

**Roanoke Valley Governor's School for Science and Technology**  
**AP Physics**  
**Competency List, 2018-2019**

August 15, 2018

AP Physics C is the equivalent to a first year college Mechanics Course for science and engineering majors. Topics include Kinematics, Forces, Newton's Laws, Energy, Momentum, Rotational Dynamics, Gravity, and Oscillations. Emphasis is placed on the use of technology for data collection, analysis, and lab report presentation in order to enhance self-directed learning. Use of outside resources is encouraged. Computer use includes modeling, graphing, lab interfacing, and video analysis. Individual and/or group explorations at an advanced level will be required during the year. AP Physics C is a very challenging course and students must be actively engaged in completing assigned homework. Students are expected to obtain a qualifying score of 3, 4, or 5 on the AP Physics C Mechanics exam at the end of this course

**Gifted Education Principles:**

( Hockett, J.A. (2009) "Curriculum for Highly Able Learners That Conforms to General Education and Gifted Education Quality Indicators." *Journal of Education for the Gifted*. Vol. 32, No. 3, p. 394-440)

1. High-quality curriculum for gifted learners uses a conceptual approach to organize or explore content that is discipline based and integrative.
2. High-quality curriculum for gifted learners pursues advanced levels of understanding beyond the general education curriculum through abstraction, depth, breadth, and complexity.
3. High-quality curriculum for gifted learners asks students to use processes and materials that approximate those of an expert, disciplinarian, or practicing professional.
4. High-quality curriculum for gifted learners emphasizes problems, products, and performances that are true to life, and outcomes that are transformational.
5. High-quality curriculum for gifted learners is flexible enough to accommodate self-directed learning fueled by student interests, adjustments for pacing, and variety.

COMPETENCY I:

**Students will develop an understanding of Mechanics: Kinematics One Dimensional motion**

*Enabling Objectives:*

1. Students should understand the general relationships among position, velocity, and acceleration for the motion of a particle along a straight line, so that:
  - a. Given a graph of one of the kinematic quantities, position, velocity, or acceleration, as a function of time, students can recognize in what time intervals the other two are positive, negative, or zero and can identify or sketch a graph of each as a function of time.
  - b. Given an expression for one of the kinematic quantities, position, velocity or acceleration, as a function of time, students can determine the other two as a function of time, and find when these quantities are zero or achieve their maximum and minimum values.

2. Students should understand the special case of motion with constant acceleration, so they can:
  - a. Write down expressions for velocity and position as functions of time, and identify or sketch graphs of these quantities.
  - b. Use the equations  $v = V_0 + at$ ,  $x = X_0 + v_0t + \frac{1}{2}at^2$ , and  $v^2 = V_0^2 + 2a(x - X_0)$  to solve problems involving one-dimensional motion with constant acceleration.
3. Students should know how to deal with situations in which acceleration is a specified function of velocity and time so they can write an appropriate differential equation and solve it for  $v(t)$  by separation of variables, incorporating correctly a given initial value of  $v$ .

#### COMPETENCY II:

##### **Students will develop an understanding of Mechanics: Kinematics Two Dimensional motion**

###### *Enabling Objectives:*

1. Students should be able to add, subtract, and resolve displacement and velocity vectors, so they can:
  - a. Determine components of a vector along two specified, mutually perpendicular axes.
  - b. Determine the net displacement of a particle or the location of a particle relative to another.
  - c. Determine the change in velocity of a particle or the velocity of one particle relative to another.
2. Students should understand the general motion of a particle in two dimensions so that, given functions  $x(t)$  and  $y(t)$  which describe this motion, they can determine the components, magnitude, and direction of the particle's velocity and acceleration as functions of time.
3. Students should understand the motion of projectiles in a uniform gravitational field, so they can:
  - a. Write down expressions for the horizontal and vertical components of velocity and position as functions of time, and sketch or identify graphs of these components.
  - b. Use these expressions in analyzing the motion of a projectile that is projected with an arbitrary initial velocity

#### COMPETENCY III:

##### **Students will develop an understanding of Newton's Laws of Motion**

###### *Enabling Objectives:*

1. Students should be able to analyze situations in which a particle remains at rest, or moves with constant velocity, under the influence of several forces.
2. Students should understand the relation between the force that acts on an object and the resulting change in the object's velocity, so they can:
  - a. Calculate, for an object moving in one dimension, the velocity change that results when a constant force  $F$  acts over a specified time interval.
  - b. Calculate, for an object moving in one dimension, the velocity change that results when a force  $F(t)$  acts over a specified time interval.
  - c. Determine, for an object moving in a plane whose velocity vector undergoes a specified change over a specified time interval, the average force that acted on the object.

3. Students should understand how Newton's Second Law,  $\sum F = F_{net} = ma$ , applies to an object subject to forces such as gravity, the pull of strings, or contact forces, so they can:
  - a. Draw a well-labeled, free-body diagram showing all real forces that act on the object.
  - b. Write down the vector equation that results from applying Newton's Second Law to the object, and take components of this equation along appropriate axes.
4. Students should be able to analyze situations in which an object moves with specified acceleration under the influence of one or more forces so they can determine the magnitude and direction of the net force, or of one of the forces that makes up the net force, such as motion up or down with constant acceleration.
5. Students should understand the significance of the coefficient of friction, so they can:
  - a. Write down the relationship between the normal and frictional forces on a surface.
  - b. Analyze situations in which an object moves along a rough inclined plane or horizontal surface.
  - c. Analyze under what circumstances an object will start to slip, or to calculate the magnitude of the force of static friction.
6. Students should understand the effect of drag forces on the motion of an object, so they can:
  - a. Find the terminal velocity of an object moving vertically under the influence of a retarding force dependent on velocity
  - b. Describe qualitatively, with the aid of graphs, the acceleration, velocity, and displacement of such a particle when it is released from rest or is projected vertically with specified initial velocity.
  - c. Use Newton's Second Law to write a differential equation for the velocity of the object as a function of time.
  - d. Use the method of separation of variables to derive the equation for the velocity as a function of time from the differential equation that follows from Newton's Second Law.
  - e. Derive an expression for the acceleration as a function of time for an object falling under the influence of drag forces.
7. Students should understand Newton's Third Law so that, for a given system, they can identify the force pairs and the objects on which they act, and state the magnitude and direction of each force.
8. Students should be able to apply Newton's Third Law in analyzing the force of contact between two objects that accelerate together along a horizontal or vertical line, or between two surfaces that slide across one another.
9. Students should know that the tension is constant in a light string that passes over a mass-less pulley and should be able to use this fact in analyzing the motion of a system of two objects joined by a string.
10. Students should be able to solve problems in which application of Newton's laws leads to two or three simultaneous linear equations involving unknown forces or accelerations.

#### COMPETENCY IV:

#### **Students will develop an understanding of Work and the Work-Energy Theorem**

##### *Enabling Objectives:*

1. Students should understand the definition of work, including when it is positive, negative, or zero, so they can:

- a. Calculate the work done by a specified constant force on an object that undergoes a specified displacement.
  - b. Relate the work done by a force to the area under a graph of force as a function of position, and calculate this work in the case where the force is a linear function of position.
  - c. Use integration to calculate the work performed by a force  $F(x)$  on an object that undergoes a specified displacement in one dimension.
  - d. Use the scalar product operation to calculate the work performed by a specified constant force  $F$  on an object that undergoes a displacement in a plane.
2. Students should understand and be able to apply the work-energy theorem, so they can:
- a. Calculate the change in kinetic energy or speed that results from performing a specified amount of work on an object.
  - b. Calculate the work performed by the net force, or by each of the forces that make up the net force, on an object that undergoes a specified change in speed or kinetic energy.
  - c. Apply the theorem to determine the change in an object's kinetic energy and speed that result from the application of specified forces, or to determine the force that is required in order to bring an object to rest in a specified distance.

#### COMPETENCY V:

##### **Students will develop an understanding of Forces and Potential Energy**

###### *Enabling Objectives:*

1. Students should understand the concept of a conservative force, so they can:
  - a. State alternative definitions of "conservative force" and explain why these definitions are equivalent.
  - b. Describe examples of conservative forces and non-conservative forces.
2. Students should understand the concept of potential energy, so they can:
  - a. State the general relation between force and potential energy, and explain why potential energy can be associated only with conservative forces.
  - b. Calculate a potential energy function associated with a specified one-dimensional force  $F(x)$ .
  - c. Calculate the magnitude and direction of a one-dimensional force when given the potential energy function  $U(x)$  for the force.
  - d. Write an expression for the force exerted by an ideal spring and for the potential energy of a stretched or compressed spring.
  - e. Calculate the potential energy of one or more objects in a uniform gravitational field.

#### COMPETENCY VI:

##### **Students will develop an understanding of the Conservation of Energy**

###### *Enabling Objectives:*

1. Students should understand the concepts of mechanical energy and of total energy, so they can:
  - a. State and apply the relation between the work performed on an object by non-conservative forces and the change in an object's mechanical energy.  $\Delta K + \Delta U = W_{nc}$
  - b. Describe and identify situations in which mechanical energy is converted to other forms of energy.
  - c. Analyze situations in which an object's mechanical energy is changed by friction or by a specified externally applied force.

2. Students should understand conservation of energy, so they can:
  - a. Identify situations in which mechanical energy is or is not conserved.
  - b. Apply conservation of energy in analyzing the motion of systems of connected objects, such as an Atwood's machine.
  - c. Apply conservation of energy in analyzing the motion of objects that move under the influence of springs.
  - d. Apply conservation of energy in analyzing the motion of objects that move under the influence of other non-constant one-dimensional forces.
  - e. Students should be able to recognize and solve problems that call for application both of conservation of energy and Newton's Laws.

**COMPETENCY VII:**

**Students will develop an understanding of the Power**

*Enabling Objectives:*

1. Students should understand the definition of power, so they can:
  - a. Calculate the power required to maintain the motion of an object with constant acceleration (e.g., to move an object along a level surface, to raise an object at a constant rate, or to overcome friction for an object that is moving at a constant speed).
  - b. Calculate the work performed by a force that supplies constant power, or the average power supplied by a force that performs a specified amount of work.

**COMPETENCY VIII:**

**Students will develop an understanding of Systems of Particles and Linear Momentum**

*Enabling Objectives:*

1. Students should understand the definition of mass, so they can:
  - a. Identify by inspection the center of mass of a symmetrical object.
  - b. Identify by inspection the center of mass of a symmetrical object.
  - c. Use integration to find the center of mass of a thin rod of non-uniform density.
2. Students should be able to understand and apply the relation between center-of mass velocity and linear momentum, and between center-of-mass acceleration and net external force for a system of particles.
3. Students should be able to define center of gravity and to use this concept to express the gravitational potential energy of a rigid object in terms of the position of its center of mass.
4. Students should understand impulse and linear momentum, so they can:
  - a. Relate mass, velocity, and linear momentum for a moving object, and calculate the total linear momentum of a system of objects.
  - b. Relate impulse to the change in linear momentum and the average force acting on an object.
  - c. State and apply the relations between linear momentum and center-of-mass motion for a system of particles.
  - d. Calculate the area under a force versus time graph and relate it to the change in momentum of an object.
  - e. Calculate the change in momentum of an object given a function  $F(t)$  for the net force acting on the object.
5. Students should understand linear momentum conservation, so they can:
  - a. Explain how linear momentum conservation follows as a consequence of Newton's Third Law for an isolated system.

- b. Identify situations in which linear momentum, or a component of the linear momentum vector, is conserved.
- c. Apply linear momentum conservation to one-dimensional elastic and inelastic collisions and two-dimensional completely inelastic collisions.
- d. Apply linear momentum conservation to two-dimensional elastic and inelastic collisions.
- e. Analyze situations in which two or more objects are pushed apart by a spring or other agency, and calculate how much energy is released in such a process.

COMPETENCY IX:

**Students will develop an understanding of the Uniform circular motion of a particle**

*Enabling Objectives:*

1. Students should understand the uniform circular motion of a particle, so they can:
  - a. Relate the radius of the circle and the speed or rate of revolution of the particle to the magnitude of the centripetal acceleration.
  - b. Describe the direction of the particle's velocity and acceleration at any instant during the motion.
  - c. Determine the components of the velocity and acceleration vectors at any instant, and sketch or identify graphs of these quantities
  - d. Analyze situations in which an object moves with specified acceleration under the influence of one or more forces so they can determine the magnitude and direction of the net force, or of one of the forces that makes up the net force, in situations such as the following:
    - i. Motion in a horizontal circle (e.g., mass on a rotating merry-go-round, or car rounding a banked curve).
    - ii. Motion in a vertical circle (e.g., mass swinging on the end of a string, cart rolling down a curved track, rider on a Ferris wheel).
2. Students should understand the concept of torque, so they can:
  - a. Calculate the magnitude and direction of the torque associated with a given Force.
  - b. Calculate the torque on a rigid object due to gravity.
3. Students should be able to analyze problems in statics, so they can:
  - a. State the conditions for translational and rotational equilibrium of a rigid object.
  - b. Apply these conditions in analyzing the equilibrium of a rigid object under the combined influence of a number of coplanar forces applied at different locations.
4. Students should develop a qualitative understanding of rotational inertia, so they can:
  - a. Determine by inspection which of a set of symmetrical objects of equal mass has the greatest rotational inertia.
  - b. Determine by what factor an object's rotational inertia changes if all its dimensions are increased by the same factor.
  - c. Students should develop skill in computing rotational inertia so they can find the rotational inertia of:
    - i. A collection of point masses lying in a plane about an axis perpendicular to the Plane.
    - ii. A thin rod of uniform density, about an arbitrary axis perpendicular to the rod.

- iii. A thin cylindrical shell about its axis, or an object that may be viewed as being made ~ of coaxial shells.
- iv. Students should be able to state and apply the parallel-axis theorem.

COMPETENCY X:

**Students will develop an understanding of the Rotational Kinematics and Dynamics**

*Enabling Objectives:*

1. Students should understand the analogy between translational and rotational kinematics so they can write and apply relations among the angular acceleration, angular velocity, and angular displacement of an object that rotates about a fixed axis with constant angular acceleration.
  - a. Students should be able to use the right-hand rule to associate an angular velocity vector with a rotating object.
  - b. Students should understand the dynamics of fixed-axis rotation, so they can:
    - i. Describe in detail the analogy between fixed-axis rotation and straight-line translation.
    - ii. Determine the angular acceleration with which a rigid object is accelerated about a fixed axis when subjected to a specified external torque or force.
    - iii. Determine the radial and tangential acceleration of a point on a rigid object.
    - iv. Apply conservation of energy to problems of fixed-axis rotation.
    - v. Analyze problems involving strings and massive pulleys.
2. Students should understand the motion of a rigid object along a surface, so they can:
  - a. Write down, justify, and apply the relation between linear and angular velocity, or between linear and angular acceleration, for an object of circular cross-section that rolls without slipping along a fixed plane, and determine the velocity and acceleration of an arbitrary point on such an object.
  - b. Apply the equations of translational and rotational motion simultaneously in analyzing rolling with slipping.
  - c. Calculate the total kinetic energy of an object that is undergoing both translational and rotational motion, and apply energy conservation in analyzing such motion.

COMPETENCY XI:

**Students will develop an understanding of Angular Momentum and Conservation**

*Enabling Objectives:*

1. Students should be able to use the vector product and the right-hand rule, so they can:
  - a. Calculate the torque of a specified force about an arbitrary origin.
  - b. Calculate the angular momentum vector for a moving particle.
  - c. Calculate the angular momentum vector for a rotating rigid object in simple cases where this vector lies parallel to the angular velocity vector.
2. Students should understand angular momentum conservation, so they can:
  - a. Recognize the conditions under which the law of conservation is applicable and relate this law to one- and two-particle systems such as satellite orbits.
  - b. State the relation between net external torque and angular momentum, and identify situations in which angular momentum is conserved.

- c. Analyze problems in which the moment of inertia of an object is changed as it rotates freely about a fixed axis.
- d. Analyze a collision between a moving particle and a rigid object that can rotate about a fixed axis or about its center of mass.