Unit 1 Kinematics

Content Area: **Science**
Course(s): **AP Physics 1**
Time Period: **September**
Length: **8 blocks**
Status: **Published**

Enduring Understandings

- All forces share certain common characteristics when considered by obersers in inertial reference frames.
- The acceleration of the center of mass of a system is related to the net force exerted on the system, where **a = ΣF**/m.
- In a projectile, horizontal and vertical motions happen independently from one another.
- Vectors can be broken down into horizontal and vertical components to predict the motion of an object.

Essential Questions

- How can the motion of an object moving at constant velocity be described, represented, predicted and/or explained?
- How can the motion of an object that is accelerating be described, represented, predicted and/or explained?
- Can equations be used to answer questions regardless of the question's specifity?
- How can the idea of frames of reference allow two people to tell the truth yet have conflicting reports?
- How can we use models to help us understand motion?
- Why is the general rule for stopping your car "when you double your speed, you must give yourself four times as much distance to stop?"
- What information can be gathered from motion graphs?
- How is velocity fundamentally different from speed, and why is this difference important when solving kinematics problems?
- What are the characteristics of the motion of a projectile?
- What advantages are gained from the use of vectors, as opposed to scalars?
- How can accelerated motion in one and two dimensions be described qualitatively, quantitatively, and graphically?
- Why is free fall considered a special case of accelerated motion?

Content

1.1 Position, Velocity, and Acceleration

3.A.1: An observer in a reference frame can describe the motion of an object using such quantities as position, displacement, distance, velocity, speed, and acceleration.

- a. Displacement, velocity, and acceleration are all vector quantities.
- b. Displacement is change in position. Velocity is the rate of change of position with time. Acceleration is the rate of change of velocity with time. Changes in each property are expressed by subtracting initial values from final values.

Relevant Equations:

$$\mathbf{v_{avg}} = \mathbf{\Delta x}/\Delta t$$

$$\mathbf{a_{avg}} = \mathbf{\Delta v}/\Delta t$$

- c. A choice of reference frame determines the direction and the magnitude of each of these quantities.
- d. There are three fundamental interactions or forces in nature: the gravitational force, the electroweak force, and the strong force. The fundamental forces determine both the structure of objects and the motion of objects.
- e. In inertial reference frames, forces are detected by their influence on the motion (specifically the velocity) of an object. So force, like velocity, is a vector quantity. A force vector has magnitude and direction. When multiple forces are exerted on an object, the vector sum of these forces, referred to as the net force, causes a change in the motion of the object. The acceleration of the object is proportional to the net force.
- f. The kinematic equations only apply to constant acceleration situations. Circular motion and projectile motion are both included. Circular motion is further covered in Unit 3. The three kinematic equations describing linear motion with constant acceleration in one and two dimensions are

$$v_x = v_{x0} + a_x t$$

$$x = x_0 + v_{x0}t + 1/2at^2$$

$$v_x^2 = v_{x0}^2 + 2a_x(x - x_0)$$

- g. For rotational motion, there are analogous quantities such as angular position, angular velocity, and angular acceleration.
- h. This also includes situations where there is both a radial and tangential acceleration for an object moving in a circular path.

1.2 Representations of Motion

4.A.1: The linear motion of a system can be described by the displacement, velocity, and acceleration of its center of mass.

- a. The variables x, v, and a all refer to the center-of-mass quantities.

Relevant Equations:

$$v_x = v_{x0} + a_x t$$

$$x = x_0 + v_{x0}t + 1/2at^2$$

$$v_x^2 = v_{x0}^2 + 2a_x(x - x_0)$$

4.A.2: The acceleration is equal to the rate of change of velocity with time, and velocity is equal to the rate of change of position with time.

- a. The acceleration of the center of mass of a system is directly proportional to the net force exerted on it by all objects interacting with the system and inversely proportional to the mass of the system.
- b. Force and acceleration are both vectors, with acceleration in the same direction as the net force.
- c. The acceleration of the center of mass of a system is equal to the rate of change of the center of mass velocity with time, and the center of mass velocity is equal to the rate of change of position of the center of mass with time.
- d. The variables x, v, and a all refer to the center-of-mass quantities.

Relevant Equations:

$$\mathbf{a} = \mathbf{\Sigma F}/m_{system}$$

$$\mathbf{v_{avg}} = \mathbf{\Delta x}/\Delta t$$

$$a_{avg} = \Delta v/\Delta t$$

Vocabulary

- Vector
- scalar
- vector components
- resultant
- distance
- displacement
- Position-Time graph
- Velocity-Time Graph
- Kinematics in one-dimension
- uniform motion
- speed
- velocity
- Instantaneous velocity
- average velocity
- constant velocity
- Acceleration
- uniform accelerated motion
- Free-Fall
- Vector addition
- vector subtraction
- Coordinate system
- Component Vectors
- limiting cases
- relative motion
- inertial reference frames
- relative velocity
- projectile motion
- launch angle
- range
- Kinematics in two-dimensions

Skills

Science Practices

- 1.5: The student can re-express key elements of natural phenomena across multiple representations in the domain.
- 2.1: The student can justify the selection of mathematical routine to solve problems.
- 2.2: The student can apply mathematical routines to quantities that describe natural phenomena.
- 4.2: The student can design a plan for collecting data to answer a particular scientific question.

- 5.1: The student can analyze data to identify patterns of relationships.
- 1.2: The student can describe representations and models of natural or man-made phenomena and systems in the domain.
- 1.4: The student can use representations and models to analyze situations or solve problems qualitatively and quantitatively.
- 2.2: The student can apply mathematical routines to quantities that describe natural phenomena.
- 2.3: The student can estimate quantities that describe natural phenomena.
- 6.4: The student can make claims and predictions about natural phenomena based on scientific theories and models.
- Learning Objective (3.A.1.1): The student is able to express the motion of an object using narrative, mathematical, and graphical representations.
- Learning Objective (3.A.1.2): The student is able to design an experimental investigation of the motion of an object.
- Learning Objective (3.A.1.3): The student is able to analyze experimental data describing the motion of an object and is able to express the results of the analysis using narrative, mathematical, and graphical representations.
- Learning Objective (4.A.2.1): The student is able to make predictions about the motion of a system based on the fact that acceleration is equal to the change in velocity per unit time, and velocity is equal to the change in position per unit time.
- Learning Objective (4.A.2.3): The student is able to create mathematical models and analyze graphical relationships for acceleration, velocity, and position of the center of mass of a system and use them to calculate properties of the motion of the center of mass of a system.

Standards

Big Idea 3: The interactions of an object with other objects can be described by forces

- Enduring Understanding 3.A: All forces share certain common characteristics when considered by observers in inertial reference frames.
    - Learning Objective (3.A.1.1): Express the motion of an object using narrative, mathematical, and graphical representations. [SP 1.5, 2.1, 2.2]
    - Learning Objective (3.A.1.2): Design an experimental investigation of the motion of an object. [SP 4.2]
    - Learning Objective (3.A.1.3) Analyze experimental data describing the motion of an object and be able to express the results of the analysis using narrative, mathematical, and graphical representations. [SP 5.1]

Big Idea 4: Interactions between systems can result in changes in those systems

- Enduring Understanding 4.A: The acceleration of the center of mass of a system is related to the net force exerted on the system, where $\mathbf{a} = \Sigma\mathbf{F}/m$.
    - Learning Objective (4.A.1.1): Use representations of the center of mass of an isolated two-object system to analyze the motion of the system qualitatively and semi-quantitatively. [SP 1.2, 1.4, 2.3, 6.4]
    - Learning Objective (4.A.2.1): Make predictions about the motion of a system based on the fact that acceleration is equal to the change in velocity per unit time, and velocity is equal to the change in position per unit time. [SP 6.4]
    - Learning Objective (4.A.2.3): Create mathematical models and analyze graphical relationships

for acceleration, velocity, and position of the center of mass of a system and use them to calculate properties of the motion of the center of mass of a system. [SP 1.4, 2.2]

Note: SP stands for Science Practices.