different central scientific explanations. • 5.1.12.A.2 Develop and use mathematical, physical, and computational tools to build evidence-based models and to pose theories. • 5.1.12.A.3 Use scientific principles and theories to build and refine standards for data collection, posing controls, and presenting evidence. • 5.1.12.B.1 Design investigations, collect evidence, analyze data, and evaluate evidence to determine measures of central tendencies, causal/correlational relationships, and anomalous data. • 5.1.12.B.2 Build, refine, and represent evidence-based models using mathematical, physical, and computational tools. • 5.1.12.B.3 Revise predictions and explanations using evidence, and connect explanations/arguments to established scientific knowledge, models, and theories. • 5.1.12.B.4 Develop quality controls to examine data sets and to examine evidence as a means of generating and reviewing explanations. • 5.1.12.C.1 Reflect on and revise understandings as new evidence emerges. • 5.1.12.C.2 Use data representations and new models to revise predictions and explanations. • 5.1.12.C.3 Consider alternative theories to interpret and evaluate evidence-based arguments. • 5.1.12.D.1 Engage in multiple forms of discussion in order to process, make sense of, and learn from others' ideas, observations, and

	experiences. • 5.1.12.D.2 Represent ideas using literal representations, such as graphs, tables, journals, concept maps, and diagrams. • 5.2.12.A.1 Use atomic models to predict the behaviors of atoms in interactions. • 5.2.12.C.1 Use the kinetic molecular theory to describe and explain the properties of solids, liquids, and gases. • 5.2.12.E.1 Compare the calculated and measured speed, average speed, and acceleration of an object in motion, and account for differences that may exist between calculated and measured values.
Materials and Resources	Selected text and activity resources from Physics Union Mathematics (PUM), c 2009, Rutgers University, Light and Matter & The Peoples Physics Book, Santa Cruz Institute of Particle Physics, J. Kovalcin, c 2001, and Glencoe Physics: Principles and Problems, c 2001. Lab activities utilize a variety of common lab equipment as well as PASCO probe ware and PhET computer based simulations, University of Colorado, 2013.
Notes	**Common Misconceptions:** • Black is created by mixing all colors of light. • A prism creates color. • The primary colors for drawing with crayons are red, yellow and blue. Why is this not the case? • Black is a color. • Light always travels at the “speed of light” (this one is true but the speed of propagation through mediums is not always c) • The moon emit light • Highly curved lenses magnify more than almost flat ones. **Key Vocabulary** • Light • Color by Addition • Color by subtraction • Polarization • Law of Reflection • Specular Reflection • Diffuse Reflection • Index of refraction • Snell’s Law of Refraction • Total Internal Reflection • Diffraction • Plane Mirror • Convex Mirror • Concave Mirror • Principal Axis

	• Real Image • Virtual Image • Focal Point • Center of curvature (and its relationship to focal point) • Mirror Lens Equation • Concave Lens • Convex Lens

Grade: 11 and 12 **Subject:** Physics CP	**Unit 13: Electricity and Basic Circuits**
Big Idea/Rationale	Our final unit takes us to the study of electrical phenomena. Our understanding of how electricity works is perhaps the most important of our discoveries in physics, at least certainly in terms of the technological impact on our lives. For this reason, a basic understanding of the rules that govern electrical forces and fields, an understanding about how we can manipulate these forces to create electrical circuits, and a basic understanding of electric power, potential (voltage) and current flow is fundamental to understanding most of the technology that permeates the modern world.
Enduring Understanding (Mastery Objective)	• A charged body produces an electric field that mediates the interactions between the body and other charges. • Mathematics is a tool used to model objects, events, and relationships in the natural and designed world.
Essential Questions (Instructional Objective)	• How can charged particles, the electric fields they produce and the interaction between those fields be represented verbally, graphically and mathematically? • How is the structure and properties of matter determined by the strength of electrical charges and the electric field they produce? • What is the relationship between electrical field forces and the energy of charged particles moving within the electric field? • How many different types of charges are there? • What are the subatomic particles associated with charge? • What does it mean if an object is neutral? • How processes can an object undergo in order to gain a charge? • What are the different interactions that can occur between objects with charge? • What is an electroscope and how is it utilized? • How is a conductor different from an insulator in the way charges are transferred? • How are charges distributed in a conductor and an insulator? • What are the similarities and differences between electric force and gravitational force? What factors affect electrostatic interactions? • How are electric forces calculated using Coulomb's Law? • What is electric potential energy? • How is electric potential energy similar to gravitational and elastic potential energy? • How is the electric potential energy of a charge object calculated? • How do series and parallel circuits work and what are the implications for home electrical wiring systems?
Content	• Understand the basic principles of electric charges and the subatomic

(Subject Matter)	particles associated with them. • Determine the net charge on a particle or object. • Distinguish between charging through contact, polarization and induction. • Identify interactions between particles and objects possessing similar and different electric charges. • Use an electroscope to determine whether an object possesses net charge. • Distinguish between conductors and insulators. • Identify properties associated with conductors in electrostatic equilibrium. • Develop models to represent charges distributed in conductors and insulator. • Develop models identifying factors that affect electrostatic interactions • Compare and contrast gravitational force with electric force, including how mass interactions are analogous to charge interactions. • Calculate electric force using Coulomb's Law. • Create free body diagrams showing forces acting on a charged particle by other charged particles in the system. • Differentiate between electrical potential energy, potential difference, and voltage. • Calculate electrical potential for various systems of charge distributions. • Calculate electrical Power consumption in home energy systems and discuss why parallel circuits are used in wiring hope electrical systems.
Skills/ Benchmarks (CCSS Standards)	• 5.1.12.A.1 Refine interrelationships among concepts and patterns of evidence found in different central scientific explanations. • 5.1.12.A.2 Develop and use mathematical, physical, and computational tools to build evidence-based models and to pose theories. • 5.1.12.A.3 Use scientific principles and theories to build and refine standards for data collection, posing controls, and presenting evidence. • 5.2.2.D.1 Predict and confirm the brightness of a light, the volume of sound, or the amount of heat when given the number of batteries, or the size of batteries. • 5.2.4.D.1 Repair an electric circuit by completing a closed loop that includes wires, a battery (or batteries), and at least one other electrical component to produce observable change. • 5.2.6.D.1 Use simple circuits involving batteries and motors to compare and predict the current flow with different circuit arrangements. • 5.1.12.B.2 Build, refine, and represent evidence-based models using mathematical, physical, and computational tools. • 5.1.12.B.1 Design investigations, collect evidence, analyze data, and evaluate evidence to determine measures of central tendencies, causal/correlation relationships, and anomalous data. • 5.1.12.C.2 Use data representations and new models to revise

	predictions and explanations. • 5.1.12.D.1 Engage in multiple forms of discussion in order to process, make sense of, and learn from others' ideas, observations, and experiences. • 5.1.12.D.2 Represent ideas using literal representations, such as graphs, tables, journals, concept maps, and diagrams.
Materials and Resources	Selected text and activity resources from Physics Union Mathematics (PUM), c 2009, Rutgers University, Light and Matter & The Peoples Physics Book, Santa Cruz Institute of Particle Physics, J. Kovalcin, c 2001, and Glencoe Physics: Principles and Problems, c 2001. Lab activities utilize a variety of common lab equipment as well as PASCO probe ware and PhET computer based simulations, University of Colorado, 2013.
Notes	**Common Misconceptions:** • Objects become positively charged because they have gained protons. • Objects become positively charged because their electrons have been destroyed. • All atoms carry a net charge. • Larger magnets are stronger than smaller magnets. • Current flows from a battery (or other source of electricity) to a light bulb (or other item that consumes electricity), but not from the light bulb to the battery. • Current flows out of both terminals of a dry cell or both connections in an electrical outlet. • Current flows around a complete circuit, but it is used u by objects like light bulbs so less current returns than leaves the source of the electricity. • All the electrons that make up a electrical current are initially contained in the battery or generator that is the source of the electricity. • Electricity is produced in the wall socket. • Electrons change into light when a lamp is turned on. • A larger battery will make a motor run faster or a bulb burn brighter. • Pure water is a good conductor of electricity. • Electricity from a dry cell will shock or hurt if it is touched. • Insulation is used to keep electricity in the wire. • All wires are insulated, • Birds can perch on bare wires without being hurt because birds have insulated feet. • A charge object can only affect other charged objects. • The electrostatic force between two charged objects in not affected by the distance between them. • Gravitational forces are stronger than electrostatic forces.