Forces and Motion

8-5 The student will demonstrate an understanding of the effects of forces on the motion of an object. (Physical Science)

8-5.1 Use measurement and time-distance graphs to represent the motion of an object in terms of position, direction, or speed.
Taxonomy level: 3.2-B Apply Conceptual Knowledge

Previous/Future knowledge: Students have been introduced to the concept of motion in terms of speed and direction in 3rd grade (3-5.2) and to position, speed, and direction in 5th grade (5-5.2). 5th grade students constructed a line graph (5-1.5) with the proper placement of the variables, as well as used a graph to illustrate motion (5-5.5). Students will further develop the concept of measuring and graphing motion using equations in high school Physical Science (PS-5.6).

It is essential for students to know that *motion* occurs when there is a change in position of an object with respect to a reference starting point. The final position of an object is determined by measuring the change in position and direction of the segments along a trip. The following terms are used to describe and determine motion:

Position
- *Position* is the location of an object.
- An object changes position if it moves relative to a *reference point*.
- The change in position is determined by the distance and direction of an object's change in position from the starting point (*displacement*).

Direction
- *Direction* is the line, or path along which something is moving, pointing, or aiming.
- Direction is measured using a reference point with terms such as up, down, left, right, forward, backward, toward, away from, north, south, east, or west.

For example, given the following data table, determine the change in the object's position based on its final position, distance, and direction, from a starting point.

Segment	Distance (m)	Direction
X	10	East
Y	7	North
Z	10	West

- Draw a line to scale representing 10 meters in an easterly direction.
- At the end of that line, draw a line representing 7 meters in a northerly direction.
- From the end of the second line, draw a line representing 10 meters in a westerly direction.
- Connect the end of the third line to the starting point.
- Measure the distance and direction from the starting point to the end of the third line.
- The position at the end of the trip is 7 meters north of the starting point.

Motion can also be described by the relationship between distance an object travels and the period of time it travels. This measurement of motion is a rate.

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Speed

- *Speed* is a measure of how fast something moves a particular distance (for example, meters) over a given amount of time (for example, seconds).
- Therefore, speed is the rate of change of the position of an object, or how far something will move in a given period of time.
- Speed does not necessarily mean that something is moving fast.

NOTE TO TEACHER: Calculations for speed will be done in the next indicator (8-5.2).

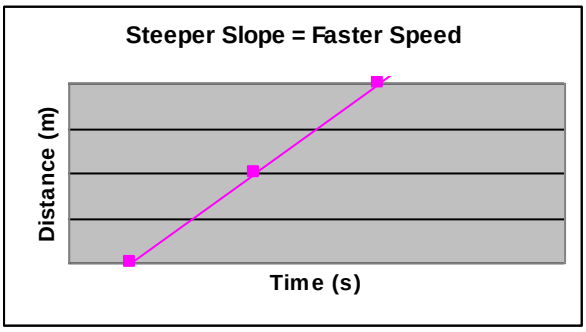
It is essential for students to use (construct and interpret) a distance-time graph to represent the motion of an object in terms of speed. Students should graph objects moving in only one direction away from the reference point (starting point).

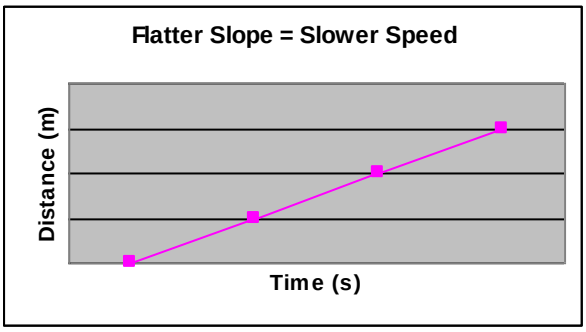
Distance-Time Graph

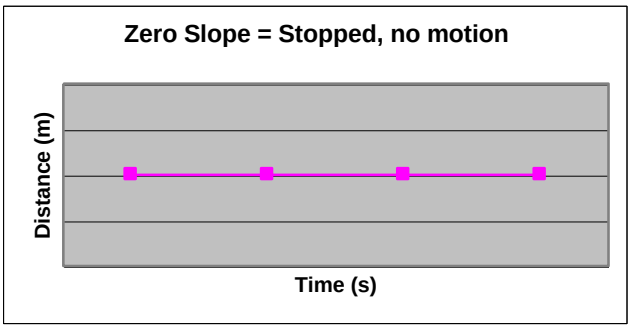
- A graph that can be used to represent how both speed and distance change with time.
- For this type of graph, time (the independent variable) is plotted on the x-axis and the distance (the dependent variable) is plotted on the y-axis.

Speed

- The slope of the line can tell the relative speed of the object.
- When the slope of the line is steep, the speed is faster than if the slope were flatter.
- When the slope of the line is flatter, the speed is slower.
- When the slope of the line is horizontal to the x-axis, the speed is zero (the object is not moving). For example:







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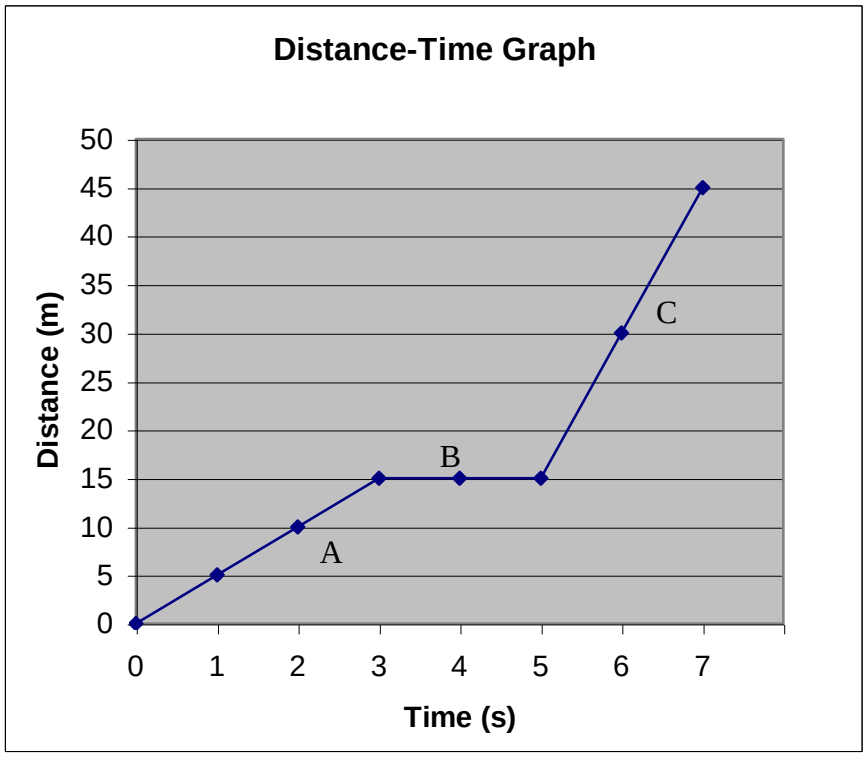
8-5 The student will demonstrate an understanding of the effects of forces on the motion of an object. (Physical Science)

NOTE TO TEACHER: Classroom experiments should be designed so that time is being manipulated (the independent variable) and distance is the dependent variable.

Data can be represented in a table. For example:

Time (s)	Distance (m)
0	0
1	5
2	10
3	15
4	15
5	15
6	30
7	45

This data can then be represented on a *distance-time graph*.



This distance-time graph can then be used to describe the speed of the object. For example, the speed of segment A is slower than segment C. The speed of segment B is zero, the object is not moving.

Forces and Motion

8-5 The student will demonstrate an understanding of the effects of forces on the motion of an object. (Physical Science)

It is not essential for students to know that speed in a given direction is called velocity or that the rate of changing velocity is called acceleration. Students do not need to interpret distance-time graphs in terms of the direction or position of the object. Students do not need to calculate the slope of the graphs. Students do not need to address speed-time (acceleration) graphs.

Assessment Guidelines:

The objective of this indicator is to *use* measurements and time-distance graphs to represent motion of objects in terms of position, distance, or speed; therefore, the primary focus of assessment should be to apply measurement and graphing skills to demonstrate the motion of objects in terms as listed in the indicator. However, appropriate assessments should also require students to *recognize* the variables (position, direction, speed) of motion; *interpret* the motion of an object from data on a graph; *match* a data table with its appropriate motion graph; *compare* faster and slower speed using the slope of a graph; or *represent* the motion of an object (with respect to a reference point) with a scale drawing using appropriate terms for position and direction.

Forces and Motion

8-5 The student will demonstrate an understanding of the effects of forces on the motion of an object. (Physical Science)

8-5.2 Use the formula for average speed, *v=d/t,* to solve real world problems.
Taxonomy level: 3.2-B Apply Conceptual Knowledge

Previous/Future knowledge: Students have been introduced to the concept of speed and direction in 3rd grade (3-5.2) and to position, speed, and direction in 5th grade (5-5.2). Students have not been introduced to the concept of average speed or calculating speed using the formula, *v=d/t* in previous grades. Students will further develop the concepts of using motion formulas to solve problems in high school Physical Science (PS-5.2).

It is essential for students to know that average speed can be calculated by dividing the total distance the object travels by the total amount of time it takes to travel that distance.

- While the speed of the object may vary during the total time it is moving, the average speed is the result of the *total distance* divided by the *total time* taken.
- Speed measurements contain a unit of distance divided by a unit of time. Examples of units of speed might include "meters per second" (m/s), "kilometers per hour" (km/h), or "miles per hour" (mph or mi/hr).
- Average speed can be calculated using the formula v=d/t where the variables are:
  - ***v*** is the average speed of the object
  - ***d*** is the total distance or length of the path of the object
  - ***t*** is the total time taken to cover the path

NOTE TO TEACHER: Students need to recall the formula v=d/t and use the formula to calculate problems involving average speed.

It is not essential for students to know that velocity is the speed in a given direction or that acceleration is the rate of change in velocity. Students do not need to solve problems for time or distance.

Assessment Guidelines:
The objective of this indicator is to *use* the formula for average speed to solve real-world problems*;* therefore, the primary focus of assessment should be to solve problems using the formula v=d/t. However, appropriate assessments should require students to *identify* the variables involved in solving problems related to speed; *recognize* appropriate units for representing average speed; or *recall* the formula for average speed.

Forces and Motion

8-5 The student will demonstrate an understanding of the effects of forces on the motion of an object. (Physical Science)

8-5.3 Analyze the effects of forces (including gravity and friction) on the speed and direction of an object.
Taxonomy level: 4.1-B Analyze Conceptual Knowledge

Previous/Future knowledge: Students have been introduced to the concept the pull of gravity in 3rd grade (3-5.4) and to the concepts of the effects of forces of gravity and friction on the motion of objects in 5th grade (5-5.1). Students have not been analyzed the effects of forces of gravity and friction with regards to the speed and direction of an object in previous grade levels. Students will further develop the concepts of the effects of gravity quantitatively in high school Physical Science (PS-5.5)

It is essential for students to know that forces (including gravity and friction) can affect the speed and direction of an object.

Gravity

- *Gravity* is a force that always attracts or pulls objects toward each other without direct contact or impact.
- Gravitational attraction depends on the mass of the two objects and the distance they are apart.
- Objects on Earth are pulled toward the center of Earth.
- The force of gravity, like all other forces, can cause changes in the speed of objects. As an object falls, its speed will continually increase as Earth's gravity continually pulls it downward. When air resistance is ignored, all objects will speed up at the same rate as they fall.
- Gravity can also cause an object that is thrown into the air to change its upward motion, slow down, and fall back toward Earth's surface.
- The pull of Earth's gravity keeps the Moon in orbit; the moon is constantly changing direction because of gravity.

Friction

- *Friction* is a force that occurs when one object rubs against another object. Two factors determine the amount of friction – (1) the kinds of surfaces, and (2) the force pressing the surfaces together.
- Friction is the force that acts to resist sliding between two surfaces that are touching. It can slow down or stop the motion of an object.
  - The slowing force of friction always acts in the direction opposite to the force causing the motion.
  - For example, friction slows or stops the motion of moving parts of machines.
  - Another example would be athletic shoes with tread grooves to increase friction have better traction for starting or stopping motion than smooth-soled dress shoes.
- Friction can also be the force that makes it difficult to start an object moving. Enough force must be applied to a nonmoving object to overcome the friction between the touching surfaces.

Forces and Motion

8-5 The student will demonstrate an understanding of the effects of forces on the motion of an object. (Physical Science)

- The smoother the two surfaces are, the less friction there is between them; therefore, the moving object will not slow down as quickly.
  - Friction between surfaces can be reduced, in order for objects to move more easily, by smoothing the surfaces, using wheels or rollers between the surfaces, or lubricating/oiling the surfaces.
  - If friction could be removed, an object would continue to move.
- The greater the force pushing the two surfaces together, the stronger friction prevents the surfaces from moving.
  - As an object gets heavier, the force of friction between the surfaces becomes greater.
  - To move a heavy object, a greater force must be applied to overcome the friction between the surfaces.

It is not essential for students to know how to calculate acceleration due to gravity, calculate weight, or the effect of gravity on different masses. Students do not need to differentiate between static, sliding, or rolling friction.

Assessment Guidelines:
The objective of this indicator is to *analyze* the effects of gravity and friction on the speed and direction of objects; therefore, the primary focus of assessment should be to determine how the forces of gravity and friction relate to the overall concept of speed and direction of objects. However, appropriate assessments should also require students to explain the effects of gravity or friction on the speed and direction of objects; *infer* whether gravity or friction could be causing a given change in the speed or direction of an object; or *exemplify* effects of gravity or friction on the speed and direction of an object.

Forces and Motion

8-5 The student will demonstrate an understanding of the effects of forces on the motion of an object. (Physical Science)

8-5.4 Predict how varying the amount of force or mass will affect the motion of an object.
Taxonomy level: 2.5-B Understand Conceptual Knowledge

Previous/Future knowledge: Students have been introduced to the concept of the importance of pushing and pulling to cause a change in motion in the 1st grade (1-5.2). In the 3rd grade students have studied how the motion of an object is affected by the strength of the push or pull on an object (3-5.3) and the relationship between the motion of an object and the pull of gravity (3-5.4). Students have been introduced to the concept of forces and how they affect motion in 5th grade (5-5.1) as well as to the concept of how mass can affect motion (5-5.6) Students will further develop the concept of the how force and mass affect motion quantitatively in high school Physical Science (PS-5.8).

It is essential for students to know that varying the amount of force or mass will affect the motion of an object.

Force

- If an object is in motion and more force is applied to it, the object will begin moving faster.
- If two objects have the same mass and a greater force is applied to one of the objects, the object which receives the greater force will change speeds more quickly. For example if a ball is hit harder, it will speed up faster.
- If an object must be slowed down quickly, the force applied to the object must be greater than what is needed for a gradual slowing down. For example, the greater the force applied to the brakes of a bicycle, the more quickly it will slow down or stop.
- Varying the amount of force applied to a moving object can also change the direction that the object is moving more or less quickly. For example, a baseball pitched toward the batter may quickly change direction and speed if hit very hard, or may change direction and speed more slowly if hit softly as with a bunt.

Mass

- If a heavy (more massive) object is in motion, more force must be applied to get the object moving faster.
- If the same force is applied to two objects, the object with the smaller mass will change speeds more quickly. For example if a baseball and a bowling ball are thrown with the same force the baseball will speed up faster.
- In order to slow down or stop a heavier (more massive) object, the force on that object must be greater than for a less massive object. For example, if the same braking force is applied to a small car and a large truck, the car will slow down more quickly.
- It is more difficult to change the direction of a heavy moving object, than one that is lighter in mass.

It is not essential for students to know the specific quantitative relationships among force, mass, and movement of objects (F = ma) or Newton's Laws of Motion.

Forces and Motion

8-5 The student will demonstrate an understanding of the effects of forces on the motion of an object. (Physical Science)

Assessment Guidelines:

The objective of this indicator is to *predict* how varying the amount of force or mass will affect the motion of an object; therefore, the primary focus of assessment should be to infer from the presented material how the amount of force or mass will affect the motion of an object in terms of change in speed and/or direction. However, appropriate assessments should also require students to *exemplify* ways that varying the amount of force exerted on an object affect the motion of the object; or *exemplify* how changes in mass affect the motion of objects; or *explain* how varying the amount of force or mass will affect the motion of an object.

Forces and Motion

8-5 The student will demonstrate an understanding of the effects of forces on the motion of an object. (Physical Science)

8-5.5 Analyze the resulting effect of balanced and unbalanced forces on an object's motion in terms of magnitude and direction.
Taxonomy level: 3.1-B Apply Conceptual Knowledge

Previous/Future knowledge: Students have been introduced to the concept of unbalanced forces and rate and direction of motion in 5th grade (5-5.3). In 6th grade, students measured force in Newtons using a spring scale (6-5.6). Students have not been introduced to the concept of balanced and unbalanced forces in previous grades. The quantitative concepts that affect the magnitude and direction of moving objects will be further developed in high school Physical Science (PS-5.8).

It is essential for students to know that forces have a *magnitude* (strength) and a *direction*. Forces can be represented as arrows with the length of the arrow representing the magnitude of the force and the head of the arrow pointing in the direction of the force. Using such arrows, the resulting force (net force) and direction can be determined.

Forces acting on an object can be *balanced or unbalanced.*

Balanced forces will cause no change in the motion of an object.

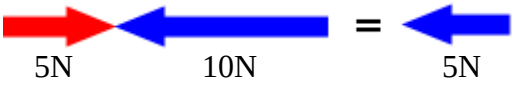
- Balanced forces acting on an object in opposite directions and equal in strength, as shown in the arrows below, do not cause a change in the speed/magnitude or direction of a moving object.
- Objects that are not moving will not start moving if acted on by balanced forces.
  - For example, in arm wrestling where there is no winner, the force exerted by each person is equal, but they are pushing in opposite directions. The resulting force (net force) is zero.

  - Or, in a tug of war, if there is no movement in the rope, the two teams are exerting equal, but opposite forces that are balanced. Again, the resulting force (net force) is zero.

Unbalanced forces are not equal, and they always cause the motion of an object to change the speed and/or direction that it is moving.

- When two unbalanced forces are exerted in opposite directions, their combined force is equal to the difference between the two forces.
  - The magnitude and direction of the net force affects the resulting motion.
  - This combined force is exerted in the direction of the larger force. For example, if two students push on opposite sides of a box sitting on the floor, the student on the left pushes with less force (small arrow) on the box than the student on the right side of the box (long arrow). The resulting action (net force: smaller arrow to the right of the =) shows that the box will change its motion in the direction of the greater force as shown below:

Forces and Motion	
8-5	**The student will demonstrate an understanding of the effects of forces on the motion of an object. (Physical Science)**



- Or, if in a tug of war, one team pulls harder than the other, the resulting action (net force) will be that the rope will change its motion in the direction of the force with the greater strength/magnitude as shown below:

- If unbalanced forces are exerted in the same direction, the resulting force (net force) will be the sum of the forces in the direction the forces are applied.
  - For example, if two people pull on an object at the same time in the same direction, the applied force on the object will be the result of their combined forces (net force or longer arrow to the right of the =) as shown below:

5N + 10N = 15N

- When forces act in the same direction, their forces are added. When forces act in opposite directions, their forces are subtracted from each other.
- Unbalanced forces also cause a nonmoving object to change its motion

If there is no net force acting on the object, the motion does not change. If there is net force acting on an object, the speed of the object will change in the direction of the net force.

It is not essential for students to know how to determine net force when the forces act at an angle. Students do not need to calculate problems with more than two forces acting on an object.

Assessment Guidelines:
The objective of this indicator is to *analyze* the effects of balanced and unbalanced forces on the magnitude and direction of moving objects; therefore, the primary focus of assessment should be to determine from the factors presented how the balanced or unbalanced forces affect the magnitude and direction of moving objects. However, appropriate assessments should also require students to *recognize* whether forces acting on an object are balanced or unbalanced; *illustrate* forces as balanced or unbalanced depending on their magnitude and direction of moving objects; *infer* the resulting force of two balanced or unbalanced forces acting in opposite directions; *use* arrows to show balanced and unbalanced forces; or *use* the correct procedure (add or subtract) to calculate the net force.

Forces and Motion

8-5 The student will demonstrate an understanding of the effects of forces on the motion of an object. (Physical Science)

8-5.6 Summarize and illustrate the concept of inertia.
Taxonomy level: 2.2 and 2.4-B Understand Conceptual Knowledge

Previous/Future knowledge: Students have not been introduced to the concept of inertia in previous grades. They will further develop the concept of inertia in high school Physical Science (PS-5.7) in relation to Newton's first law of motion.

It is essential for students to know that inertia is the tendency of objects to resist any change in motion. Inertia is a property of the object; it is not a force.

- It is the tendency for objects to stay in motion if they are moving or to stay at rest if they are not moving unless acted on by an outside force.
- The more mass an object has, the harder it is to start it in motion, to slow it down or speed it up, or to turn it.
- In other words, the more mass an object has, the more inertia it has.

Examples of the effects of inertia might include:

- Inertia causes a passenger in a car to continue to move forward even though the car stops. This is the reason that seat belts are so important for the safety of passengers in vehicles.
- Inertia is the reason that it is impossible for vehicles to stop instantaneously.
- Inertia is the reason that it is harder to start pushing a wheelbarrow full of bricks than to start pushing an empty wheelbarrow. The filled wheelbarrow has more mass and therefore, more inertia.
- Inertia is also the reason that it is harder to stop a loaded truck going 55 miles per hour than to stop a car going 55 miles per hour. The truck has more mass resisting the change of its motion and therefore, more inertia.

It is not essential for students to know that the concept of inertia as Newton's first law of motion. Students do not need to know how momentum relates to inertia or to calculate momentum.

Assessment Guidelines:
One objective of this indicator is to *summarize* the concept of inertia; therefore, the primary focus of assessment should be to generalize the major points concerning the concept of inertia. However, appropriate assessments should also require students to *recall* the meaning of inertia.

Another objective of this indicator is to *illustrate* the concept of inertia; therefore, the primary focus of assessment should be to give illustrations of this concept or use illustrations to show understanding of inertia using pictures, diagrams, or word descriptions. However, appropriate assessments should also require students to *exemplify* inertia with moving objects or with objects at rest resisting motion.