Curriculum Map: Independent Study of Physics with Calculus Applications

MASH

Science

Course Description: This is an independent study calculus-based physics course designed for students who have taken or are concurrently taking a calculus course, to prepare students for a college-based physics curriculum and/or to prepare students who wish to sit for the AP Physics C Mechanics and/or Electromagnetics exams. Students will also have already completed an algebra-based physics mechanics course and either have completed or are concurrently enrolled in an algebra-based physics course that address electromagnetics. Students can choose to concentrate on just mechanics, just electromagnetics, or both. Under mechanics, the topics covered will be linear and rotational kinematics, Newton's laws of motion and gravity, work, energy, and power. Under electromagnetism, the topics covered will be electrostatics, conductors, capacitors, inductors, electric circuits, magnetic fields, and electromagnetism.

Textbook and Materials includes, but is not necessarily limited to

1. *Calculus-Based Physics, a Free Physics Textbook*, Jeffrey W. Schnick, Ph.D., Physics Department, Saint Anselm College (Copyright 2005-2008, Jeffrey W. Schnick, Creative Commons Attribution Share-Alike License 3.0) (http://www.anselm.edu/internet/physics/cbphysics/)

2. *Introductory Physics I Elementary Mechanics*, Robert G. Brown, Duke University Physics Department, Durham, NC 27708-0305 (Robert G. Brown 2013)
(http://www.phy.duke.edu/~rgb/Class/intro_physics_1.php)
Open Public License (modified): http://www.phy.duke.edu/~rgb/OPL.php

3. *Introductory Physics II Electricity, Magnetism and Optics*, Robert G. Brown, Duke University Physics Department, Durham, NC 27708-0305 (Robert G. Brown 2013)
(http://www.phy.duke.edu/~rgb/Class/intro_physics_2.php)
Open Public License (modified): http://www.phy.duke.edu/~rgb/OPL.php

4. www.people.fas.harvard.edu/~djmorin/book.html

5. *Problems and Solutions in Introductory Mechanics*, David Morin, Harvard University, 2014

6. *Feynman Lectures on Physics, the Definitive Edition, Volumes I, II, and III*, Richard Feynman, Leighton, and Sands, Pierson Addison Wesley, 2006

7. *Exercises for the Feynman Lectures on Physic the New Millennium Edition*, Richard Feynman, *et al* Basic Books, 2014

8. *College Physics, Tenth Edition*, Raymond A. Serway and Chris Vuille, Cengage Learning, 2015

Unit Title: Kinematics in One Dimension

Suggested time frame:

Mechanics & Electromagnetism track	5 days
Mechanics only track	10 days
Electromagnetism only track	0 days

Standards: Course - 3.2.P.B: PHYSICS

Standard - 3.2.P.B1: Differentiate among translational motion, simple harmonic motion, and rotational motion in terms of position, velocity, and acceleration. Use force and mass to explain translational motion or simple harmonic motion of objects. Relate torque and rotational inertia to explain rotational motion.

Standard - 3.2.P.B6: PATTERNS SCALE MODELS CONSTANCY/CHANGE Use Newton's laws of motion and gravitation to describe and predict the motion of objects ranging from atoms to the galaxies.

Essential Questions:

- Big Idea 3: The interactions of an object with other objects can be described by forces.
- Big Idea 4: Interactions between systems can result in changes in those systems.

1. How do we qualitatively and quantitatively describe the motion of an object?
2. How can graphs help us understand the motion of an object?
3. How do approximations made in the analysis of motion affect our understanding of the motion of an object?
4. How does calculus help us understand the motion of an object, beyond using algebra-based only techniques?

Competency	Vocabulary	Strategy	Resource
Students will be able to: 1. Quantitatively and qualitatively analyze graphs of a kinematic quantity (position, velocity, or acceleration) as a function of time by recognizing when the other two quantities are positive, negative, or zero, over a time interval.	kinematic; one dimension; scalar; vector; displacement; distance; speed; velocity; acceleration; kinematic equation; average velocity; instantaneous velocity;	1. Notes, example problems, readings, homework, online simulations, formative assessment, summative assessment 2. Displacement vs. Time, Velocity vs. Time, and	1. Textbook and materials listed on page 2 of this curriculum 2. Online video and interactive sources

Competency	Vocabulary	Strategy	Resource
2. Sketch graphs of kinematic quantities as a function of time. 3. Given a kinematic quantity as a function of time, determine the other two quantities, and determine when those other two quantities are at a maximum or minimum value. 4. Determine an equation for velocity as a function of time, given an expression for acceleration as a function of time, by using calculus methods.	average acceleration; instantaneous acceleration; motion diagram; free-fall; gravity; acceleration due to gravity;	Acceleration vs. Time Laboratory exercises using air track and electronic data collection devices 3. Computer programs to analyze the data collected	

Unit Title: Kinematics in Two Dimensions

Suggested time frame:

Mechanics & Electromagnetism track	8 days
Mechanics only track	16 days
Electromagnetism only track	0 days

Standards: Course – 3.2.P.B: PHYSICS

Standard – 3.2.P.B1: Differentiate among translational motion, simple harmonic motion, and rotational motion in terms of position, velocity, and acceleration. Use force and mass to explain translational motion or simple harmonic motion of objects. Relate torque and rotational inertia to explain rotational motion.

Standard – 3.2.P.B2: Explain the translation and simple harmonic motion of objects using conservation of energy and conservation of momentum. Describe the rotational motion of objects using the conservation of energy and conservation of angular momentum. Explain how gravitational, electrical, and magnetic forces and torques give rise to rotational motion.

Essential Questions:

- Big Idea 3: The interactions of an object with other objects can be described by forces.
- Big Idea 4: Interactions between systems can result in changes in those systems.

1. How do we qualitatively and quantitatively describe the motion of an object?
2. How can graphs help us understand the motion of an object?
3. How do vectors help us understand motion if two or more dimensions?
4. How does understanding motion in one-dimension help us to understand motion in two or more dimensions?
5. How do approximations made in the analysis of motion affect our understanding of the motion of an object?
6. How does calculus help us understand the motion of an object, beyond using algebra-based only techniques?

Competency	Vocabulary	Strategy	Resource
Students will be able to: 1. Apply vector analysis to velocity and displacement vectors 2. Determine the change in velocity of a particle or the velocity of one particle relative to another. 3. Use parametric equations for x(t) and y(t), to describe the motion of a particle in two dimensions, in terms of position, velocity, and acceleration. 4. Describe qualitatively and quantitatively the motion of projectiles in a uniform gravitational field.	two dimensions; vector; scalar; resultant vector; vector addition; vector subtraction; component vectors; projectile motion; parabolic motion; relative velocity	1. Notes, example problems, readings, homework, online simulations, formative assessment, summative assessment 2. Projectile motion Laboratory exercises using electronic data collection devices 3. Computer programs to analyze the data collected	1. Textbook and materials listed on page 2 of this curriculum 2. Online video and interactive sources

Unit Title: Newton's Laws of Motion

Suggested time frame:	Mechanics & Electromagnetism track	14 days
	Mechanics only track	28 days
	Electromagnetism only track	0 days

Standards: Course – 3.2.P.B: PHYSICS

Standard – 3.2.P.B1: Differentiate among translational motion, simple harmonic motion, and rotational motion in terms of position, velocity, and acceleration. Use force and mass to explain translational motion or simple harmonic motion of objects. Relate torque and rotational inertia to explain rotational motion.

Standard – 3.2.P.B6: PATTERNS SCALE MODELS CONSTANCY/CHANGE Use Newton's laws of motion and gravitation to describe and predict the motion of objects ranging from atoms to the galaxies.

Essential Questions:

- Big Idea 1: Objects and systems have properties such as mass and charge. Systems may have internal structure.
- Big Idea 2: Fields existing in space can be used to explain interactions.
- Big Idea 3: The interactions of an object with other objects can be described by forces.
- Big Idea 4: Interactions between systems can result in changes in those systems.
- Big Idea 5: Changes that occur as a result of interactions are constrained by conservation laws.

1. What causes objects to move?
2. How do Newton's laws of motion help us understand the motion of objects?
3. What is the cause of the forces that affect objects?
4. How is Newton's second law of motion related to the kinematic equations?
5. How does making approximations, such as frictionless motion, help us to understand how an object is actually moving?

Competency	**Vocabulary**	**Strategy**	**Resource**
Students will be able to: 1. Determine kinematic quantities for objects subject to a force that changes over time. 2. Determine the terminal velocity of an object subject to a retardant force dependent on velocity. 3. Describe qualitatively, using graphs, the acceleration, velocity, and displacement of an object subject to a retarding force that is release from rest or projected vertically with a specified velocity. 4. From Newton's second law of motion, use calculus concepts to write a differential equation for the velocity of an object as a function of time and solve that equation for velocity. 5. Derive an expression for acceleration as a function of time for an object falling under the influence of a retarding force. 6. Determine the force contact between objects that accelerate together either vertically or horizontally, or between two surfaces sliding across one another. 7. Solve problems that result in a system of two or three linear equations.	force, contact force; field force; force of gravity; electromagnetic force; strong nuclear force; weak nuclear force; Newton's first law of motion; equilibrium Newton's second law of motion; mass; acceleration; Universal Law of Gravitation; weight; Newton's third law of motion; reaction force; free-body diagram; force of friction; normal force; coefficient of friction; static friction; kinetic friction	1. Notes, example problems, readings, homework, online simulations, formative assessment, summative assessment 2. Laboratory exercise using air track and electronic data collection devices 3. Laboratory exercise using force meters and electronic data collection devices 4. Computer programs to analyze the data collected	1. Textbook and materials listed on page 2 of this curriculum 2. Online video and interactive sources

Unit Title: Work, Energy, and Power

Suggested time frame:

Mechanics & Electromagnetism track	10 days
Mechanics only track	20 days
Electromagnetism only track	0 days

Standards: Course - 3.2.P.B: PHYSICS

Standard – 3.2.P.B1: Differentiate among translational motion, simple harmonic motion, and rotational motion in terms of position, velocity, and acceleration. Use force and mass to explain translational motion or simple harmonic motion of objects. Relate torque and rotational inertia to explain rotational motion.

Standard – 3.2.P.B2: Explain the translation and simple harmonic motion of objects using conservation of energy and conservation of momentum. Describe the rotational motion of objects using the conservation of energy and conservation of angular momentum. Explain how gravitational, electrical, and magnetic forces and torques give rise to rotational motion.

Standard – 3.2.P.B6: PATTERNS SCALE MODELS CONSTANCY/CHANGE Use Newton's laws of motion and gravitation to describe and predict the motion of objects ranging from atoms to the galaxies.

Essential Questions:

- Big Idea 1: Objects and systems have properties such as mass and charge. Systems may have internal structure.
- Big Idea 2: Fields existing in space can be used to explain interactions.
- Big Idea 3: The interactions of an object with other objects can be described by forces.
- Big Idea 4: Interactions between systems can result in changes in those systems.
- Big Idea 5: Changes that occur as a result of interactions are constrained by conservation laws.

1. How might a non-scientific definition of work differ from the scientific definition of work?
2. Why might a person become tired pushing on an "immovable" object, but under the scientific definition of work the person does no work on the object?
3. How is potential energy and work related?
4. How are work, energy, and power related?
5. What are distinguishing factors for conservative and non-conservative forces?

6. How are conservation of energy and the kinematic equations related?

Competency	Vocabulary	Strategy	Resource
Students will be able to: 1. Using calculus concepts, determine work being down by a force given an expression of the applied force as a function of position. 2. Using the work-energy theorem, determine the change in kinetic energy of an object given a force as a function of time or position. 3. Calculate the potential energy of an object given a force as a function of position. 4. Determine the magnitude of a one-dimensional force, given an expression for potential energy as a function of position. 5. Derive the expression for the potential energy of an ideal spring using the ideal-spring force equation. 6. Use conservation of energy to determine kinematic quantities of objects under the influence of springs and/or gravity. 7. Calculate the power supplied by a force to an object to keep the object in translational equilibrium. 8. Determine the work done by a force that is changing as a function of position or time. 9. Determine the power delivered by a force that is represented as a graph of force vs. time.	work; joule; Newton-meter; foot-pound; British thermal unit; dissipative force; nonconservative force; conservative force; kinetic energy; work-energy theorem; gravitational potential energy; gravitational work; reference level; mechanical energy; ideal spring; spring potential energy; spring constant; Hooke's law; elastic potential energy; conservation of energy; power; watt; average power; instantaneous power; power delivered; power dissipated	1. Notes, example problems, readings, homework, online simulations, formative assessment, summative assessment 2. Laboratory exercise using air tracks, force meters and electronic measurement devices 3. Computer programs to analyze the data collected	1. Textbook and materials listed on page 2 of this curriculum 2. Online video and interactive sources

Unit Title: Momentum

Suggested time frame:

Mechanics & Electromagnetism track	8 days
Mechanics only track	16 days
Electromagnetism only track	0 days

Standards: Course - 3.2.P.B: PHYSICS

Standard – 3.2.P.B1: Differentiate among translational motion, simple harmonic motion, and rotational motion in terms of position, velocity, and acceleration. Use force and mass to explain translational motion or simple harmonic motion of objects. Relate torque and rotational inertia to explain rotational motion.

Standard – 3.2.P.B2: Explain the translation and simple harmonic motion of objects using conservation of energy and conservation of momentum. Describe the rotational motion of objects using the conservation of energy and conservation of angular momentum. Explain how gravitational, electrical, and magnetic forces and torques give rise to rotational motion.

Standard – 3.2.P.B6: PATTERNS SCALE MODELS CONSTANCY/CHANGE Use Newton's laws of motion and gravitation to describe and predict the motion of objects ranging from atoms to the galaxies.

Essential Questions:

- Big Idea 1: Objects and systems have properties such as mass and charge. Systems may have internal structure.
- Big Idea 2: Fields existing in space can be used to explain interactions.
- Big Idea 3: The interactions of an object with other objects can be described by forces.
- Big Idea 4: Interactions between systems can result in changes in those systems.
- Big Idea 5: Changes that occur as a result of interactions are constrained by conservation laws.

1. How is conservation of momentum and conservation of energy related?
2. How is a system defined for conservation of momentum purposes?
3. What are the distinguishing differences between elastic collisions an inelastic collisions?
4. Under what conditions does an elastic collision occur in the universe?
5. How does friction affect the analysis of conservation of momentum?

Competency	**Vocabulary**	**Strategy**	**Resource**
Students will be able to: 1. Determine the center of mass of symmetrical objects or systems of two objects. 2. Use calculus concepts to determine the center of mass of an object with non-uniform density. 3. Determine the momentum of an object using the concept of the center-of-mass velocity. 4. Determine the net external force of a system of objects using the center-of-mass acceleration of the objects. 5. Define the center of gravity and use it to determine the gravitational potential energy of a rigid object. 6. Calculate the momentum of an object subject to a force that varies over time. 7. Determine the change in momentum using a graph of a force vs. time curve. 8. Derive the conservation of momentum using Newton's third law of motion. 9. Solve various systems of objects interacting through elastic and/or inelastic collisions. 10. Determine the amount of energy being released when two objects are pushed apart by a spring. 11. Describe the motion of an object in reference to a moving medium. 12. Describe the motion of an object relative to a frame of reference that is moving with a constant acceleration in one-dimension.	momentum; kg·m/s; impulse; impulse-momentum theorem; conservation of momentum; recoil; elastic collision; inelastic collision; perfectly inelastic collision; collision; glancing collision; ballistic pendulum; propulsion	1. Notes, example problems, readings, homework, online simulations, formative assessment, summative assessment 2. Laboratory exercise using air tracks and electronic data measurement devices 3. Computer programs to analyze the data collected	1. Textbook and materials listed on page 2 of this curriculum 2. Online video and interactive sources

Unit Title: Rotational Motion

Suggested time frame:

Mechanics & Electromagnetism track	13 days
Mechanics only track	26 days
Electromagnetism only track	0 days

Standards: Course - 3.2.P.B: PHYSICS

Standard – 3.2.P.B1: Differentiate among translational motion, simple harmonic motion, and rotational motion in terms of position, velocity, and acceleration. Use force and mass to explain translational motion or simple harmonic motion of objects. Relate torque and rotational inertia to explain rotational motion.

Standard – 3.2.P.B2: Explain the translation and simple harmonic motion of objects using conservation of energy and conservation of momentum. Describe the rotational motion of objects using the conservation of energy and conservation of angular momentum. Explain how gravitational, electrical, and magnetic forces and torques give rise to rotational motion.

Standard – 3.2.P.B6: PATTERNS SCALE MODELS CONSTANCY/CHANGE Use Newton's laws of motion and gravitation to describe and predict the motion of objects ranging from atoms to the galaxies.

Essential Questions:

- Big Idea 1: Objects and systems have properties such as mass and charge. Systems may have internal structure.
- Big Idea 2: Fields existing in space can be used to explain interactions.
- Big Idea 3: The interactions of an object with other objects can be described by forces.
- Big Idea 4: Interactions between systems can result in changes in those systems.
- Big Idea 5: Changes that occur as a result of interactions are constrained by conservation laws.
- Big Idea 6: Waves can transfer energy and momentum from one location to another without the permanent transfer of mass and serve as a mathematical model for the description of other phenomena.

1. How are circular motion and translational/tangential motion related to each other?
2. How are circular motion and trigonometric concepts related?
3. What is the mechanism to create circular motion?
4. How are torque and circular motion related?

Competency	Vocabulary	Strategy	Resource
Students will be able to: 1. Determine the centripetal acceleration in relation to an objects angular speed. 2. Determine the instantaneous net acceleration and velocity of an object that is rotating with a constant angular acceleration. 3. Determine the components of an objects velocity and acceleration that is rotating using graphs of these quantities. 4. Sketch the velocity and acceleration vectors vs. time for a rotating object. 5. Determine the net force acting on an object for situations involving motion in a horizontal or vertical circle. 6. Determine by inspection which set of symmetrical objects has a greater rotational inertia. 7. Determine how an objects rotational inertia changes due to geometric changes in the object's structure. 8. Determine the angular acceleration of a rigid object due to a constant force or a force that changes with time. 9. Determine angular kinematics for a system of pulleys and strings. 10. Use conservation of energy to determine the rotational kinematics of an object 11. Determine the velocity and acceleration of a point on a ball that rolls along a surface without slipping. 12. Determine the kinetic energy of an object that is rolling along a surface without slipping.	radial motion; radian; degrees; radius; angular position; angular displacement; angular speed; angular acceleration; rad/s; rad/s^2; instantaneous angular speed; average angular speed; instantaneous angular acceleration; average angular acceleration; tangential velocity/speed; tangential acceleration; centripetal acceleration; centripetal force;	1. Notes, example problems, readings, homework, online simulations, formative assessment, summative assessment 2. Laboratory exercise to measure the centripetal force needed to keep a mass in rotational motion both horizontally to the ground and at an angle to the ground 3. Computer programs to analyze the data collected	1. Textbook and materials listed on page 2 of this curriculum 2. Online video and interactive sources

Competency	**Vocabulary**	**Strategy**	**Resource**
13. Determine the angular momentum of a rotating object. 14. Determine the angular momentum vector of a rigid rotating object for cases when that vector is parallel to the rotational velocity. 15. Apply conservation of momentum to one- and two-particle systems. 16. Analyze systems in which the moment of inertia of an object is changed as it rotates freely about a fixed axis.			

Unit Title: Newton's Law of Gravity and Orbits of Planets and Satellites

Suggested time frame:

Mechanics & Electromagnetism track	6 days
Mechanics only track	12 days
Electromagnetism only track	0 days

Standards: Course - 3.2.P.B: PHYSICS

Standard – 3.2.P.B1: Differentiate among translational motion, simple harmonic motion, and rotational motion in terms of position, velocity, and acceleration. Use force and mass to explain translational motion or simple harmonic motion of objects. Relate torque and rotational inertia to explain rotational motion.

Standard – 3.2.P.B2: Explain the translation and simple harmonic motion of objects using conservation of energy and conservation of momentum. Describe the rotational motion of objects using the conservation of energy and conservation of angular momentum. Explain how gravitational, electrical, and magnetic forces and torques give rise to rotational motion.

Standard – 3.2.P.B5: Explain how waves transfer energy without transferring matter. Explain how waves carry information from remote sources that can be detected and interpreted. Describe the causes of wave frequency, speed, and wave length.

Standard – 3.2.P.B6: PATTERNS SCALE MODELS CONSTANCY/CHANGE Use Newton's laws of motion and gravitation to describe and predict the motion of objects ranging from atoms to the galaxies.

Essential Questions:

- Big Idea 1: Objects and systems have properties such as mass and charge. Systems may have internal structure.
- Big Idea 2: Fields existing in space can be used to explain interactions.
- Big Idea 3: The interactions of an object with other objects can be described by forces.
- Big Idea 4: Interactions between systems can result in changes in those systems.
- Big Idea 5: Changes that occur as a result of interactions are constrained by conservation laws.
- Big Idea 6: Waves can transfer energy and momentum from one location to another without the permanent transfer of mass and serve as a mathematical model for the description of other phenomena.

1. What is gravity?
2. What causes the force of gravity to exist?
3. How does gravity affect motion?
4. Why do we assume that the acceleration due to gravity is constant near the surface of the Earth?
5. How does gravity keep the planets in motion?
6. Why is gravity consider a weak force?
7. How do Kepler's laws of planetary motion describe the motion of planets?

Competency	**Vocabulary**	**Strategy**	**Resource**
Students will be able to: 1. Determine the forces acting on objects due gravity. 2. Determine the strength of a gravitational field at a point outside of a spherically symmetrical mass. 3. Determine the motion of objects that are interacting due to the law of gravitation and the concept of gravitational potential energy. 4. Calculate the force of gravity at points inside and outside of a symmetrical sphere of uniform density. 5. Use the concepts of conservation of mechanical energy to determine escape speeds of small objects from large objects. 6. Show that the mass of an object orbiting a large mass does not depend on the mass of the orbiting object. 7. Derive the expressions for the velocity and period of revolution of an object orbiting a large mass in a circular orbit. 8. Derive Kepler's third law for the case of circular orbits	gravity; law of gravitation; force of gravity; constant of universal gravitation (G); inverse-square law; gravitational potential energy; escape speed/velocity; geocentric/heliocentric model Kepler's laws of planetary motion	1. Notes, example problems, readings, homework, online simulations, formative assessment, summative assessment 2. Designing a Microsoft Excel application that will simulate kinematic data for planetary motion about the sun	1. Textbook and materials listed on page 2 of this curriculum 2. Online video and interactive sources

Competency	Vocabulary	Strategy	Resource
9. Derive and apply the relations among kinetic energy, potential energy, and total energy for circular orbits. 10. Describe qualitatively the motion of a planet in an elliptical orbit using Kepler's three laws of planetary motion. 11. Use the concept of conservation of angular momentum to determine the velocity and radial distance of a planet at any point in its orbit. 12. For an object in elliptical orbit, use the concept of conservation of angular momentum to relate the speeds of an object at the apogee and perigee of the orbit.			

Unit Title: Harmonic Motion

Suggested time frame:

Mechanics & Electromagnetism track	6 days
Mechanics only track	12 days
Electromagnetism only track	0 days

Standards: Course - 3.2.P.B: PHYSICS

Standard – 3.2.P.B1: Differentiate among translational motion, simple harmonic motion, and rotational motion in terms of position, velocity, and acceleration. Use force and mass to explain translational motion or simple harmonic motion of objects. Relate torque and rotational inertia to explain rotational motion.

Standard – 3.2.P.B2: Explain the translation and simple harmonic motion of objects using conservation of energy and conservation of momentum. Describe the rotational motion of objects using the conservation of energy and conservation of angular momentum. Explain how gravitational, electrical, and magnetic forces and torques give rise to rotational motion.

Standard – 3.2.P.B5: Explain how waves transfer energy without transferring matter. Explain how waves carry information from remote sources that can be detected and interpreted. Describe the causes of wave frequency, speed, and wave length.

Standard – 3.2.P.B6: PATTERNS SCALE MODELS CONSTANCY/CHANGE Use Newton's laws of motion and gravitation to describe and predict the motion of objects ranging from atoms to the galaxies.

Essential Questions:

- Big Idea 1: Objects and systems have properties such as mass and charge. Systems may have internal structure.
- Big Idea 2: Fields existing in space can be used to explain interactions.
- Big Idea 3: The interactions of an object with other objects can be described by forces.
- Big Idea 4: Interactions between systems can result in changes in those systems.
- Big Idea 5: Changes that occur as a result of interactions are constrained by conservation laws.
- Big Idea 6: Waves can transfer energy and momentum from one location to another without the permanent transfer of mass and serve as a mathematical model for the description of other phenomena.

1. What is harmonic motion?
2. What is the difference between harmonic motion and simple harmonic motion?
3. What are the advantages of using conservation of energy versus the kinematic equations for analyzing systems in harmonic motion?
4. How do graphs of object in harmonic motion aid in understanding the object's motion?

Competency	**Vocabulary**	**Strategy**	**Resource**
Students will be able to: 1. Determine the amplitude, period and frequency of an object in simple harmonic motion ("SHM") from the graph of the displacement vs. time. 2. Determine the parametric time expressions for the displacement of an object in SMH. 3. Determine the velocity of an object in SHM. 4. For an object in SHM, determine the points where its acceleration, velocity, and displacement are zero, a maximum, or a minimum. 5. Determine the frequency and period for an object in SHM using the equation, $d^2x/dt^2 = -\omega^2$. 6. Derive the relationship between the total energy of a system in SHM and the amplitude of the motion. 7. Determine the expressions for the potential energy and kinetic energy of an object in SHM as a function of time. 8. Graph the experssions for kinetic energy and potential energy of an object in SHM, and show that their sum is constant. 9. Derive the expression for the period of oscillation of a mass on a spring and show that it is SHM.	Hooke's law; spring constant; harmonic motion; simple harmonic motion; oscillation; harmonic oscillator; amplitude; period; frequency; equilibrium; elastic potential energy; circular motion; uniform circular motion; sine wave; sine function; sinusoidal; pendulum; simple pendulum; damped oscillation; wave; transverse wave; longitudinal wave; medium; wavelength; superposition; interference; constructive interference; destructive	1. Notes, example problems, readings, homework, online simulations, formative assessment, summative assessment 2. Laboratory exercise to compare pendulum harmonic motion that is nearly simple harmonic motion to just harmonic motion by varying the initial displacement angle 3. Computer programs to analyze the data collected	1. Textbook and materials listed on page 2 of this curriculum 2. Online video and interactive sources

Competency	Vocabulary	Strategy	Resource
10. Determine the periods of oscillation of a system of springs in series and/or parallel combinations of springs. 11. Derive the expression for the period of oscillation of a pendulum for small angles of displacement.	interference; reflection		

Unit Title: Electrostatics

Suggested time frame:	Mechanics & Electromagnetism track	21 days
	Mechanics only track	0 days
	Electromagnetism only track	42 days

Standards: Course - 3.2.P.B: PHYSICS

Standard – 3.2.P.B4: Explain how stationary and moving particles result in electricity and magnetism. Develop qualitative and quantitative understanding of current, voltage, resistance, and the connections among them. Explain how electrical induction is applied in technology.

Essential Questions:

- Big Idea 1: Objects and systems have properties such as mass and charge. Systems may have internal structure.
- Big Idea 2: Fields existing in space can be used to explain interactions.
- Big Idea 3: The interactions of an object with other objects can be described by forces.
- Big Idea 4: Interactions between systems can result in changes in those systems.
- Big Idea 5: Changes that occur as a result of interactions are constrained by conservation laws.
- Big Idea 6: Waves can transfer energy and momentum from one location to another without the permanent transfer of mass and serve as a mathematical model for the description of other phenomena.

1. What causes the electrical force between charged objects?
2. What are electric fields?
3. What is the difference between electrical conduction and induction?
4. How do fields help to understand the electrical force between charged objects?
5. How are the electrical force and the electric field related?
6. How are the electric field and the electric potential related?
7. How are electric potential and electric potential energy related?
8. How do graphs of electric field lines and equipotential surfaces aid us in understand the effect of the electrical force on charged objects?

Competency	Vocabulary	Strategy	Resource
Students will be able to: 1. Explain the concept of conservation of charge. 2. Explain the concepts of charge conduction and charge induction. 3. State Coulomb's law. 4. Apply Coulomb's law to systems of static charges. 5. Determine the motion of a charged particle under the influence of a static charge(s) as a function of time. 6. State the definition of an electric field. 7. Determine the electric field produced by a system of charged particles. 8. State the rules for drawing electric field lines and create field lines for simple charge configurations. 9. Interpret an electric field graph. 10. Determine the motion of a charged particle under the influence of a constant electric field. 11. Use Coulomb's law and the work-energy theorem to derive the equation for the electric potential at a distance from a point charge. 12. Define electric potential energy difference in a constant electric field in terms of the work done by the field. 13. Apply the work-energy theorem to systems involving electric potential and electric potential energy. 14. Define the electric potential of point charges and pairs of point charges. 15. Apply electric potential and potential energy to systems of charges. 16. Define equipotential surface and describe its electrical properties.	electric charge; fundamental charge; proton; electron; neutron; positive; negative; neutral; repel; attract; conservation of charge; insulator; conductor; induction; conduction; ground; coulomb; Coulomb's Law; superposition; electric field; Newton's per Coulomb; dipole; electrostatic equilibrium; electric flux; permittivity; capacitance; dielectric; farad; voltage; emf; electric potential; equipotential surfaces; parallel and series capacitors; equivalent capacitance	1. Notes, example problems, readings, homework, online simulations, formative assessment, summative assessment 2. Laboratory exercise mapping electric field line directions 3. Laboratory exercise to map equipotential lines	1. Textbook and materials listed on page 2 of this curriculum 2. Online video and interactive sources

Competency	Vocabulary	Strategy	Resource
17. Determine the direction and relative strength of an electric field at a point given a graph of equipotential lines. 18. Use calculus concepts to determine the electric potential difference between two points on a line, given an equation for the electric field strength as a function of position. 19. Use Gauss's law to determine the electric flux through a surface given that the electric field is perpendicular to the surface. 20. Use Gauss's law to determine the electric flux of an electric field that is perpendicular to and uniform over the surface. 21. Calculate the electric field through a rectangle when the field is perpendicular of the rectangle and a function of only one coordinate. 22. Apply Gauss's law, in integral form, to determine the electric field for planar, spherical, or cylindrically symmetric charge distributions. 23. Apply Gauss's law to determine the charge density or total charge on a surface, in terms of the electric field near the surface. 24. Use integration to calculate the electric field and the electric potential of a straight uniformly charged electric wire, on the axis of a thing ring of charge, and on the center of circular arc of charge 25. Determine the direction, pattern, and variation at a distance of the electric filed due to highly symmetric charge distributions of various symmetrically formed geometric objects. 26. Determine the electric field and derive the expressions for electric potential for charged parallel planes, coaxial cables, and concentric spheres.			

Competency	Vocabulary	Strategy	Resource
27. Describe the mechanics regarding charge distribution for electric conductors. 28. Sketch graphs of electric fields and electrical potential inside and outside of conductors. 29. Describe the process of charging by induction. 30. Describe the electric field outside of a hollow conductor that has charges located inside of the conductor. 31. Determine the stored charge, voltage across, and stored energy for a capacitor. 32. Use Gauss's law to determine the electric between and outside of a parallel-plate capacitor. 33. Derive expressions for the capacitance and energy stored for a parallel plate, cylindrical, and spherical capacitors, electric field between the conducing plates of a capacitor. 34. Describe the effect that inserting a dielectric between the conductors of a capacitor has on the capacitance.			

Unit Title: Electric Circuits

Suggested time frame:

Mechanics & Electromagnetism track	14 days
Mechanics only track	0 days
Electromagnetism only track	28 days

Standards: Course - 3.2.P.B: PHYSICS

Standard – 3.2.P.B4: Explain how stationary and moving particles result in electricity and magnetism. Develop qualitative and quantitative understanding of current, voltage, resistance, and the connections among them. Explain how electrical induction is applied in technology.

Essential Questions:

- Big Idea 1: Objects and systems have properties such as mass and charge. Systems may have internal structure.
- Big Idea 2: Fields existing in space can be used to explain interactions.
- Big Idea 3: The interactions of an object with other objects can be described by forces.
- Big Idea 4: Interactions between systems can result in changes in those systems.
- Big Idea 5: Changes that occur as a result of interactions are constrained by conservation laws.
- Big Idea 6: Waves can transfer energy and momentum from one location to another without the permanent transfer of mass and serve as a mathematical model for the description of other phenomena.

1. Why is current defined as the flow of positive charges?
2. Why do charges move?
3. What impedes the flow of charges?
4. How are current and electric potential related?
5. How do conservation of charge and conservation of energy relate to electric circuits?

Competency	Vocabulary	Strategy	Resource
Students will be able to: 1. Determine the current in a circuit based on the flow rate of positive and negative charges in the circuit. 2. Calculate the conductivity, resistivity and resistance of an object based on the material used for the object. 3. Use Ohm's law to determine voltages, currents, and/or resistances in a circuit. 4. Derive expressions for the rate of heat produced for a current-carrying resistor based on the current, voltage, and resistance of a circuit containing the resistor. Apply the relationships for the rate of heat production in a resistor. 5. Determine the equivalent resistance of a network of resistors. 6. Use Ohm's law and Kirchhoff's rules to determine current through, voltage across, and power dissipated by resistors, and current supplied by batteries in circuits comprised of batteries and resistors. 7. Determine the terminal voltage, internal resistance, and/or emf of a battery using circuit analysis. 8. Determine the rate at which a battery is supplying energy to a circuit or is being charged by a circuit. 9. Understand and sketch proper use of voltmeters and ammeters in circuit diagrams. 3. Capacitors ¡n circuits. 10. Calculate the equivalent capacitance of a series or parallel combination of capacitors.	voltage/volt, ampere/amp; resistance; ohm; current; emf; battery; voltage source; terminal voltage, internal resistance, load resistance, current, wattage/watt; power dissipation; power delivery; voltage drop; voltage polarity; time constant; charge; discharge; equivalent resistance; equivalent capacitance	1. Notes, example problems, readings, homework, online simulations, formative assessment, summative assessment 2. Laboratory exercise using Kirchhoff's rules to analyze complex resistor-battery circuits 3. Laboratory exercise to analyze the charging and discharging of a capacitor in an RC circuit using an oscilloscope 4. Using a computer program to analyze the data collected	1. Textbook and materials listed on page 2 of this curriculum 2. Online video and interactive sources

Competency	Vocabulary	Strategy	Resource
11. Calculate the voltage or stored charge, under steady-state conditions, for a capacitor connected to a circuit consisting of a battery and resistors. 12. Determine the time constant for RC circuits. 13. Sketch graphs of current or voltage for RC circuits. 14. Derive the time-dependent equation for the charging and discharging of RC circuits. 15. Analyze graphically and arithmetically RC circuits that are charging or discharging over time.			

Unit Title: Magnetism

Suggested time frame:

Mechanics & Electromagnetism track	14 days
Mechanics only track	0 days
Electromagnetism only track	28 days

Standards: Course - 3.2.P.B: PHYSICS

Standard – 3.2.P.B4: Explain how stationary and moving particles result in electricity and magnetism. Develop qualitative and quantitative understanding of current, voltage, resistance, and the connections among them. Explain how electrical induction is applied in technology.

Essential Questions:

- Big Idea 1: Objects and systems have properties such as mass and charge. Systems may have internal structure.
- Big Idea 2: Fields existing in space can be used to explain interactions.
- Big Idea 3: The interactions of an object with other objects can be described by forces.
- Big Idea 4: Interactions between systems can result in changes in those systems.
- Big Idea 5: Changes that occur as a result of interactions are constrained by conservation laws.
- Big Idea 6: Waves can transfer energy and momentum from one location to another without the permanent transfer of mass and serve as a mathematical model for the description of other phenomena.

1. What is the nature of the force of magnetism?
2. How is the force of magnetism and the electrical force different?
3. How are magnetism and electricity related?

Competency	Vocabulary	Strategy	Resource
Students will be able to: 1. Calculate the magnitude and direction of the force in terms of q, v, and B, and explain why the magnetic force can perform no work. 2. For a charged particle moving through a magnetic field, determine the charge, velocity, or magnetic	Magnetism, magnetic field, magnetic field strength, charge, wire loop, Ampere's law, Biot-Savart law	1. Notes, example problems, readings, homework, online simulations, formative assessment, summative assessment	1. Textbook and materials listed on page 2 of this curriculum 2. Online video and interactive sources

Competency	Vocabulary	Strategy	Resource
field when given sufficient information to determine the values of the other two terms. 3. Determine the path of a charged particle moving in a path whereby its velocity is perpendicular to a uniform magnetic field. 4. Describe under what conditions particles will move with constant velocity through crossed electric and magnetic fields. 5. Calculate the magnitude and direction of the force on a straight segment of current-carrying wire in a uniform magnetic field. 6. Determine the torque experienced by a loop of wire carrying a current in a magnetic field. 7. Calculate the magnitude and direction of the field at a paint in the vicinity of such a wire. 8. Calculate the force of attraction or repulsion between two long, current-carrying wires. 9. Use Biot-Savart law and Ampere's law to determine the contribution to the magnetic field made by a short straight segment of current-carrying wire. 10. Derive and apply the expression for the magnitude of B on the axis of a circular loop of current. 11. Use Ampere's law in integral form, symmetry arguments, and the right-hand rule, to relate magnetic field strength to current for planar or cylindrical symmetries and combinations of such symmetries.		2. Laboratory exercise using Kirchhoff's rules to analyze complex resistor-battery circuits 3. Using a computer program to analyze the data collected	

Unit Title: Electromagnetism

Suggested time frame:

Mechanics & Electromagnetism track	11 days
Mechanics only track	0 days
Electromagnetism only track	22 days

Standards: Course - 3.2.P.B: PHYSICS

Standard – 3.2.P.B4: Explain how stationary and moving particles result in electricity and magnetism. Develop qualitative and quantitative understanding of current, voltage, resistance, and the connections among them. Explain how electrical induction is applied in technology.

Essential Questions:

- Big Idea 1: Objects and systems have properties such as mass and charge. Systems may have internal structure.
- Big Idea 2: Fields existing in space can be used to explain interactions.
- Big Idea 3: The interactions of an object with other objects can be described by forces.
- Big Idea 4: Interactions between systems can result in changes in those systems.
- Big Idea 5: Changes that occur as a result of interactions are constrained by conservation laws.
- Big Idea 6: Waves can transfer energy and momentum from one location to another without the permanent transfer of mass and serve as a mathematical model for the description of other phenomena.

1. How are magnetic flux and magnetic fields related?
2. How do Maxwell's equation relate to electricity, magnetism, and electromagnetism?

Competency	Vocabulary	Strategy	Resource
Students will be able to: 1. Calculate the flux of a uniform magnetic field through a conducting loop. 2. Use integration to calculate the flux through a loop, the plane of which is perpendicular to a	Magnetic flux, Faraday's law, Lenz's law, inductor, inductance, self-inductance, solenoid, LR circuit, RC circuit,	1. Notes, example problems, readings, homework, online simulations, formative assessment, summative assessment	1. Textbook and materials listed on page 2 of this curriculum

Competency	Vocabulary	Strategy	Resource
magnetic field that varies over time or position along one coordinate. 3. Use Faraday's law and Lenz's law to determine the induced emf and current for a loop subject to a flux through the plane of the loop that is changing over time. 4. Describe physically what an inductor is. 5. Calculate the emf in an inductor through which a specified changing current is flowing. 6. Derive and apply the expression for the self-inductance of a long solenoid. 7. Apply Kirchhoff's rules to an LR series circuit to obtain a differential equation for the current as a function of time. 8. Using calculus methods, solve the LR series circuit differential equation for the current as a function of time through the battery. 9. Calculate the initial transient currents and final steady-slate currents through any part of a simple series and parallel circuit containing an inductor and one or more resistors. 10. Sketch graphs of the current through or voltage across the resistors or inductor in a simple series and parallel circuit. 11. Calculate the rate of change of current in the inductor as a function of time. 12. Calculate the energy stored in an inductor that has a steady current flowing through it. 13. Describe the implications of Maxwell's equations.	time constant, steady-state, Maxwell's equations	2. Laboratory exercise to analyze the energizing an de-energizing of an inductor in an RL circuit 3. Using a computer program to analyze the data collected	2. Online video and interactive sources

Unit Title: Review for AP Physics C Exam(s)

Suggested time frame:

Mechanics & Electromagnetism track	14 days
Mechanics only track	14 days
Electromagnetism only track	14 days

Standards: Course - 3.2.P.B: PHYSICS

Standard – 3.2.P.B1: Differentiate among translational motion, simple harmonic motion, and rotational motion in terms of position, velocity, and acceleration. Use force and mass to explain translational motion or simple harmonic motion of objects. Relate torque and rotational inertia to explain rotational motion.

Standard – 3.2.P.B2: Explain the translation and simple harmonic motion of objects using conservation of energy and conservation of momentum. Describe the rotational motion of objects using the conservation of energy and conservation of angular momentum. Explain how gravitational, electrical, and magnetic forces and torques give rise to rotational motion.

Standard – 3.2.P.B3: Analyze the factors that influence convection, conduction, and radiation between objects or regions that are at different temperatures.

Standard – 3.2.P.B4: Explain how stationary and moving particles result in electricity and magnetism. Develop qualitative and quantitative understanding of current, voltage, resistance, and the connections among them. Explain how electrical induction is applied in technology.

Standard – 3.2.P.B5: Explain how waves transfer energy without transferring matter. Explain how waves carry information from remote sources that can be detected and interpreted. Describe the causes of wave frequency, speed, and wave length.

Standard – 3.2.P.B6: PATTERNS SCALE MODELS CONSTANCY/CHANGE Use Newton’s laws of motion and gravitation to describe and predict the motion of objects ranging from atoms to the galaxies.

<u>Unit Title</u>: Selected Topics/Project Based Analysis

Possible Topics: Relativity; Modern Physics; Solving problems via numerical analysis

<u>Suggested time frame</u>: Remaining time in the school year after the AP Physics C tests.

<u>Standards</u>: Course - 3.2.P.B: PHYSICS

Standard – 3.2.P.B1: Differentiate among translational motion, simple harmonic motion, and rotational motion in terms of position, velocity, and acceleration. Use force and mass to explain translational motion or simple harmonic motion of objects. Relate torque and rotational inertia to explain rotational motion.

Standard – 3.2.P.B2: Explain the translation and simple harmonic motion of objects using conservation of energy and conservation of momentum. Describe the rotational motion of objects using the conservation of energy and conservation of angular momentum. Explain how gravitational, electrical, and magnetic forces and torques give rise to rotational motion.

Standard – 3.2.P.B3: Analyze the factors that influence convection, conduction, and radiation between objects or regions that are at different temperatures.

Standard – 3.2.P.B4: Explain how stationary and moving particles result in electricity and magnetism. Develop qualitative and quantitative understanding of current, voltage, resistance, and the connections among them. Explain how electrical induction is applied in technology.

Standard – 3.2.P.B5: Explain how waves transfer energy without transferring matter. Explain how waves carry information from remote sources that can be detected and interpreted. Describe the causes of wave frequency, speed, and wave length.

Standard – 3.2.P.B6: PATTERNS SCALE MODELS CONSTANCY/CHANGE Use Newton's laws of motion and gravitation to describe and predict the motion of objects ranging from atoms to the galaxies.