Physical Science, Quarter 1, Unit 1.1

Laws of Motion, Velocity, Displacement, and Acceleration

Overview

Number of instructional days: 13 (1 day = 53 minutes)

Content to be learned

- Add distance and displacement or speed and velocity both graphically and algebraically in one dimension.
- Understand relationships among displacement, velocity, acceleration, and time.
- Graph the motion of objects in different reference planes.
- Predict the motion of objects in different reference planes.
- Explain how motion in different reference planes occurs.

Processes to be used

- Create and interpret graphs.
- Analyze data using algebraic equations.
- Differentiate among reference planes.
- Analyze data to predict changes and draw conclusions.
- Use and manipulate equations.

Essential questions

- How can you use graphs or numbers to communicate the difference between constant motion and accelerated motion?
- How is adding displacement different from adding distances?
- How is calculating speed different from calculating velocity?"
- How is measuring velocity different from measuring acceleration?
- How can you predict the position, velocity, and acceleration of a projectile based on displacement–time, velocity–time, or acceleration–time graphs?

Written Curriculum

Grade Span Expectations

PS 3 - The motion of an object is affected by forces.

PS3 (9-11) POC+ INQ 8

Given information (e.g., graphs, data, diagrams), use the relationships between or among force, mass, velocity, momentum, and acceleration to predict and explain the motion of objects.

PS3 (9-11)- 8 Students demonstrate an understanding of forces and motion by…

8a predicting and/or graphing the path of an object in different reference planes and explain how ~~and why (forces)~~ it occurs.

Clarifying the Standards

Prior Learning

In the elementary curriculum, concepts of force and motion were seldom explored separately. Since kindergarten, students were expected to use simple terms to define changes in direction and motion, but different reference planes were not discussed until later.

In grade 3, students were introduced to the idea that motion is a change in position relative to the background or other objects. This subject was revisited in grades 4–5, where it continued to be connected with forces. In sixth grade, students were expected to demonstrate their understanding by using data and graphs to compare the relative speed of objects. In grade 7, students were then expected to measure the distances and times for moving objects and to use those values to calculate speed using the formula $s = d/t$. They also differentiated among speed, velocity, and acceleration.

Later, in grade 8, students expanded their use of the $s = d/t$ formula to calculate not just for speed, but for any value for the other two variables, and they represented this data graphically.

Current Learning

Displacement, velocity, time, and acceleration are defined and explored. Students learn how to use equations of motion with regard to constant acceleration. Creating, reading, and interpreting graphs of motion with constant velocity and/or constant acceleration are also addressed, and appropriate use of vocabulary is developed and emphasized. Forces are not addressed at this time.

To accomplish all of these goals, students should be able to establish reference points and reference frames. They should also be able to convert metric units and perform unit analysis with algebraic manipulations. Students need to learn the difference between vectors (quantities with direction like displacement, velocity, and acceleration) and scalars (quantities without direction like distance and speed). They need to add vectors and scalar quantities graphically and algebraically in one dimension.

Future Learning

Students will investigate changes in motion and why these changes occur (i.e., forces) from a graphical and analytical viewpoint. Students will investigate freefall, parabolic motion, and gravitational attraction as they describe accelerating systems. Two-dimensional vector analysis and kinematic equations will be explored and developed later in a grade 11 or 12 physics course.

Additional Research Findings

According to the most recent research in *Making Sense of Secondary Science* (pp. 160–161) and *Benchmarks of Science Literacy* (pp. 87, 339), appropriate use of vocabulary and scientific terminology is one of the major hurdles to understanding forces and motion. Students often develop an inaccurate set of vocabulary terms to describe changes in motion. Therefore, language tools (vocabulary, graphs, formulae) must be developed before students can understand dynamic principles.

In addition, many students don't realize that acceleration is constant; they mistakenly assume that if velocity increases, then acceleration also increases. Students often don't understand that rest is different from motion; they think that time is not important for stationary objects; and that stationary objects have a speed (velocity) of zero (*Making Sense*, p. 155; *Benchmarks*, pp. 339–340).

Students also need training in proportional reasoning, especially with regard to displacement, velocity, and time (*Making Sense*, p. 155). They have difficulty understanding that acceleration is a process over a period of time and that velocity does not change instantaneously (*Making Sense*, p. 165).

Notes About Resources and Materials

Physical Science, Quarter 1, Unit 1.2

Forces

Overview

Number of instructional days: 8 (1 day = 53 minutes)

Content to be learned

- Understand and interpret Newton's laws with regard to mass, acceleration, and force.
- Explain how forces are the cause of change, motion, and stationary objects.
- Explain the concept of inertia.
- Represent, analyze, and interpret graphical representations of mass, acceleration, and force.
- Explain how mass, acceleration, and forces apply in different reference planes.

Processes to be used

- Describe, graphically and numerically, how distance and velocity change over time for a freely falling object.
- Interpret data to predict the displacement and velocity of an object in motion in a specific reference plane.
- Analyze relationships among mass, acceleration, and force.
- Predict how changes in mass, forces, and acceleration affect motion.

Essential questions

- How do Newton's laws predict the motion of an object when forces act on it?
- What is the difference between forces applied *to* an object and forces applied *by* an object?
- According to Newton's third law, why is motion possible?
- How does the motion of a mass change due to forces acting on it?
- How can we explain the change in motion of a mass as caused by different forces?

Written Curriculum

Grade Span Expectations

PS 3 - The motion of an object is affected by forces.

PS3 (9-11) POC –9

Apply the concepts of inertia, motion, and momentum to predict and explain situations involving forces and motion, including stationary objects and collisions.

PS3 (9-11)–9 Students demonstrate an understanding of forces and motion by…

9b using Newton's Laws of Motion ~~and the Law of Conservation of Momentum~~ to predict the effect on the motion of objects.

PS3 (9-11) POC+ INQ 8

Given information (e.g., graphs, data, diagrams), use the relationships between or among force, mass, velocity, momentum, and acceleration to predict and explain the motion of objects.

PS3 (9-11)- 8 Students demonstrate an understanding of forces and motion by…

8a predicting and/or graphing the path of an object in different reference planes and explain how and why (forces) it occurs.

Clarifying the Standards

Prior Learning

The concept that forces cause changes in motion was introduced to kindergarteners when they observed how a *push* or *pull* did or did not move an object. In first grade, students furthered their discovery of forces and motion by identifying how the direction of an object's motion does or does not change if a force is applied to it. This same target was readdressed in grade 2.

In third grade, force began to be quantified and the concept of speed was introduced. Students investigated how different amounts of force changed the direction and speed of an object in motion. In grade 4, students continued predicting changes in motion, including for situations when the object itself was of a varying weight, shape, or size. Fifth-graders examined the net effect of multiple forces and made the connection that all forces can be recognized as a *push* or a *pull* on an object. They also understood that changes in the speed or direction of an object's motion were caused by forces.

There were no targets addressing forces in grade 6, but seventh-grade students recognized that it takes unbalanced forces acting on an object to change its speed, direction of motion, or both. Students made and tested predictions of how an object's motion would change due to applied unbalanced forces. In grade 8, students understood the direct and inverse relationships between mass, acceleration, and applied net force. Using the formula $F = ma$, students were able to describe and/or graphically represent those relationships.

Current Learning

Newton's laws are explained, discussed, and analyzed so that students have a thorough understanding of how mass, acceleration, and force are interrelated. Students understand that forces are the cause of change, motion, and static equilibrium. Inertia, with regard to Newton's laws, is also addressed.

Students represent, analyze, and interpret graphical representations of these quantities. They also explore how mass, acceleration, and forces apply in different reference frames. This exploration will include static equilibrium, stationary reference frames, moving reference frames, and falling objects. The analysis of falling objects includes both uniform acceleration and freefall scenarios. Students also make a clear distinction between mass and weight. Specific types of force to address include normal force, frictional forces, force of gravity, and force of tension.

Future Learning

Students will investigate different types of forces (e.g., friction, centripetal, and gravitation). Later in quarter 1, students will also apply their knowledge of forces to explain impulse and the rate change of momentum. In quarter 2, students will use this knowledge of gravitation for future units on earth/space. Electromagnetic force will be addressed in quarter 4.

Additional Research Findings

Research suggests that students have a number of misconceptions about forces. For example, as stated in *Benchmarks for Science Literacy*, "falling is natural; no force or reason is needed" (p. 340). It is necessary that students understand that force causes all motion. Another misconception is that force is a property of an object (*Benchmarks*, p. 339). The idea that forces act on objects and are not part of them is essential for student understanding.

Additionally, students believe that something is needed to sustain constant speed (*Benchmarks*, p. 339). It is key for students to know that constant speed is caused by balanced forces (or no forces) acting on an object. Student reasoning is also very context-based; they have difficulty finding parallels among different situations. Therefore, it is important to draw connections through various examples to show that the same mechanisms or laws of motion apply for all matter. Research shows that students don't apply their science concepts and tend to fall back on a layperson's beliefs when asked to explain motion in a newly given example.

Students often mistakenly assume that rest is different from motion (*Benchmarks*, p. 87). They think that in order to stay in motion, a force must be constantly applied. It's important to emphasize that moving objects have an "internal impetus force" that keeps them moving; that force is like fuel and that moving objects stop when they run out of force; and that force, acceleration, and velocity all have to be in the same direction (*Making Sense of Secondary Science*, p. 149).

In terms of Newton's third law of motion, students often think that only *active* objects (a moving person, an animal, a swung bat, etc.) exert forces and that *passive* objects (a table, a person at rest, etc.) cannot exert forces (*Benchmarks*, p. 339). Students must understand that not all forces are associated with living things, physical activities, or muscular strength (*Making Sense*, p. 149). It is often difficult for students to identify reaction forces, particularly in the case of an inanimate object, such as a book resting on a table (*Making Sense*, p. 150). It is common for students to interpret *pushes* and *pulls* literally, without recognizing kicks and throws as types of pushes (*Making Sense*, p. 160).

Notes About Resources and Materials

Graphical Analysis of Projectile and Freefall Motion

Overview

Number of instructional days: 5 (1 day = 53 minutes)

Content to be learned

- Examine falling objects and freefall motion using qualitative methods, graphing, and data analysis.
- Record, graph, and analyze data regarding the time, distance, velocity, acceleration, and mass of a falling object.
- Describe the path of a moving projectile.

Processes to be used

- Quantitatively analyze the data gathered from the motion of a projectile.
- Describe how the horizontal and freefall motion of a projectile change over time.
- Create and interpret graphs of projectile motion.

Essential questions

- Why does a projectile move at a constant velocity horizontally, but accelerate vertically?
- How do mass and surface area affect the maximum velocity of a falling object?
- What will a displacement–time graph and a velocity–time graph of a falling projectile look like?

Written Curriculum

Grade Span Expectations

PS 3 - The motion of an object is affected by forces.

PS3 (9-11) POC+ INQ 8

Given information (e.g., graphs, data, diagrams), use the relationships between or among force, mass, velocity, momentum, and acceleration to predict and explain the motion of objects.

PS3 (9-11)- 8 Students demonstrate an understanding of forces and motion by…

8b using modeling, illustrating, graphing explain how distance and velocity change over time for a free falling object.

PS3 (Ext)- 8 Students demonstrate an understanding of forces and motion by…

8aa using a quantitative representation of how distance and velocity change over time for a free falling object.

8bb using a quantitative representation of the path of an object which has horizontal and free fall motion.

Clarifying the Standards

Prior Learning

Students were introduced to freefall motion in grade 2 as they recognized that an object will fall to earth unless it has something to hold it up. This specific concept was again examined in grade 3, and also in grade 4, when students conducted experiments demonstrating the movement of a falling object.

Sixth-grade students demonstrated their understanding of freefall motion by using data and graphs to compare the relative speed of objects. They also differentiated among speed, velocity, and acceleration. By grade 7, students were expected to represent this data graphically. In grade 8, students described or graphically represented (using the formula $F = ma$) the direct and inverse relationships between the values affecting acceleration. The concepts of acceleration and velocity are integral to the understanding of freefall motion.

Current Learning

Students examine falling objects and freefall motion using qualitative measures, graphing, and data analysis. They record and analyze data regarding the time, distance, velocity, acceleration, and mass of a falling object; they also examine how changes in mass and surface area affect the time it takes an object to fall and how these variables affect terminal velocity. Students will use qualitative methods to examine an object as it travels in a parabola when projected horizontally and allowed to fall (due to constant velocity in the horizontal direction, but acceleration in the vertical direction). Students demonstrate understanding of this concept graphically and in data tables.

Future Learning

In a later physics course, students will make a more quantitative analysis of projectile motion using kinematic equations and independence of motion between the horizontal and vertical directions of a projectile.

Additional Research Findings

Research shows that most of the misconceptions students have about modeling motion involve how forces behave. Gravity is especially problematic for students, who often mistakenly believe that falling is a natural state that doesn't require force. There are conflicting misconceptions that heavy things fall faster and that objects fall with a constant speed because gravity is a constant force (*Making Sense of Secondary Science*, pp. 165–166; *Benchmarks for Science Literacy*, p. 87).

Another common misconception is that gravity starts and stops at the beginning and end of a fall (*Making Sense*, p. 165). Students often think objects that are thrown upwards run out of force, therefore there is no force of gravity at the vertex of a parabola (*Making Sense*, pp. 149, 166).

Finally, students often think that rest is different from motion (*Benchmarks*, p. 87). Mass and weight are also confused (*Making Sense*, pp. 164, 165).

Notes About Resources and Materials

Physical Science, Quarter 1, Unit 1.4

Momentum and its Conservation

Overview

Number of instructional days: 8 (1 day = 53 minutes)

Content to be learned

- Explain the relationship between inertia, motion, and momentum.
- Explain the relationship between force and momentum.
- Predict the momentum of an object before and after collisions.
- Interpret the law of conservation of momentum.

Processes to be used

- Apply algebraic equations.
- Create and interpret graphs.
- Use logical cause-and-effect reasoning.
- Illustrate and calculate the momentum transfer in a collision.
- Demonstrate understanding of the concepts in this unit through comparing and contrasting.

Essential questions

- How does the duration of an applied force affect the transfer of momentum?
- How does inertia affect the momentum of an object compared to the momentum of a system?
- How can you apply the Law of Conservation of Momentum to a real-life collision between two vehicles?
- What effect does changing the inertia and motion of an object have on its momentum?
-

Written Curriculum

Grade Span Expectations

PS 3 - The motion of an object is affected by forces.

PS3 (9-11) POC –9

Apply the concepts of inertia, motion, and momentum to predict and explain situations involving forces and motion, including stationary objects and collisions.

PS3 (9-11)–9 Students demonstrate an understanding of forces and motion by…

9b using ~~Newton's Laws of Motion~~ and the Law of Conservation of Momentum to predict the effect on the motion of objects.

Clarifying the Standards

Prior Learning

Momentum was briefly explored in grade 4, when students predicted how the motion of various objects would change as a result of different weights, shapes, and sizes.

Current Learning

The law of conservation of momentum is explained, discussed, and analyzed to give students a thorough understanding of how mass, velocity, time, and force are interrelated. Inertia is re-addressed in terms of its application to momentum. Students represent, analyze, and interpret graphical representations of these quantities. They understand that momentum is direction dependent (i.e., a vector). Students should be able to apply the principles of momentum and impulse to the two types of collisions (elastic and inelastic). It is important that students are comfortable with the idea of a closed system. The momentum of the system remains unchanged (due to the Law Of Conservation Of Momentum) even though the momentum of the individual components may change.

Future Learning

Later this year, in quarter 2, momentum will be re-addressed in terms of conservation of energy and mass during a collision. The conservation laws within a closed system will still apply.

In a grade 11 or 12 course, momentum in two dimensions will be addressed. The relationships among impulse, change in momentum, force, and time will also be more thoroughly addressed in graphical and analytical form.

Additional Research Findings

According to *Making Sense of Secondary Science*, students often mistakenly think that force gives rise to momentum and that momentum will run out when the force is gone (p. 149).

Notes About Resources and Materials