Warm-Up | Acceleration

Lesson Question

How can acceleration be used to describe motion?

Lesson Goals

Solve problems involving distance, time, velocity, and acceleration.

Analyze motion with constant acceleration using graphs.

Distinguish between constant velocity and constant acceleration.

Describe linear motion using motion maps.

Words to Know

Fill in this table as you work through the lesson. You may also use the glossary to help you.

positive acceleration	an increase in velocity over time
negative acceleration	a decrease in velocity over time
acceleration	the rate at which velocity changes over time
constant	staying the same; unchanging

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Speed and Velocity

	Definition	Formula
Speed	the distance traveled during a specific unit of time	$s = \frac{d}{t}$
Velocity	the displacement of an object during a specific unit of time	$v = \frac{\Delta x}{t}$

- Speed is a description of how fast or slow an object moves.
- Velocity is a description of how fast or slow an object is moving and in what direction.

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Acceleration

- **Acceleration** is the rate at which velocity changes over time.
  - **Positive acceleration** occurs when an object:
    - speeds up in the positive direction.
    - slows down in the negative direction.
  - **Negative acceleration** occurs when an object:
    - slows down in the positive direction.
    - speeds up in the negative direction.

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Acceleration

- The acceleration of an object depends on initial velocity, final velocity, and time.

$$a = \frac{\Delta v}{\Delta t} = \frac{v_f - v_i}{t_f - t_i}$$

- **Example:** A race car moving west speeds up from 17 m/s to 47 m/s in 2 seconds. What is the car's acceleration?

$v_i = 17\,\mathrm{m/s}$

$v_f = 47\,\mathrm{m/s}$

$t = 2\,\mathrm{s}$

$$a = \frac{47\,\mathrm{m/s} - 17\,\mathrm{m/s}}{2\,\mathrm{s}} = \frac{30\,\mathrm{m/s}}{2\,\mathrm{s}}$$

$$a = 15\,\mathrm{m/s^2}$$

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Derived Formulas

- When the acceleration of an object is constant, a set of formulas can be derived to describe the motion of the object.
- $a = \frac{v}{t} = \frac{v_f - v_i}{t}$
  - $v_f = v_i + at$
  - $x_f = x_i + v_i t + \frac{1}{2}at^2$
  - $v_f^2 = v_i^2 + 2a(x_f - x_i)$

Final Position of a Train

A train has an initial velocity of 15 m/s. It accelerates at 5 m/s^2 for 10 seconds. How far does the train travel in that time?

- Given:
  - $v_i = 15\,\text{m/s}$
  - $a = 5\,\text{m/s}^2$
  - $t = 10\,\text{s}$
- Unknown: x_f
  - Formula to use: $x_f = x_i + v_i t + \frac{1}{2}at^2$

$$x_f = (0\text{ m}) + (15\text{ m/s})(10\text{s}) + \frac{1}{2}(5\text{ m/s}^2)(10\text{s})^2$$

$$x_f = 400\text{ m}$$

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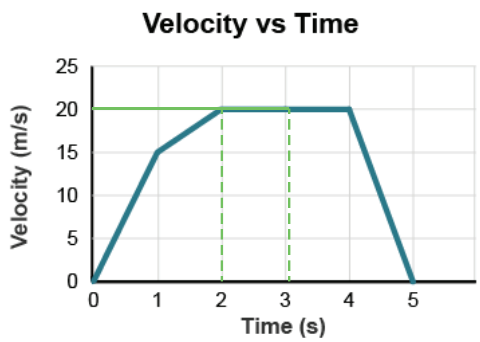
Velocity vs. Time Graphs

A velocity vs. time graph shows how the velocity of an object changes over time.

Time (s) *x*-axis	Velocity (m/s) *y*-axis
0	0
1	15
2	20
3	20
4	20
5	0



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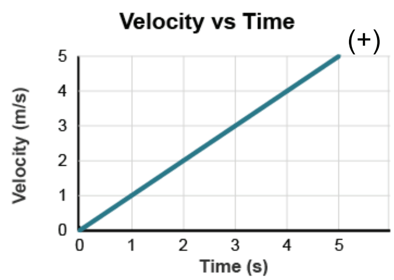
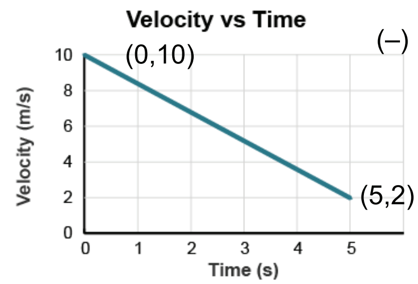
Velocity vs. Time Graphs

The [slope] of the line on a velocity vs. time graph represents acceleration.





A line with a positive slope represents a [positive] acceleration.

A line with a negative slope represents a [negative] acceleration.

$$m = \frac{y_2 - y}{x_2 - x_1}$$

$$= \frac{2\,\text{m/s} - 10\,\text{m/s}}{5\,\text{s} - 0\,\text{s}}$$

$$= \frac{-8\,\text{m/s}}{5\,\text{s}}$$

$$= [-1.6]\ \text{m/s}^2$$

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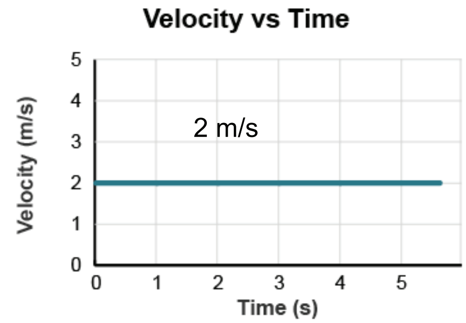
Velocity vs. Time Graphs with No Slope

- A horizontal line has no slope and represents no change in velocity.
  - The object is not accelerating. $a = 0$
  - The object is traveling at a constant velocity.



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Displacement from a Velocity vs. Time Graph

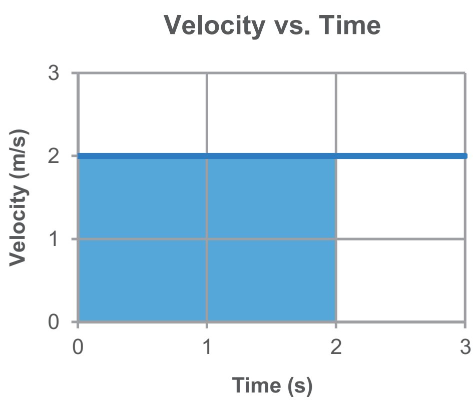
- For an object moving at a constant velocity:
  - $v = \frac{\Delta x}{t}$
- Therefore:
  - $\Delta x =$ vt

$b \times h$

$v \times t$

$2\,\mathrm{s} \times 2\,\mathrm{m/s}$

4 m



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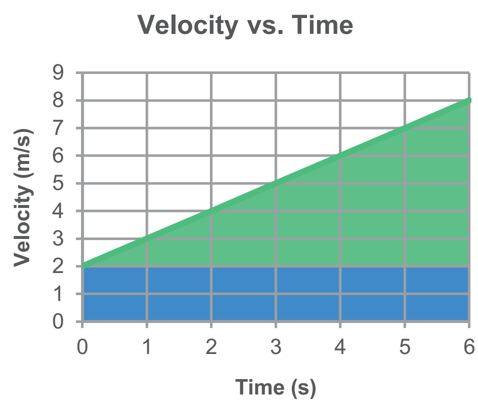
Displacement during Constant Acceleration

Displacement during constant velocity	$\Delta x = vt$
Displacement during acceleration	$\Delta x = \frac{1}{2}(v_f - v_i)t$
Total displacement is the sum of the two	$\Delta x = v_i t + \frac{1}{2}(v_f - v_i)t$
Terms are combined	$\Delta x = \frac{1}{2}(v_f + v_i)t$
When the initial position is not zero	$x_f = x_i + \frac{1}{2}(v_f + v_i)t$



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Displacement during Constant Acceleration

$b = 3\,\text{s}$

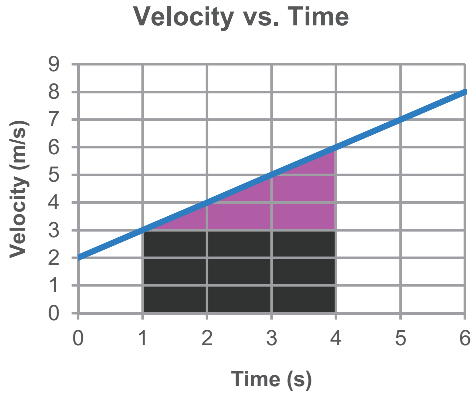
$h = 3\,\text{m/s}$

$9\,\text{m}$

$b = 3\,\text{s}$

$9\,\text{m} + 4.5\,\text{m}$

$=$ 13.5 m



$$\frac{1}{2}(3\,\text{s})(6\,\text{m/s} - 3\,\text{m/s})$$

$=$ 4.5 m

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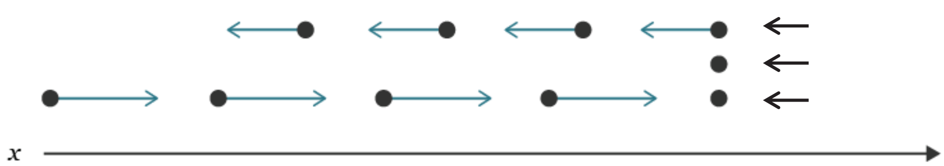
Motion Maps



Both a change in velocity indicated by the change in vectors links and the change in direction are indicated by the change in direction of the vectors.

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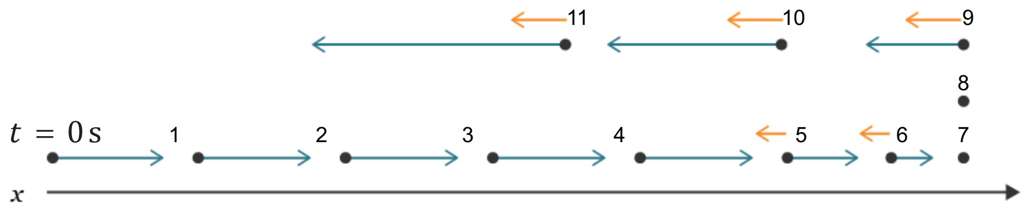

- Motion maps for accelerated motion have an additional vector above the dots indicating the object's position.
- At *t* equals 9 seconds, the object has turned around and starts to move toward the origin. We can tell it is speeding up with a larger constant acceleration because the acceleration vectors are larger than the first ones but the same length as each other.

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Summary | Acceleration

Lesson Question

How can acceleration be used to describe motion?

Answer

(Sample answer) Acceleration is used to describe the motion of objects when they speed up, slow down, or change direction. Accelerated motion can be described with formulas, graphs, and motion maps.

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Review: Key concepts

- Acceleration is the rate at which velocity changes over time.
  - $a = \frac{\Delta v}{\Delta t}$
  - Positive acceleration occurs when an object speeds up in the positive direction or slows down in the negative direction.
  - Negative acceleration occurs when an object slows down in the positive direction or speeds up in the negative direction.
- When the acceleration of an object is constant, a set of formulas can be derived to describe the motion of the object.
  - $v_f = v_i + at$
  - $x_f = x_i + v_i t + \frac{1}{2}at^2$
  - $v_f^2 = v_i^2 + 2a(x_f - x_i)$

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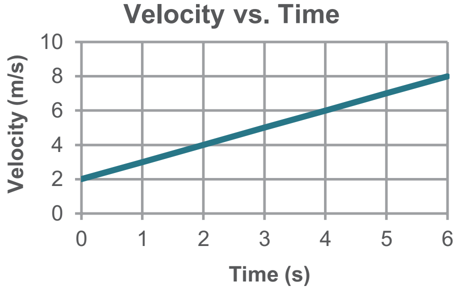
Review: Key concepts

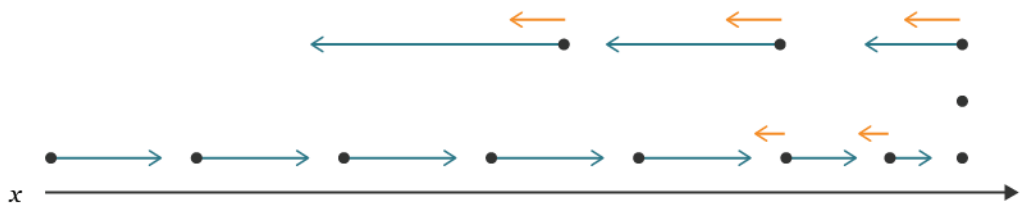
The slope of the line on a velocity vs. time graph represents acceleration.

Slope	Velocity	Acceleration
Positive	Increasing	Positive
Negative	Decreasing	Negative
None	Constant	None

The total displacement of an object can be calculated from the area under the curve or by using the formula $\Delta x = \frac{1}{2}(v_f + v_i)t$.



Review: Key concepts



In this motion map, the object travels at a constant velocity for several seconds before slowing down, stopping, and then speeding up in the opposite direction.

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Use this space to write any questions or thoughts about this lesson.

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