Module 1: Describing Motion
Topic 3 Content: Acceleration

Now that we understand displacement and velocity, we will begin to understand how to represent and analyze when velocity is changing.

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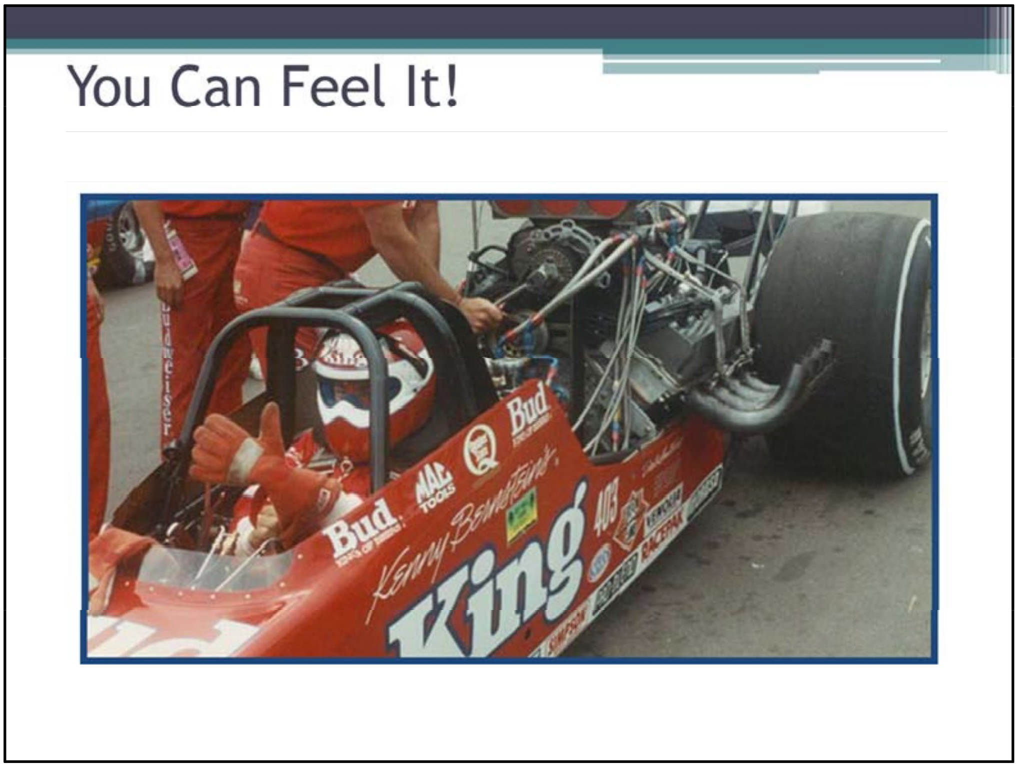
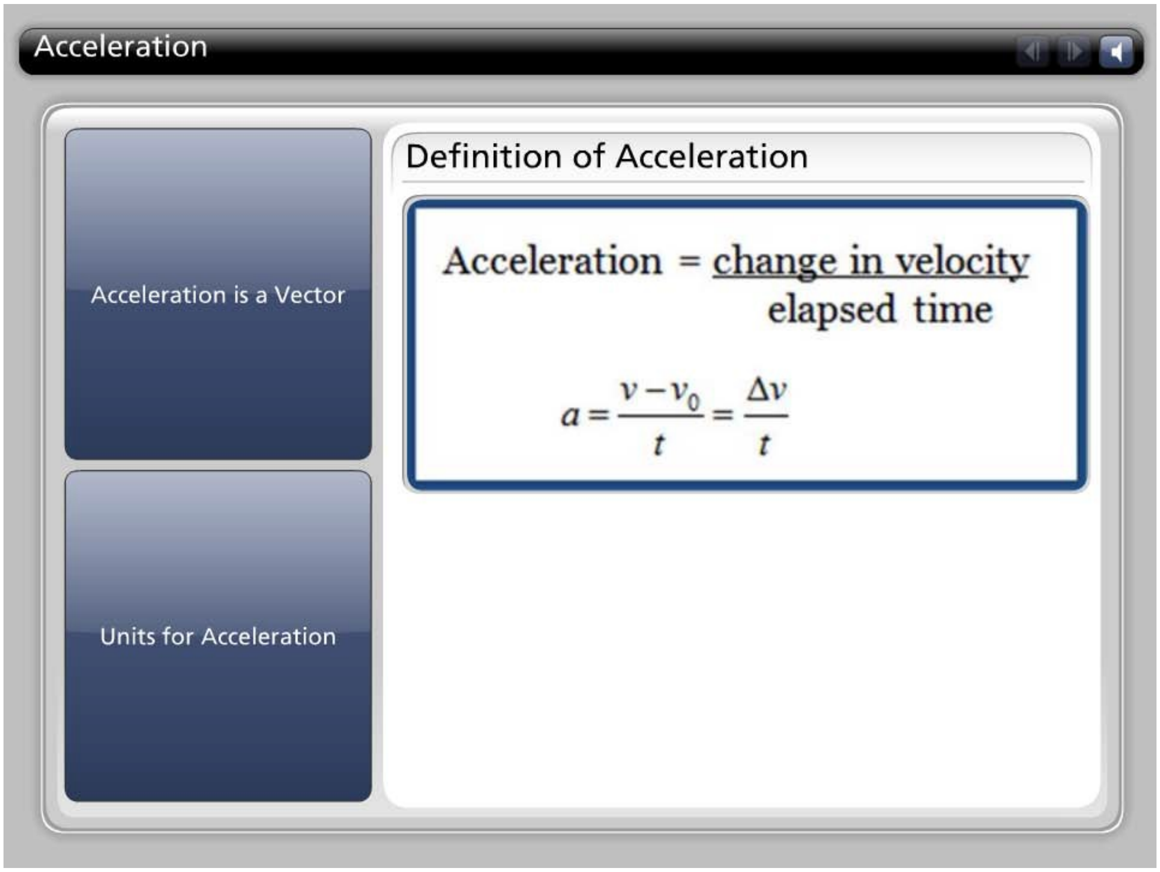


When Kenny Bernstein rolls to the line in his Top Fuel dragster, preparing to run the quarter mile, he must be anticipating the feeling to come. When the starting lights flash green, he may go from zero to over three hundred thirty miles per hour, nearly one hundred and fifty meters per second, in less than four and a half seconds. Most people can only imagine that feeling which is more dramatic than astronauts in the space shuttle feel at launch.

In our everyday lives, as we drive down the street, starting and stopping and turning left and right, we feel smaller versions of the same sensation.

All of these sensations come from being accelerated.

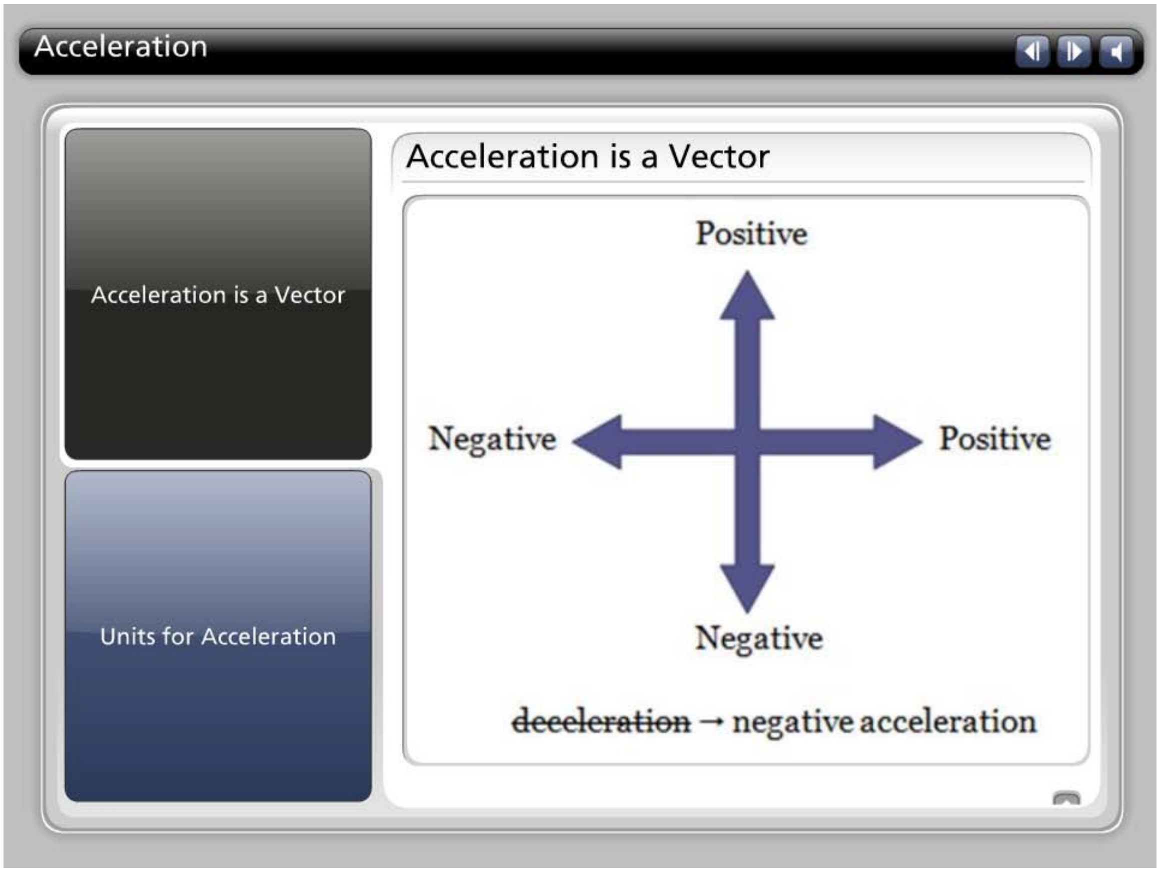


Acceleration is how fast your velocity changes. We calculate average acceleration by dividing the change in velocity by the elapsed time required to make that change. In this course, we only will be dealing with situations where the acceleration is smooth, or constant, so we will simply refer to it as acceleration and not average acceleration.

The symbol we will use for acceleration is a lower case a, so our equation for acceleration is a equals v minus v zero over t, or delta v over t.

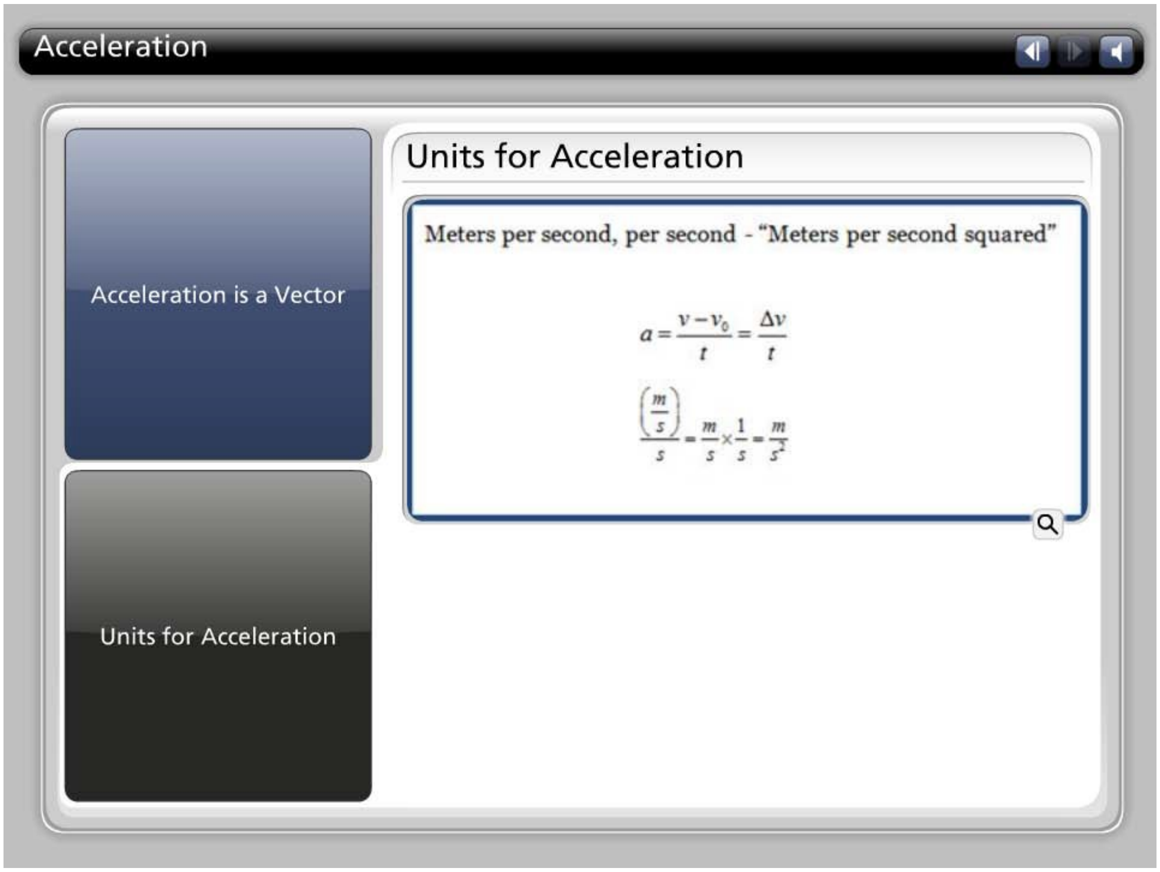
Module 1: Describing Motion

Topic 3 Content: Acceleration Presentation Notes



Acceleration is a vector quantity. Remember that vectors have both magnitude and direction. So an acceleration to the right is very different from an acceleration to the left. In most cases, we will indicate direction with the use of positive and negative. Typically up, North, right and East are considered positive directions and down, South, left and West are considered negative. All the equations would still work if you chose different directions to be positive, however. You may have used the terms acceleration and deceleration in the past to describe motion. In physics, we will avoid the use of the term deceleration. Instead, we will identify the direction in which the acceleration is happening and identify it as positive or negative acceleration. A car traveling with a positive velocity will not be said to decelerate when the driver steps on the brakes, but instead it will be said to accelerate in a negative direction, but instead will undergo negative acceleration.

Module 1: Describing Motion
Topic 3 Content: Acceleration Presentation Notes

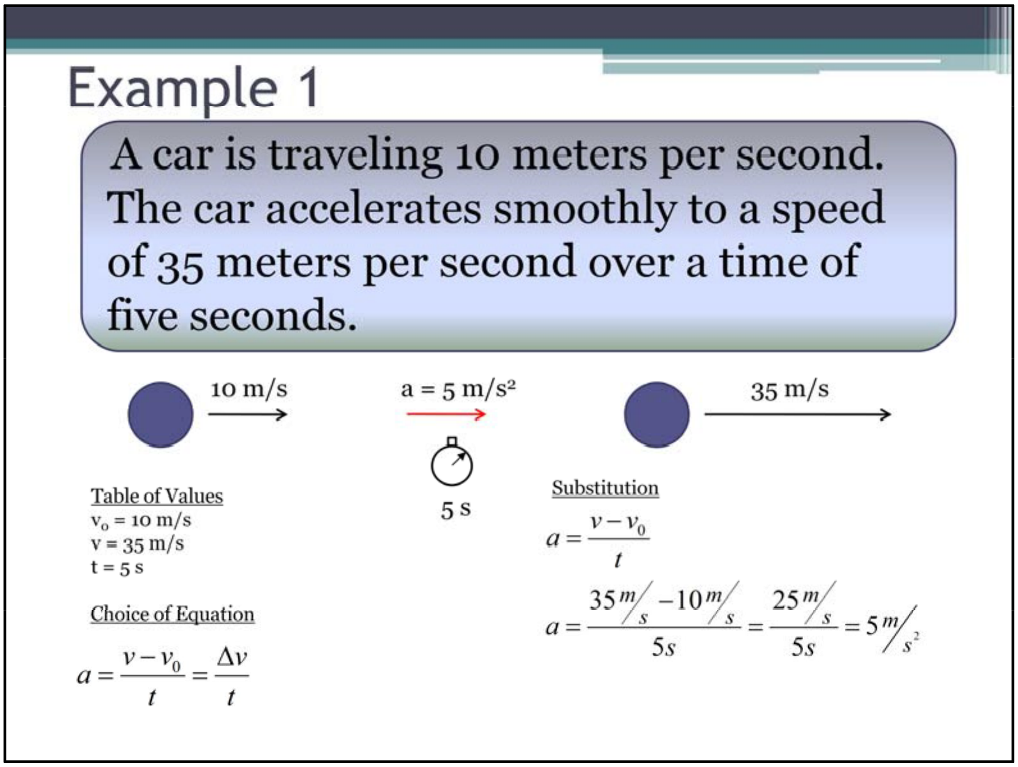


What are the units for acceleration? We can see what they are by looking at the equation.

We have a change in velocity, which is measured in meters per second, divided by time in seconds. The answer is in units of meters per second, per second. In math when dividing by a number it is the same as multiplying by one over the number. So we have meters per second times one over seconds, or meters divided by seconds squared.

We call this meters per second squared.

Don't worry that there's no such thing as a square second. You will discover that often the units in physics may be written in an interesting way, but that they will always be useful in helping you to identify logical answers from illogical ones, as well as to see if an equation you use makes sense.



Let’s take a look at how you calculate acceleration. Suppose we have a car that is traveling 10 meters per second. The driver steps on the accelerator and smoothly brings the car to a speed of 35 meters per second over a time of five seconds. You’ll consider the direction the driver is going to be positive.

It is helpful to first draw a picture. You don’t actually need to draw a picture of a car, but you can if you want to . In this case, you’ll simply represent the car with a circle.

The initial speed is 10 meters per second to the right. You’ll show this with an arrow to the right to represent the vector nature of velocity. The final velocity of the car is 35 meters per second, also to the right.

Now, let’s write down a table of values to collect our information.

Initial velocity, v zero, equals 10 meters per second.
Final velocity, v, equals 35 meters per second.
And time equals five seconds.

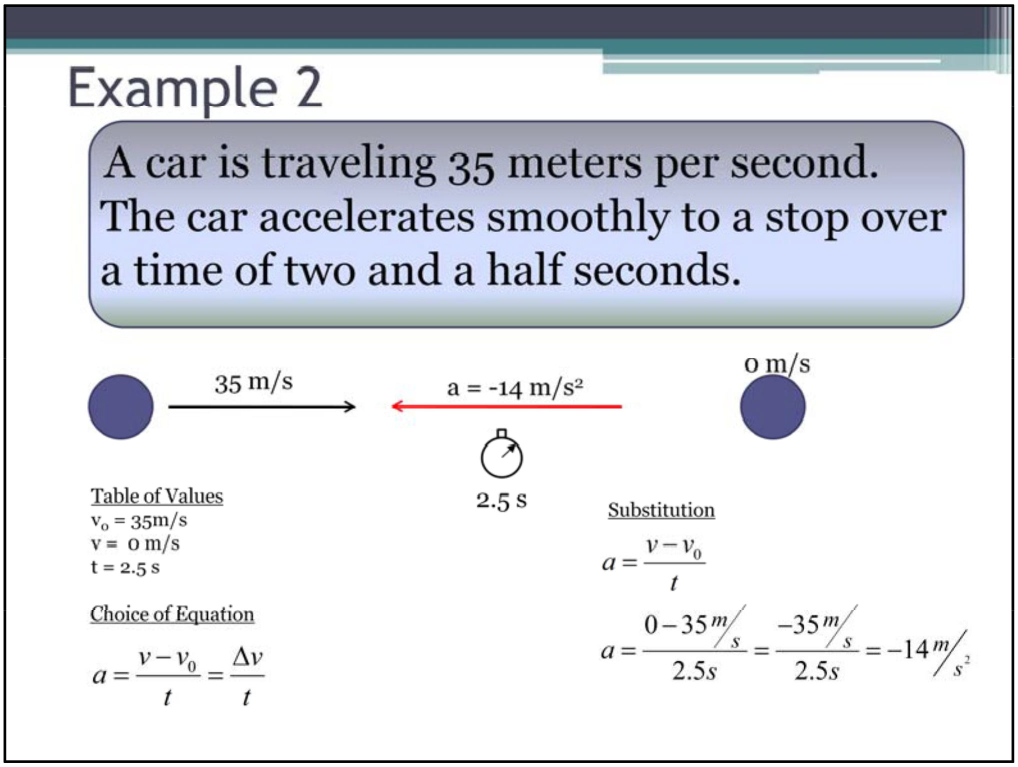
You now write down our acceleration equation, acceleration equals final velocity minus initial velocity divided by time.

Now you can plug in your values and solve.

We find that the acceleration is positive five meters per second per second, or five meters per second squared.

Positive means that the acceleration was in the same direction as the initial velocity that we had defined as positive. You can add an arrow representing the acceleration to our picture.

Notice that five meters per second per second means that each second saw an velocity increase of five meters per second. After one second the car went from ten to fifteen meters per second. Over the next second, the car added another five meters per second to its velocity to go from fifteen to twenty, and so on. An additional five meters per second added to the velocity, each second. That’s what five meters per second per second means.



For our next example, let's start with the same car, now moving positive thirty five meters per second. When the brakes are applied, the car smoothly comes to a stop over the next two and a half seconds.

Again, we'll draw a picture showing the car at its initial velocity and later at rest at its final velocity.

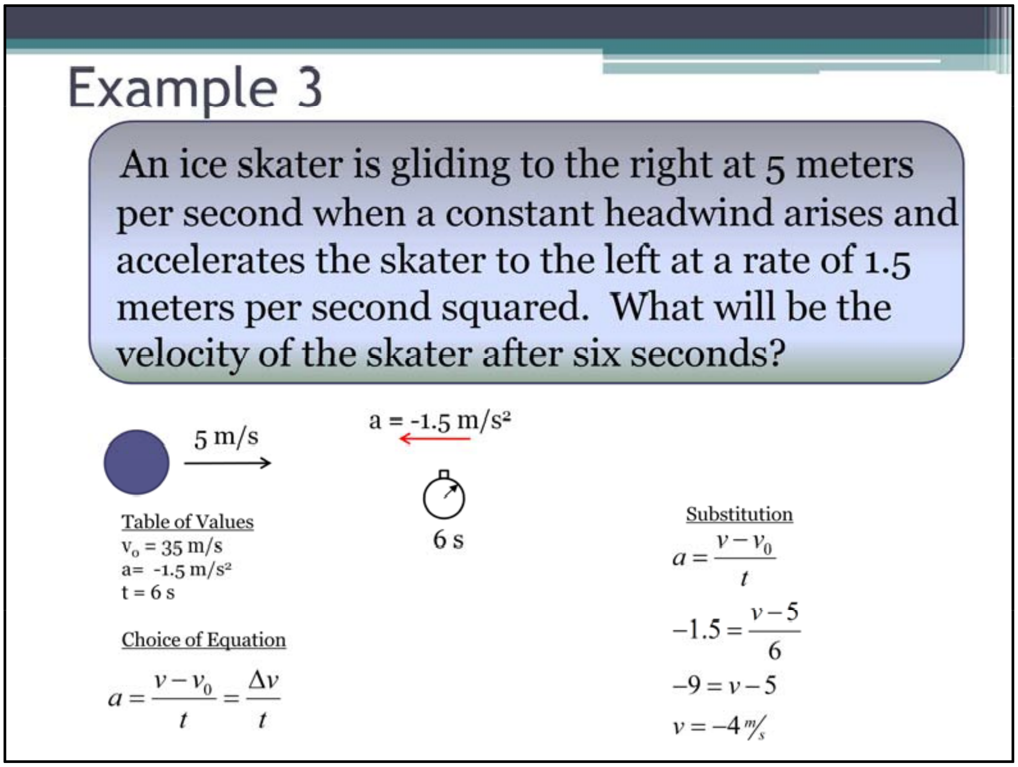
As we complete our table of values, the initial velocity is 35 meters per second, the final velocity is zero meters per second and the time is two and a half seconds.

We again select our acceleration equation.

When substituting here, you must be very careful to place v and v zero in the right places. Since the car goes from 35 meters per second to a stop, the change in velocity is actually negative thirty five meters per second, resulting in a negative acceleration.

We can now place an acceleration arrow on our diagram. The acceleration is negative (since it is to the left), and thus the acceleration arrow must also point toward the left. A negative acceleration will cause a positive velocity to decrease.

Again, you might still be tempted to call this a deceleration, but let's see what happens if a negative acceleration continues to act.



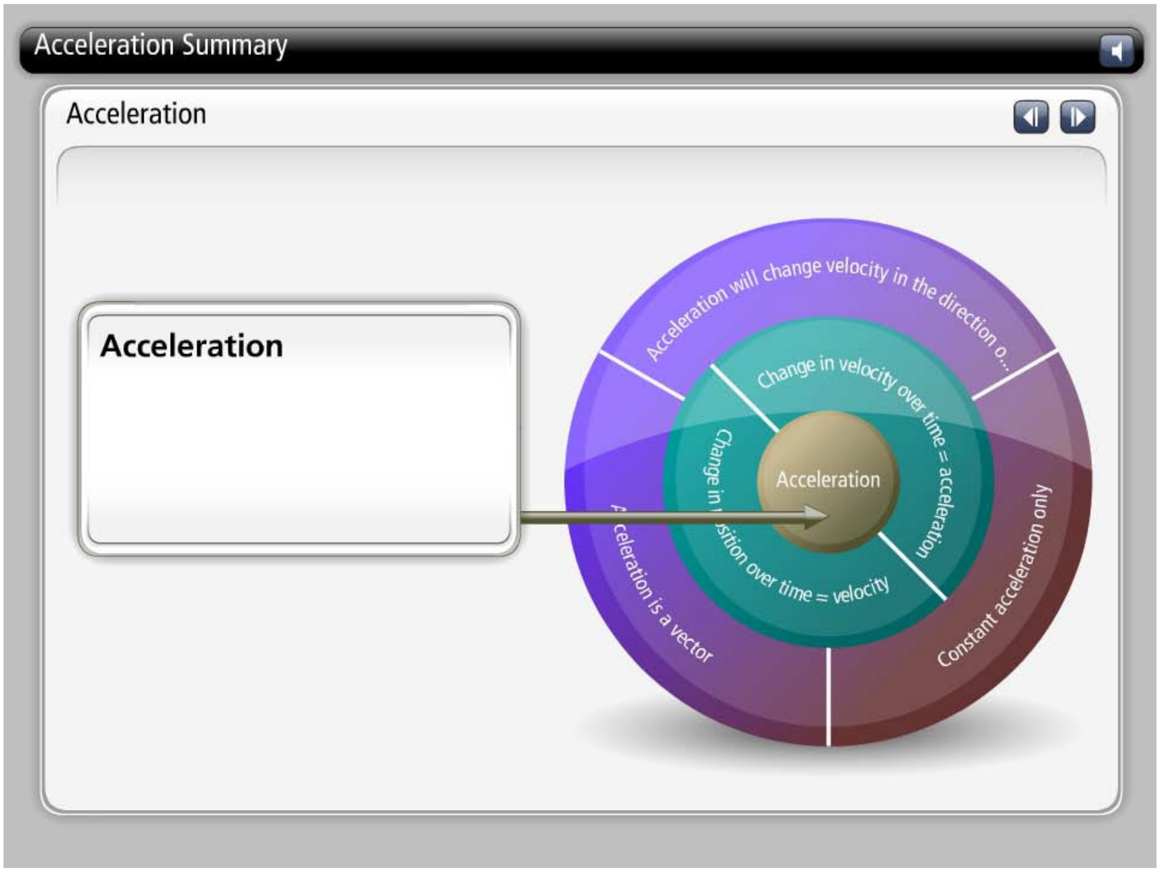
An ice skater glides along on some frictionless ice at five meters per second and a strong wind comes up opposite the skater's motion changing the skater's acceleration to the left at one point five meters per second squared. What will be the velocity of the skater after six seconds?

First, we can draw a diagram to represent the situation. The initial velocity is to the right, so we'll call that positive. The acceleration is in a negative direction, so we'll draw that arrow to the left.

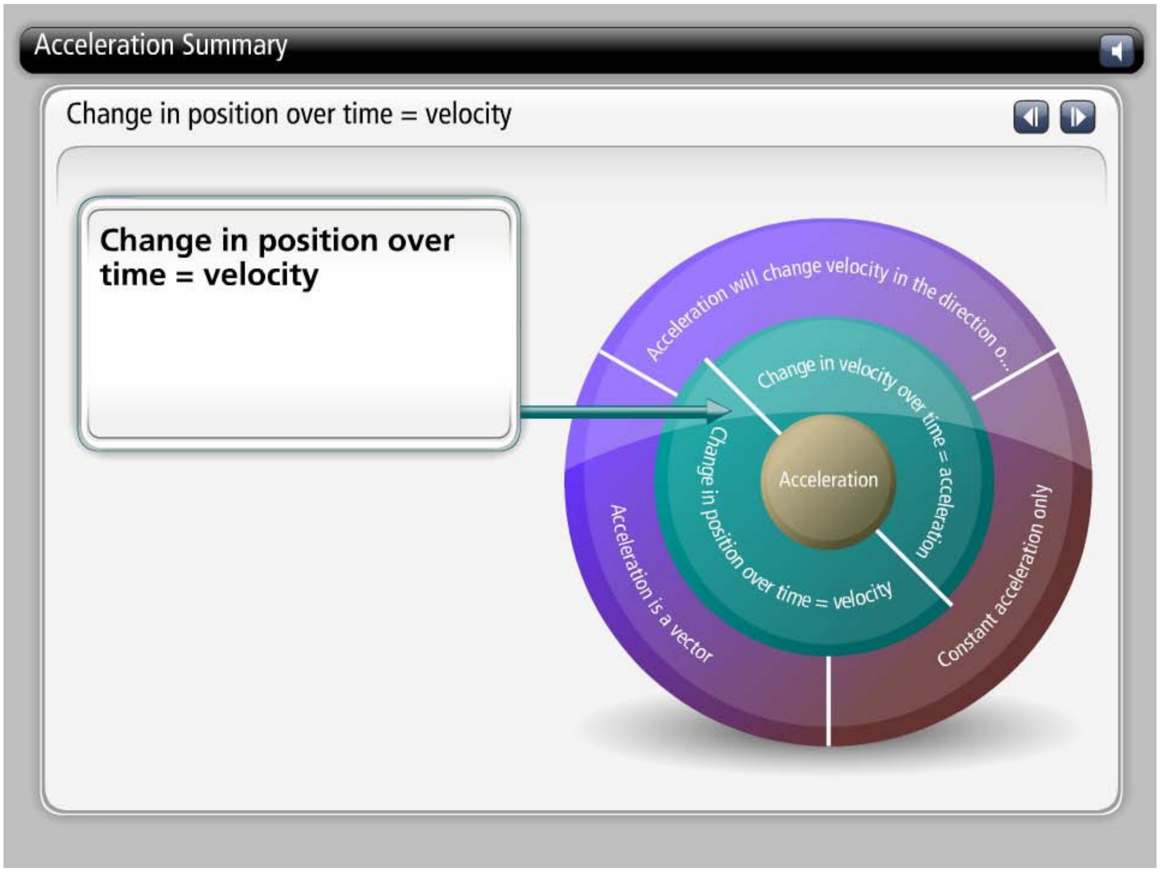
Now we can fill out our table of values. The initial velocity is five meters per second, the acceleration is negative one point five meters per second squared and the time is six seconds.

Again, we'll use our acceleration equation and substitute in the values. In this case, we have to solve for the final velocity, v, and we see that our result is negative four meters per second. That means that the skater is now moving at four meters per second to the left.

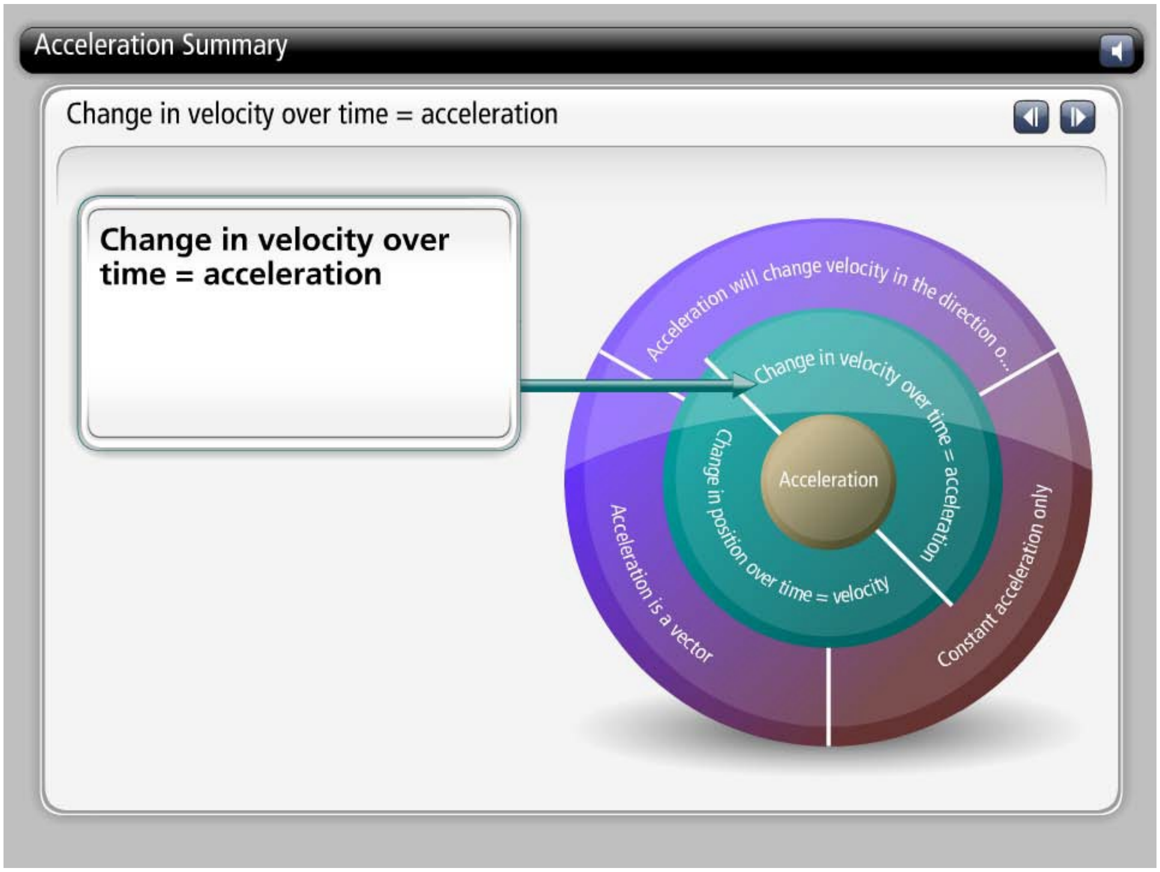
So the skater was moving to the right, had a negative acceleration, which caused it to slow down in the positive direction, then speed up in the negative direction, leading to a negative velocity. If an object is speeding up in a negative direction, can you consider it to be decelerating? This is why we simply choose to call it negative acceleration instead of deceleration, so we can avoid the confusion about speed decreasing or increasing.



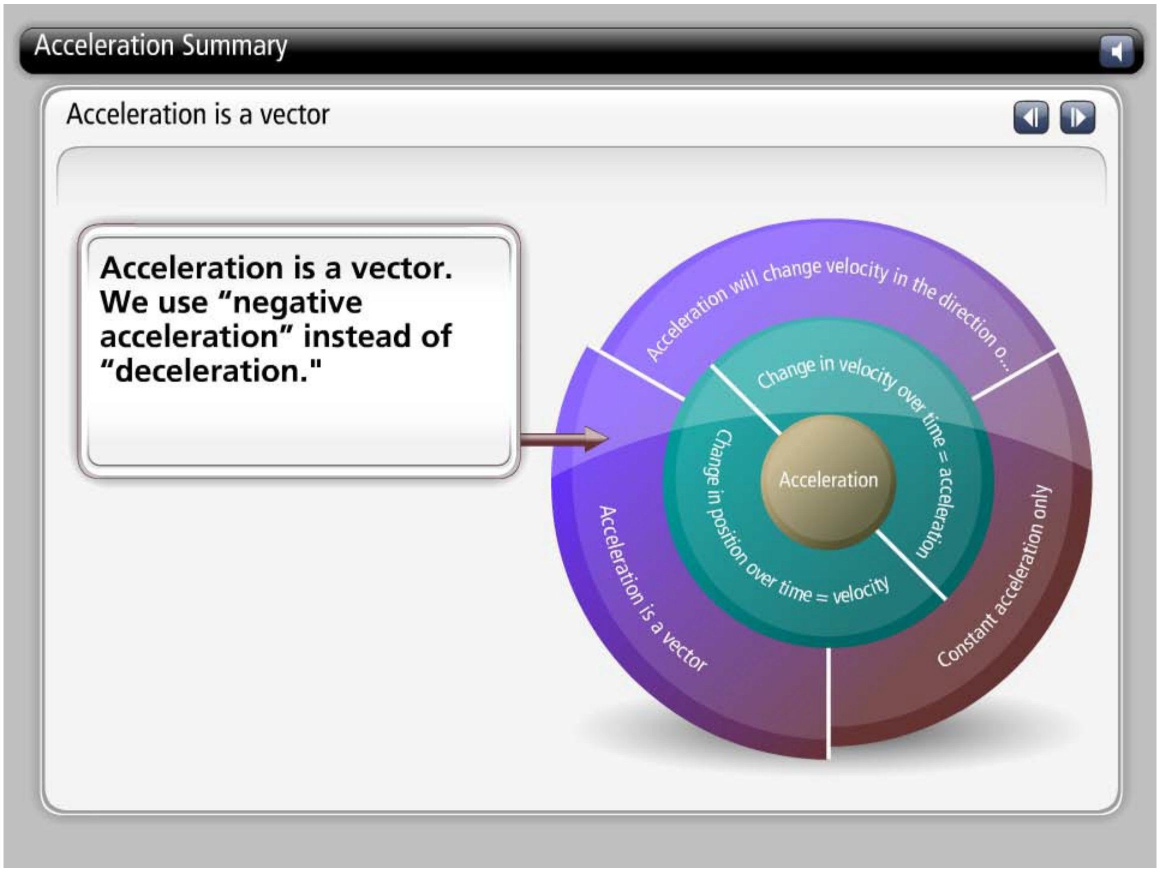
Let's summarize acceleration.



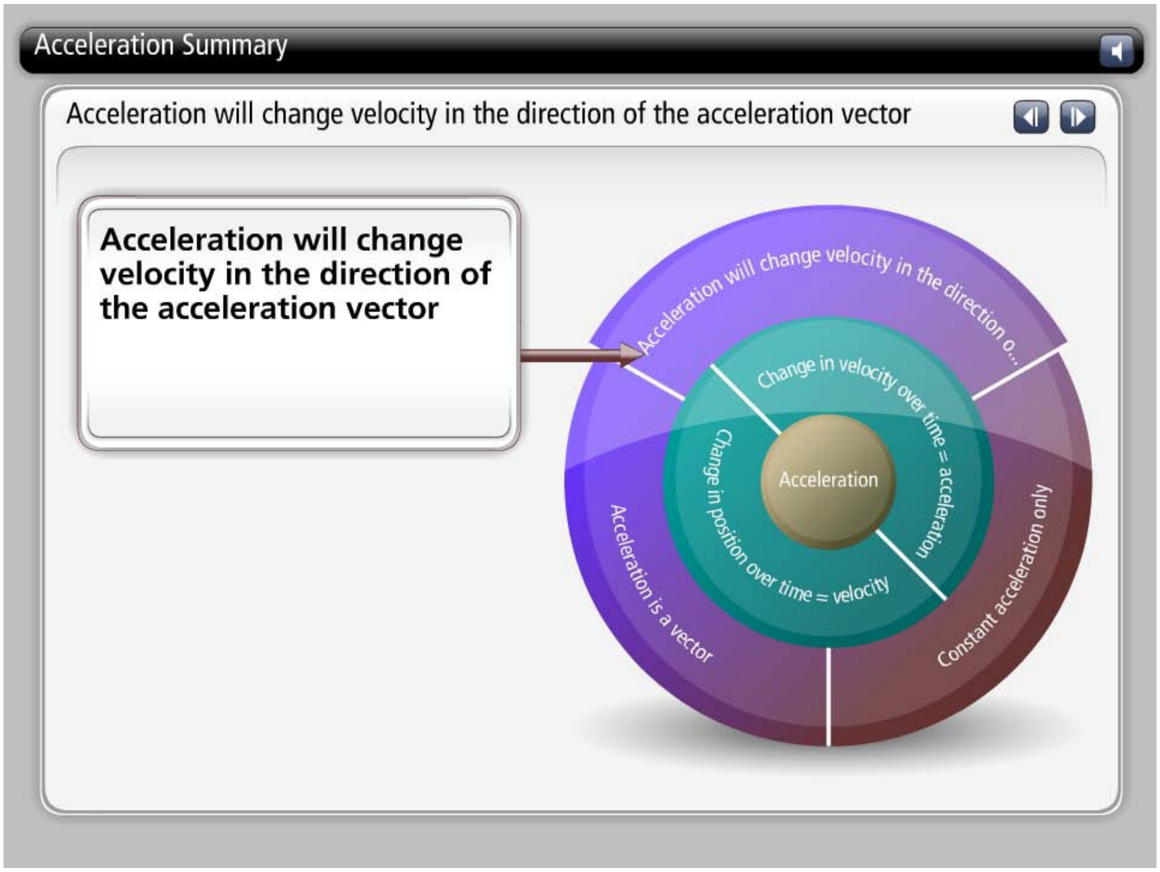
A change in position over time was defined as velocity.



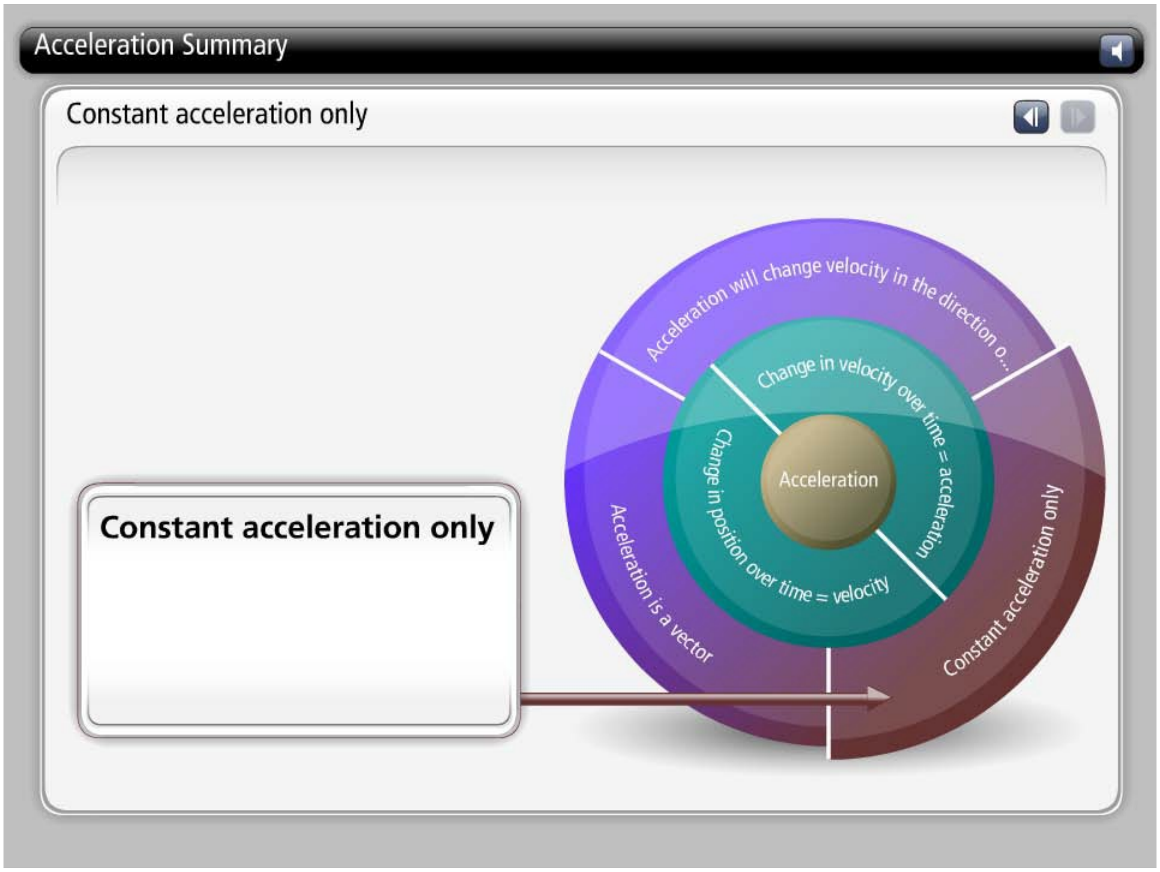
We define a change in velocity over time as an acceleration.



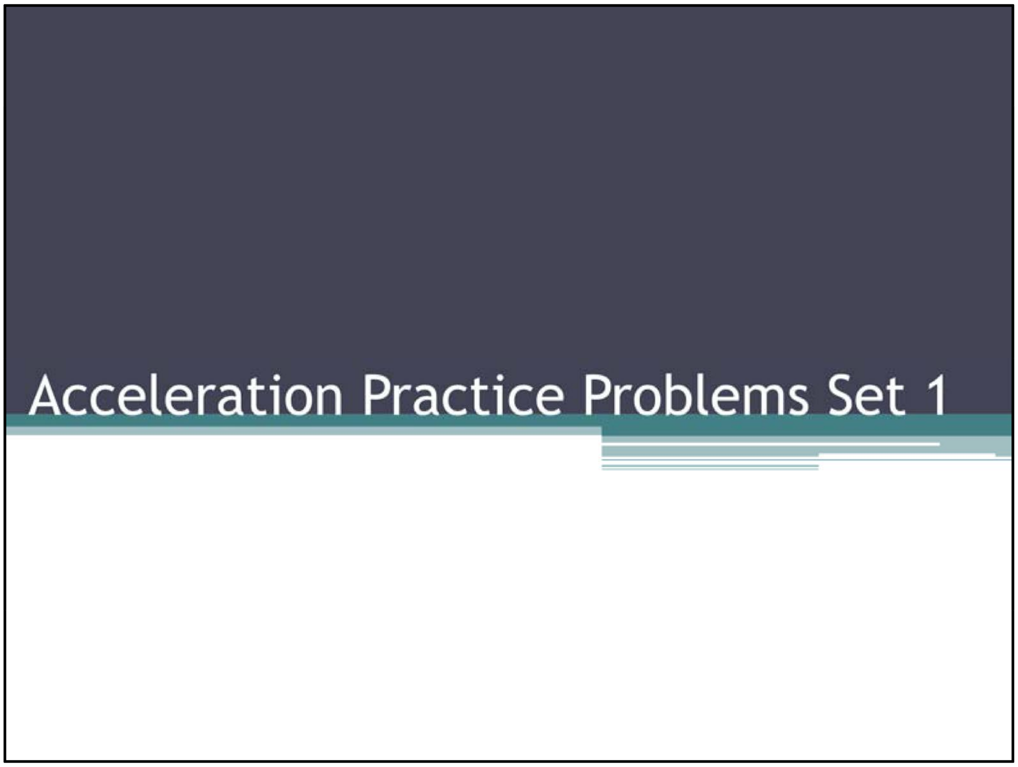
Acceleration, like velocity and displacement, is a vector quantity that includes both magnitude and direction. We will use the term negative acceleration instead of referring to deceleration because a negative acceleration can cause slowing down in the positive direction or speeding up in the negative direction.



As we saw in the examples, the direction of the acceleration vector shows the direction that the velocity vector will change. When velocity and acceleration have opposite signs, objects slow down. When velocity and acceleration have the same sign, objects speed up.



Finally, in this course, we will only be dealing with situations involving constant acceleration.



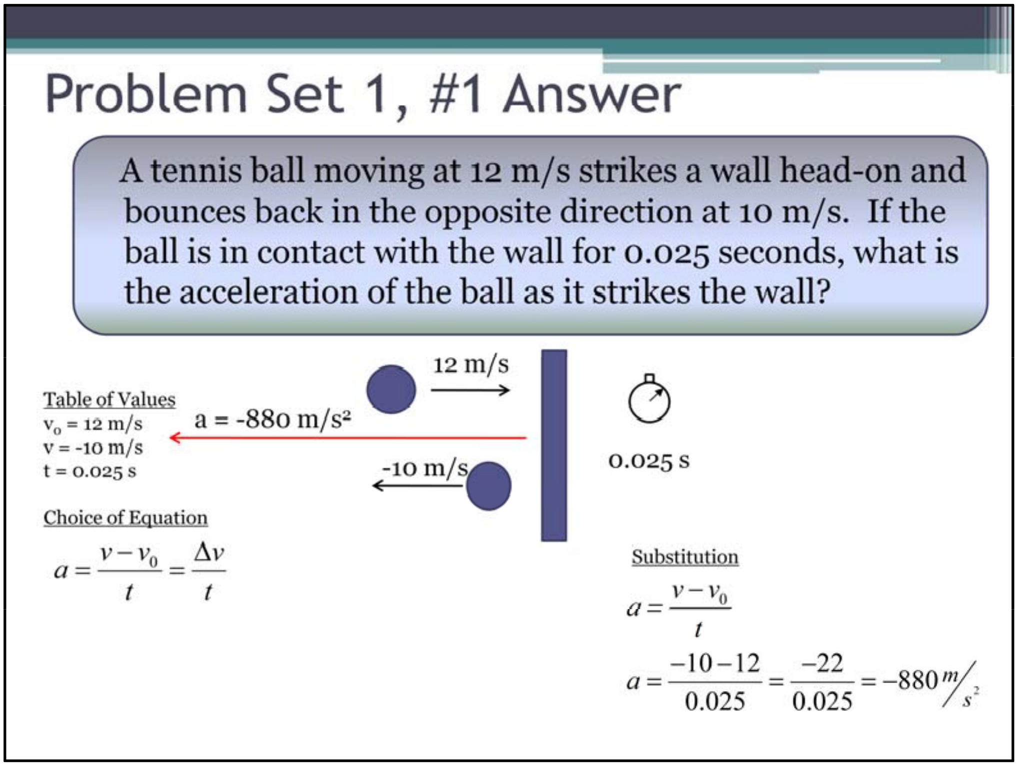
Now that you've seen some examples of calculating acceleration, you should try a few of your own. Work out the problems yourself before looking at the answers. Remember to follow the problem solving steps that we've been using, in order to properly organize your thoughts and have the best chance of effectively solving the problems.

Problem Set 1, #1

A tennis ball moving at 12 m/s strikes a wall head-on and bounces back in the opposite direction at 10 m/s. If the ball is in contact with the wall for 0.025 seconds, what is the acceleration of the ball as it strikes the wall?

A tennis ball moving at twelve meters per second strikes a wall head-on and bounces back in the opposite direction at ten meters per second. If the ball is in contact with the wall for zero point zero two five seconds, what is the average acceleration of the ball as it strikes the wall?

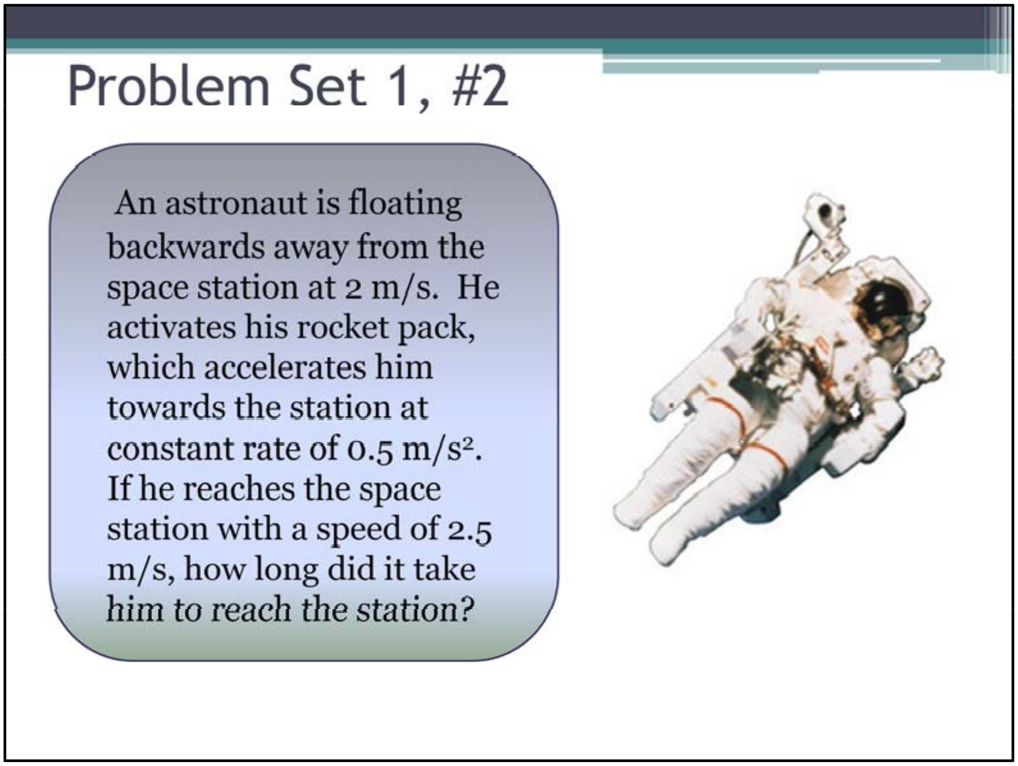
Note that we mention average acceleration here. Just as when looking at a situation where position is changing over time, we can look at the absolute change in position over a period of time to calculate average velocity, we will look at the absolute change in velocity in this example to calculate average acceleration.



First, you should draw a picture to represent the situation. Let's consider right to be positive. The initial velocity of the ball is twelve meters per second. The final velocity of the ball has to be negative ten meters per second because it is in the opposite direction. The time of contact with the wall was zero point zero two five seconds.

Now you will choose an equation, which is the same acceleration equation we've been using. As you substitute your values and solve, you must be careful to substitute the values for v and v zero in the right places and pay close attention to positive and negative values. Students will often make the mistake that the change in speed from plus twelve to negative ten is a change of only two, but if you think of these two numbers on the number line, to get from plus twelve to negative ten, you'd have to move twenty two spaces. This is why it is important to identify values with variables and place them carefully into the equations.

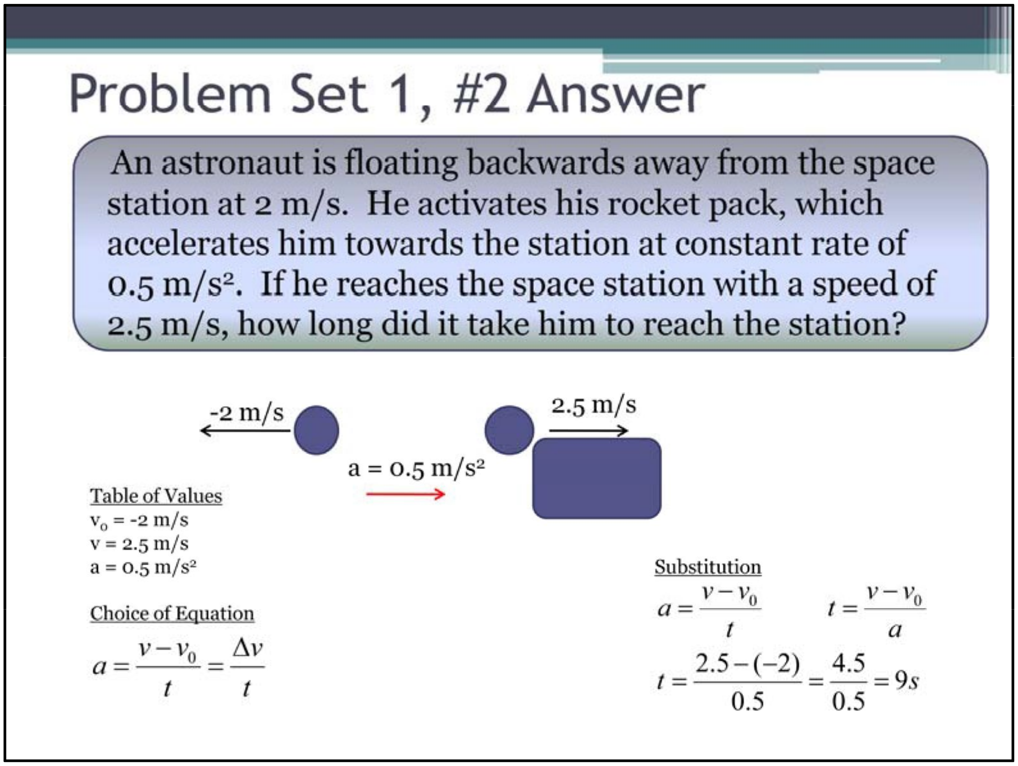
You can now add the acceleration vector to the diagram, showing that the change in the ball's velocity, from positive to negative, is in the same direction as the acceleration.



An astronaut is floating backwards away from the space station at 2 meters per second. He activates his rocket pack, which accelerates him towards the station at constant rate of 0.5 meters per second squared. If he reaches the space station with a speed of 2.5 meters per second, how long did it take him to reach the station?

Module 1: Describing Motion

Topic 3 Content: Acceleration Presentation Notes



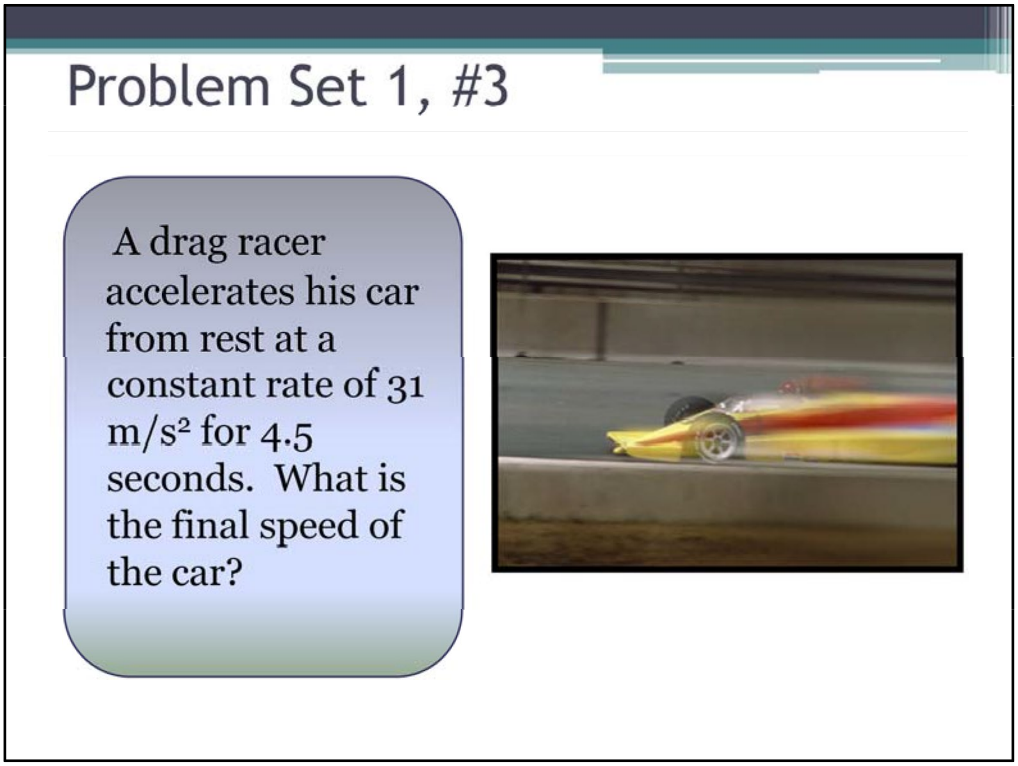
Your first step is should be to draw a picture to better represent the information you have been given. In this case, since the astronaut is moving backwards, we'll have him moving to the left at a negative velocity, with the space station to his right. It is easiest to represent the astronaut as a simple circle. After the acceleration, the astronaut is moving to the right at an unknown speed. Since he reaches the station, the acceleration must be to the right.

You can now complete the table of values. Initial velocity is negative two meters per second. Final velocity is two point five meters per second and acceleration is positive zero point five meters per second squared. Your equation, once again is the acceleration equation.

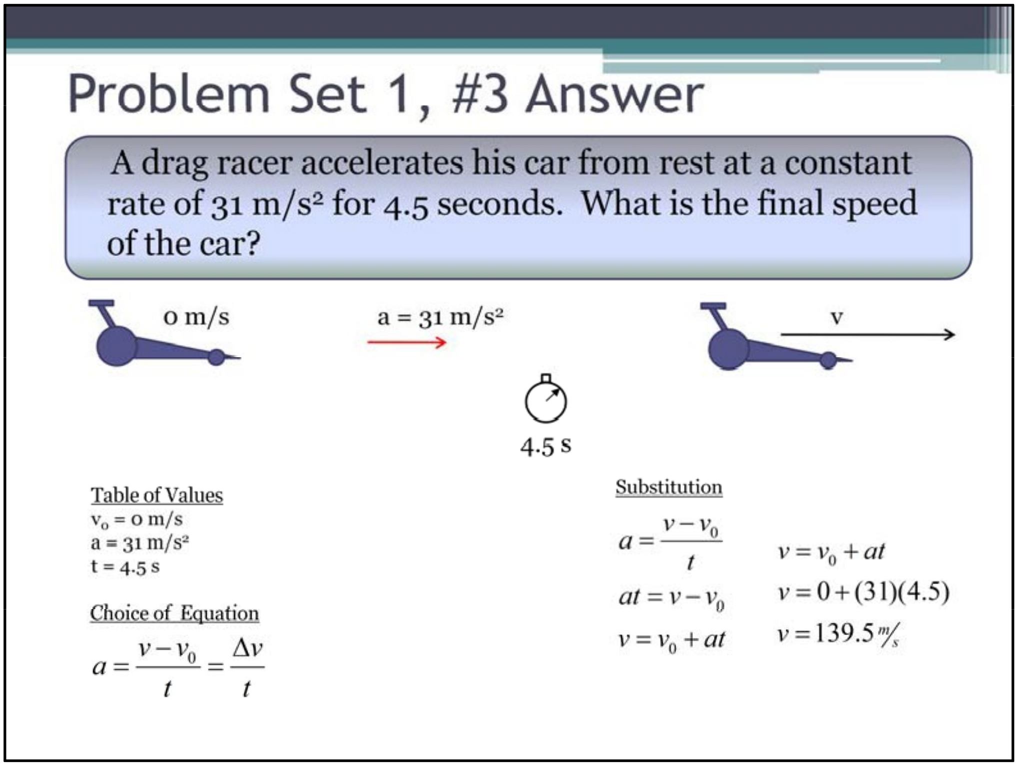
When you substitute and solve, you have a choice of rearranging the equation to solve for your unknown variable first, or plugging in the values right away and solving. Here, we've rearranged the equation showing that t equals v minus v zero over a.

We solve and get a result of nine seconds.

Notice that the acceleration vector initially points in an opposite direction to the velocity vector, causing the astronaut to slow down. The acceleration continues at a constant rate, even when the astronaut momentarily passes through zero velocity so that the velocity vector now points in the same direction as the acceleration vector, making the astronaut speed up in a positive direction.



A drag racer accelerates from rest at a constant rate of acceleration of thirty one meters per second squared for four point five seconds. What is the final speed of the car?



The first step, as always is to draw a diagram. You know that direction to the right is positive. The initial velocity of the car is zero and the acceleration is positive 31 meters per second squared, so the final velocity is going to also be to the right. The time is four point five seconds.

You can enter these values into a table of values and again choose the acceleration equation.

Now you can either substitute your values directly into the equation or rearrange the equation, solving for the unknown variable. In this case, we'll rearrange the equation to solve for v.

We multiply both sides of the equation by t, then add v zero to both sides. The final equation is v equals v zero plus a t, or final velocity equals initial velocity plus acceleration times time. This is a useful form of this equation that you will come across again in a later lesson.

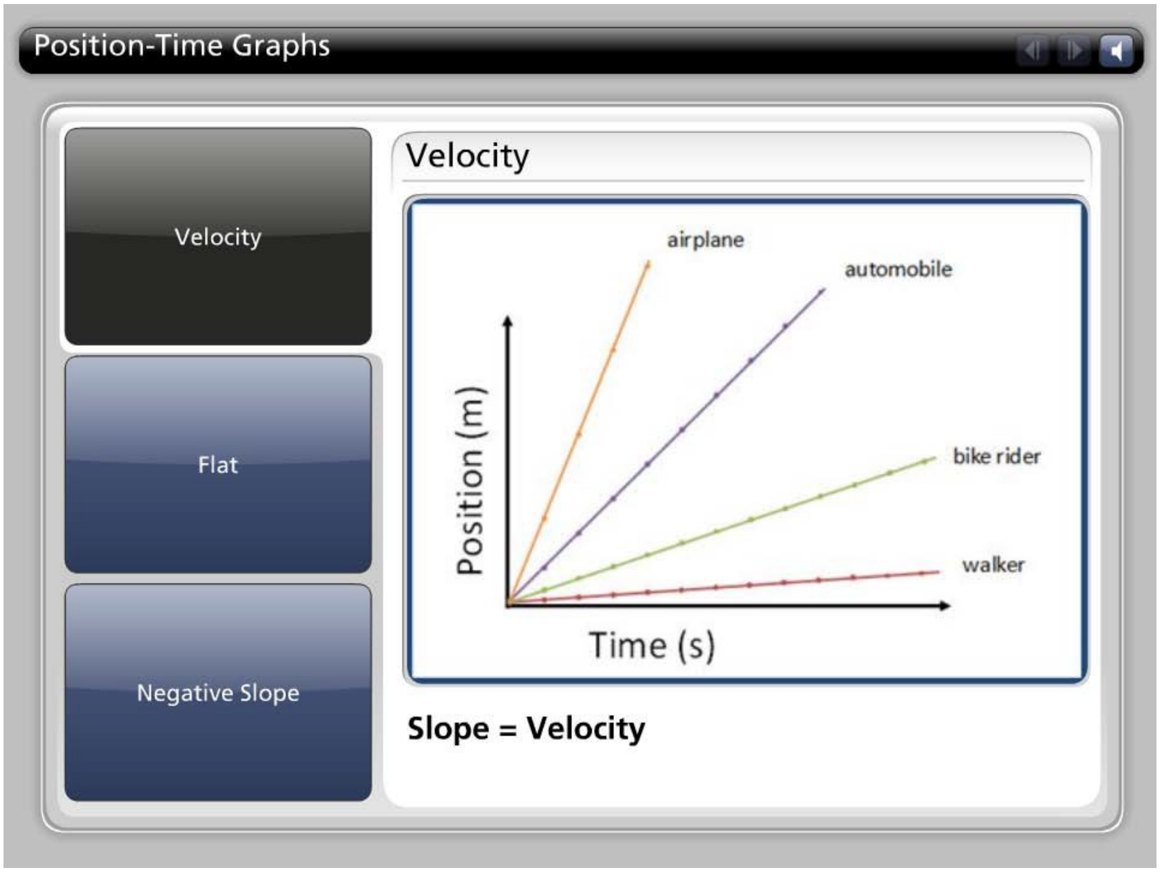
Now, we'll substitute values and solve and see that the final velocity is one hundred thirty nine point five meters per second.

This is about three hundred and twelve miles per hour, actually a reasonable speed for professional drag racing.

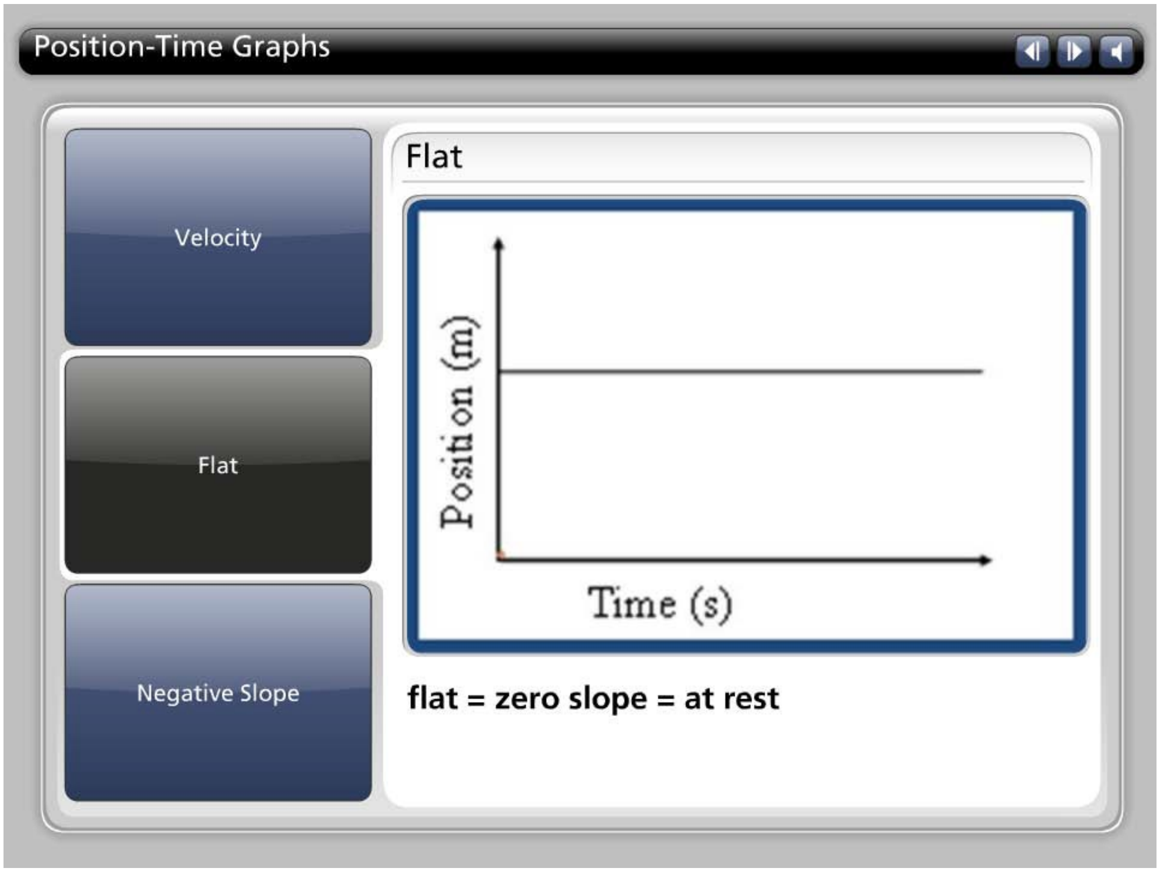
We have already taken a look at describing motion graphically. We created and analyzed position time graphs that represented objects in constant motion and at various speeds. In this lesson, we will extend our understanding, adding velocity and acceleration graphs so that we can see the relationship between all three.

Module 1: Describing Motion

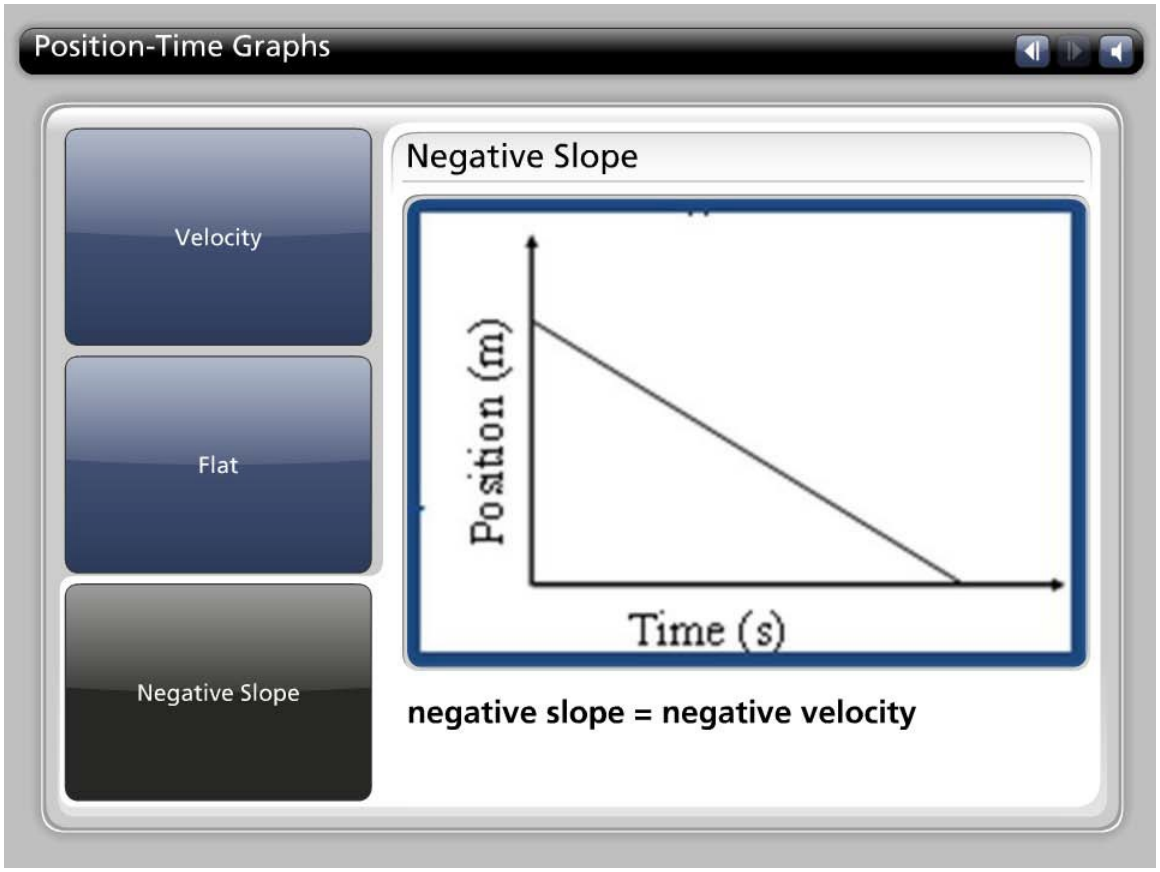
Topic 3 Content: Acceleration Presentation Notes



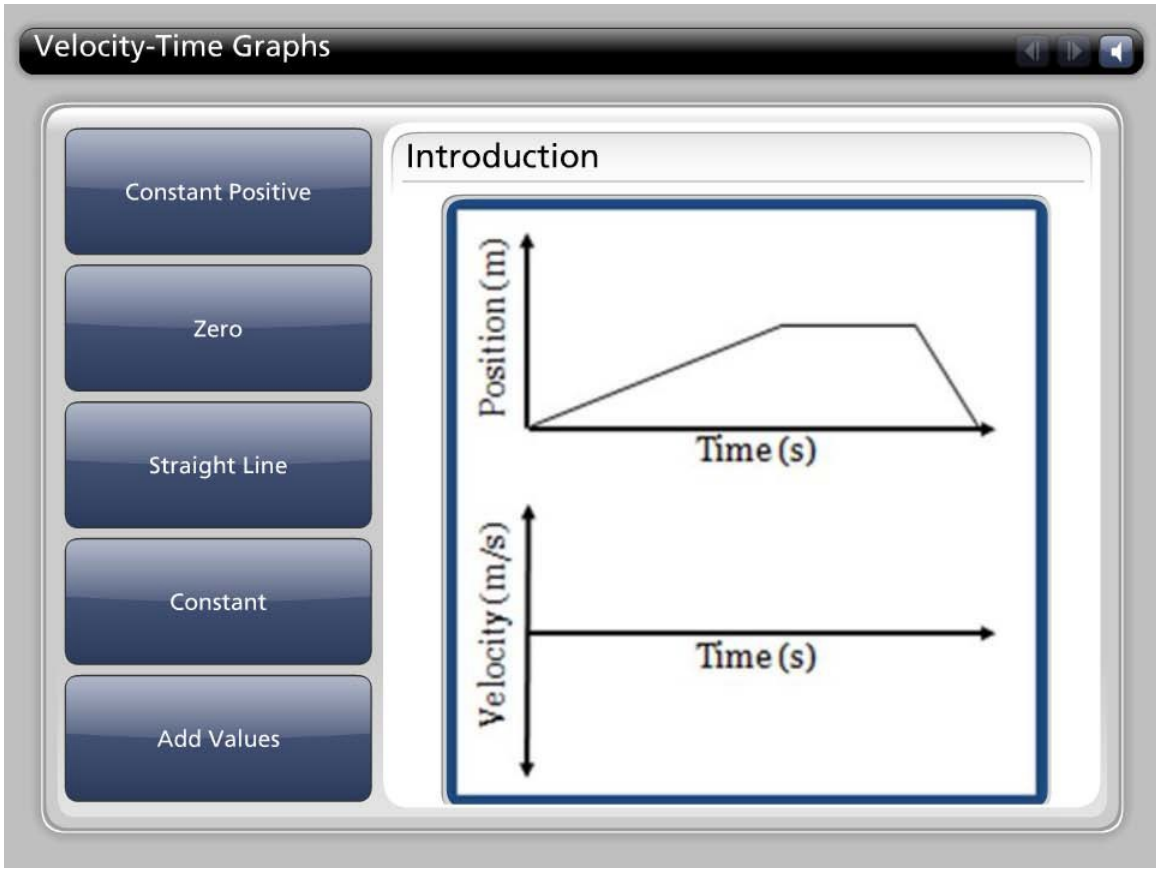
Remember that on a position-time graph, the slope of the graph represents the velocity of the object.



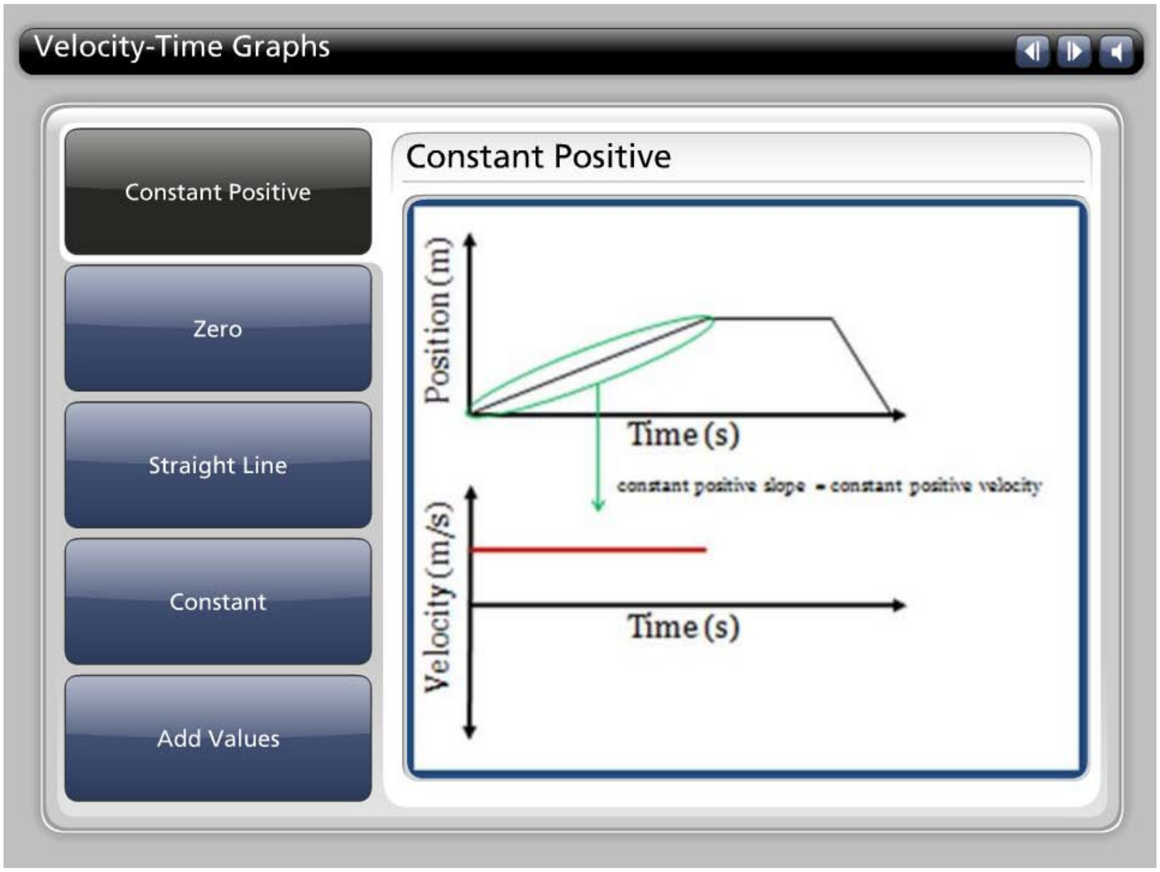
Flat lines have a slope of zero and represent a zero velocity, or an object at rest.



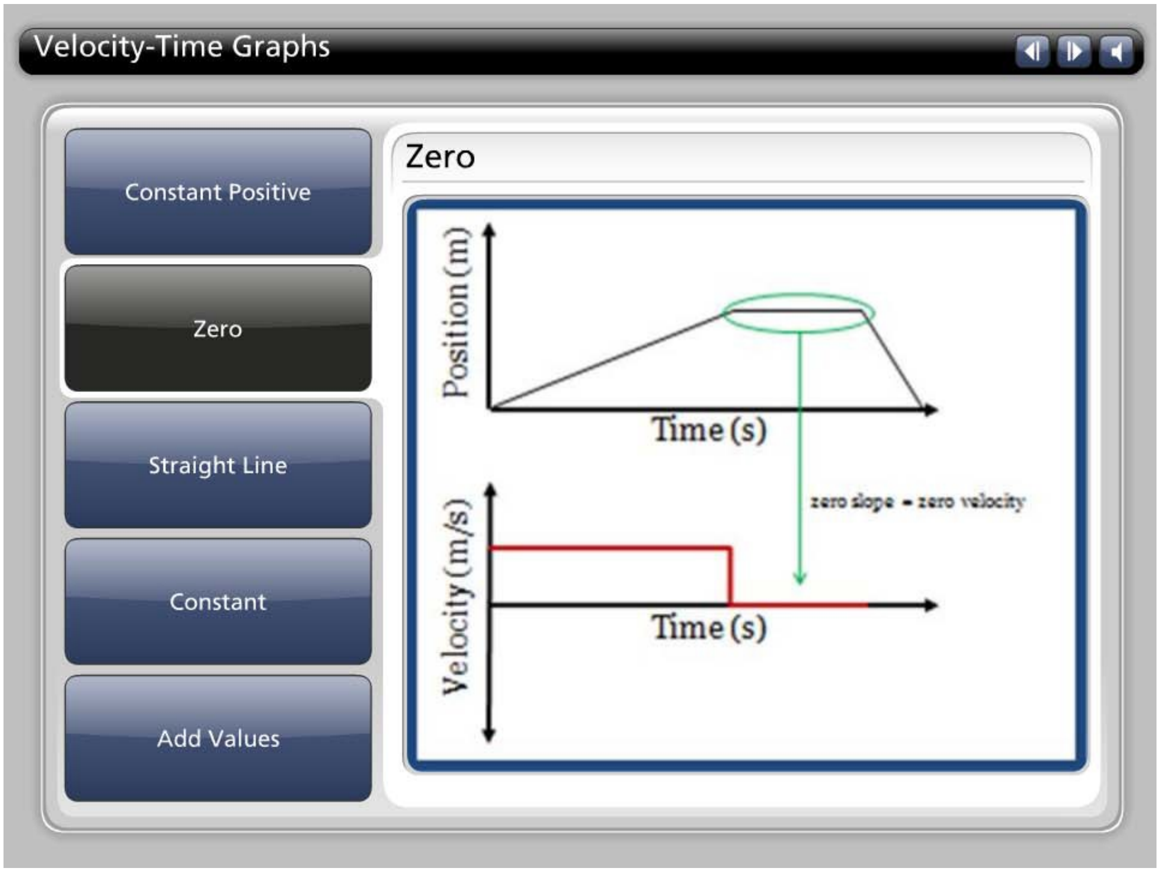
Lines with negative slope represent objects with negative velocity.



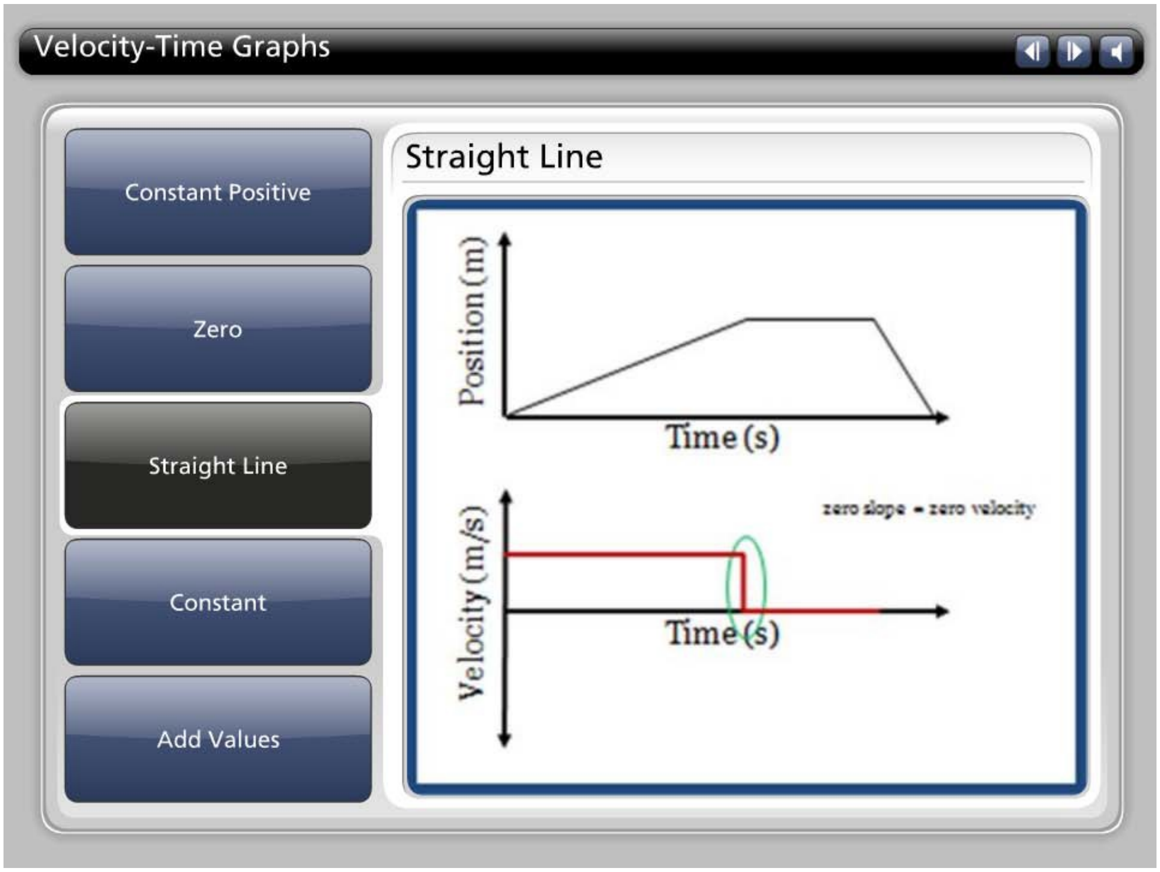
We could also create velocity-time graphs. The velocity-time graph displays the slope of the position-time graph at each instant of time.



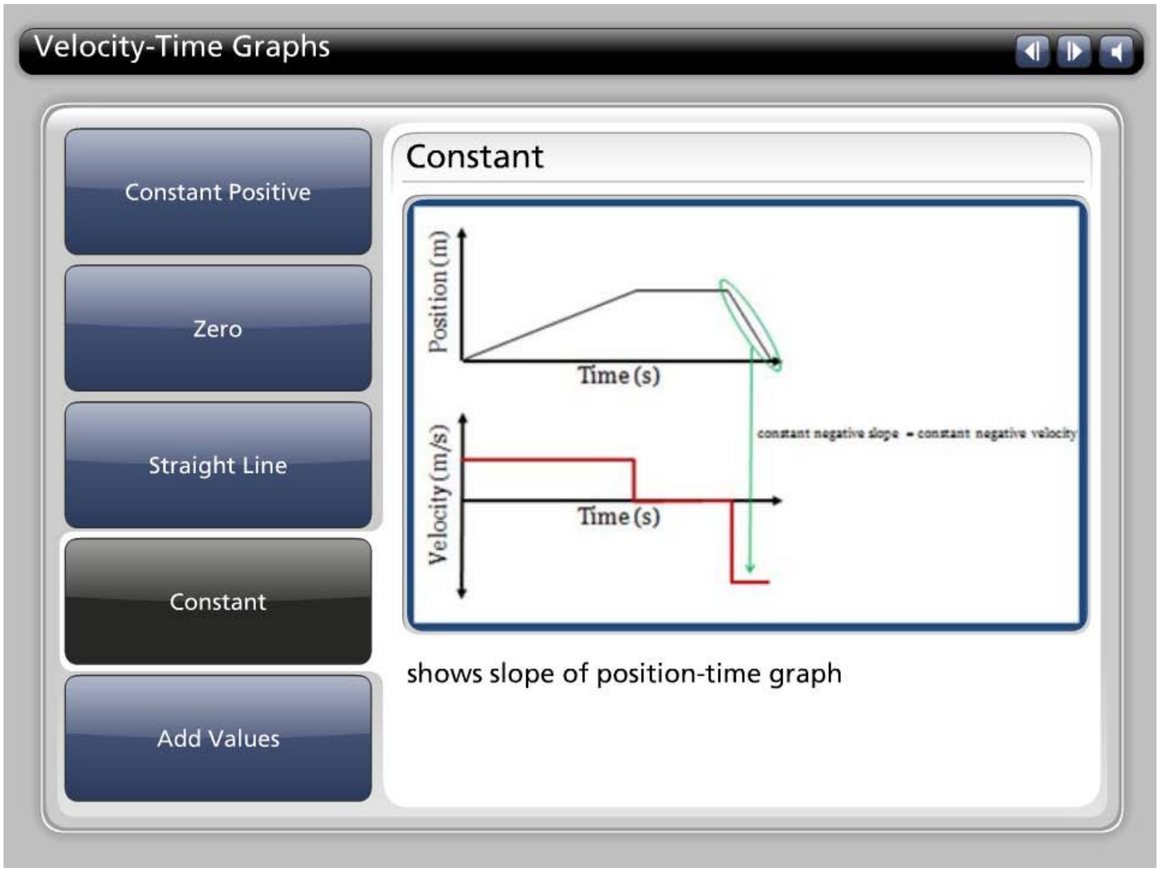
The first section of the position-time graph has a constant positive slope. The position increases at a constant rate as time increases indicating a constant velocity that is greater than zero. The velocity-time graph for this section would show a constant positive value.



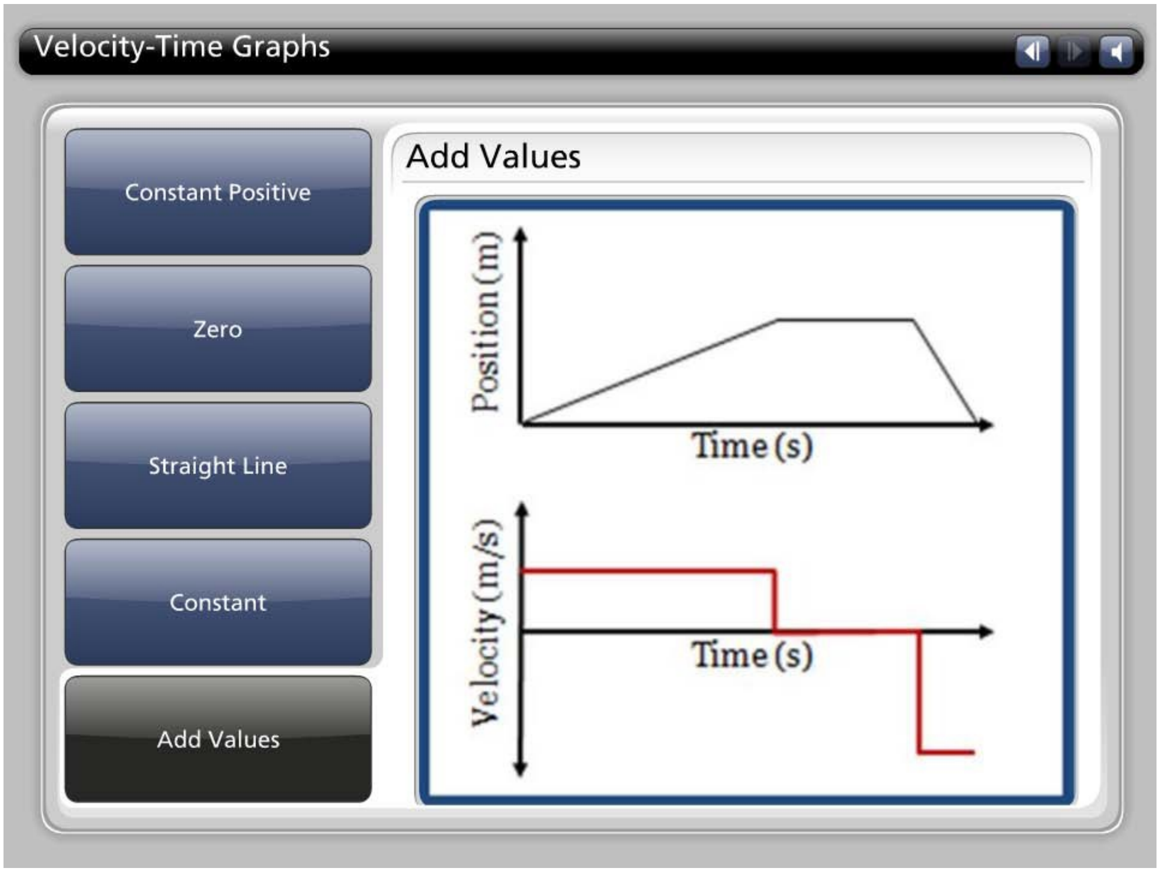
The next section is a flat line, with zero slope. The position remains constant as time passes, so the velocity in this section has a value of zero.



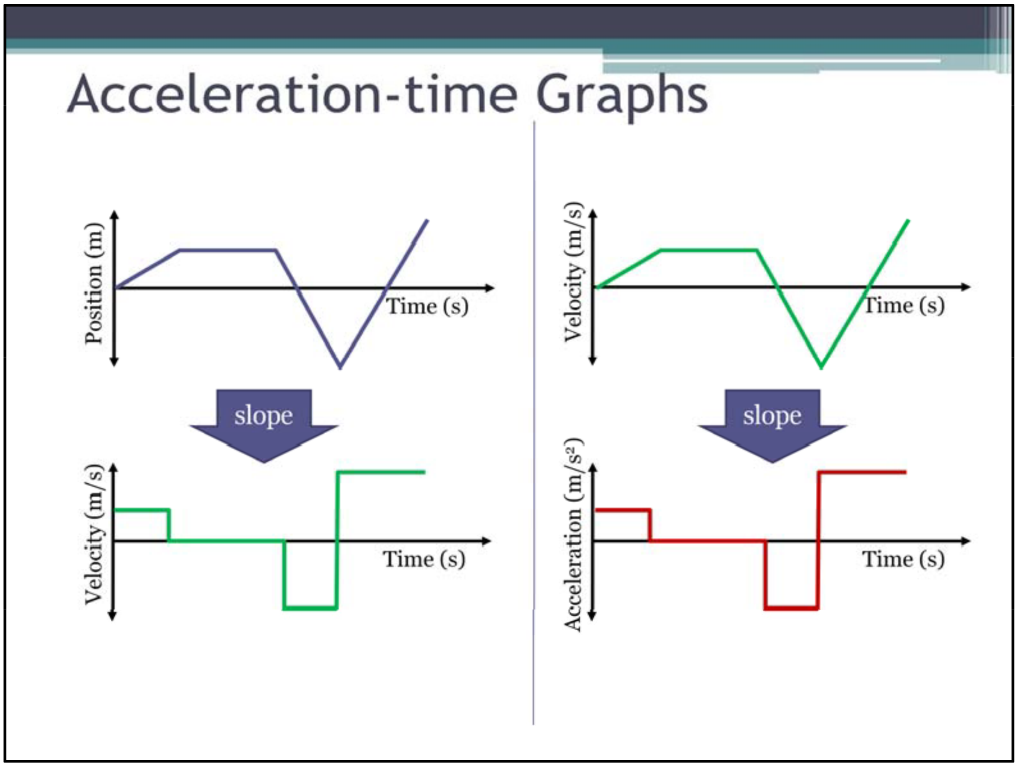
You'll notice that the two line segments were connected with a vertical line. In real life, the velocity can't change to zero instantaneously, but in this example, for simplicity, we'll simplify the situation and use a straight line.



In our final segment, the position is changing in a negative direction rather quickly. The slope of the line is constant and negative, so the velocity is constant and negative. We therefore draw the velocity as constant and negative. Notice that this portion of the velocity-time graph is further away from zero than our first portion because the slope of this segment of the position-time graph is steeper than the first one.

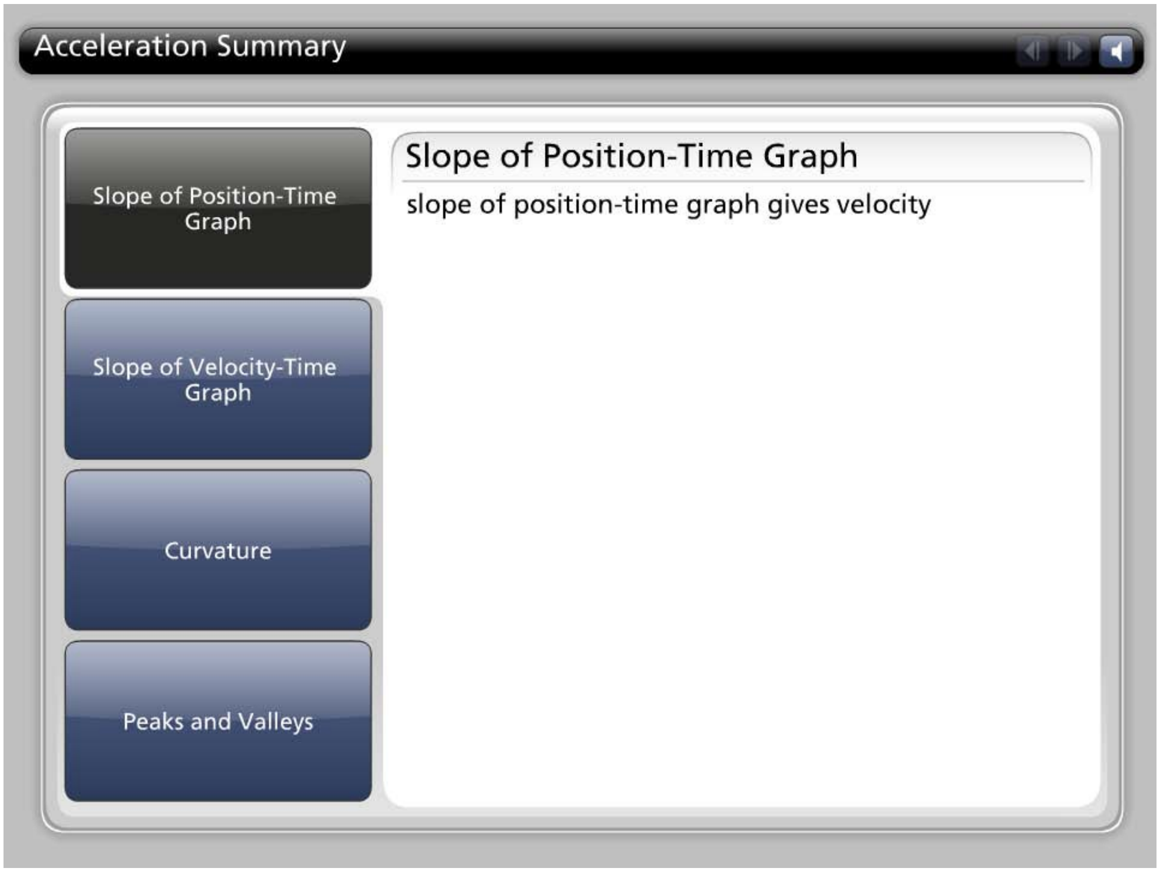


If we were to add actual values to our graphs, the value for velocity would be the slope of that section of the position-time graph.

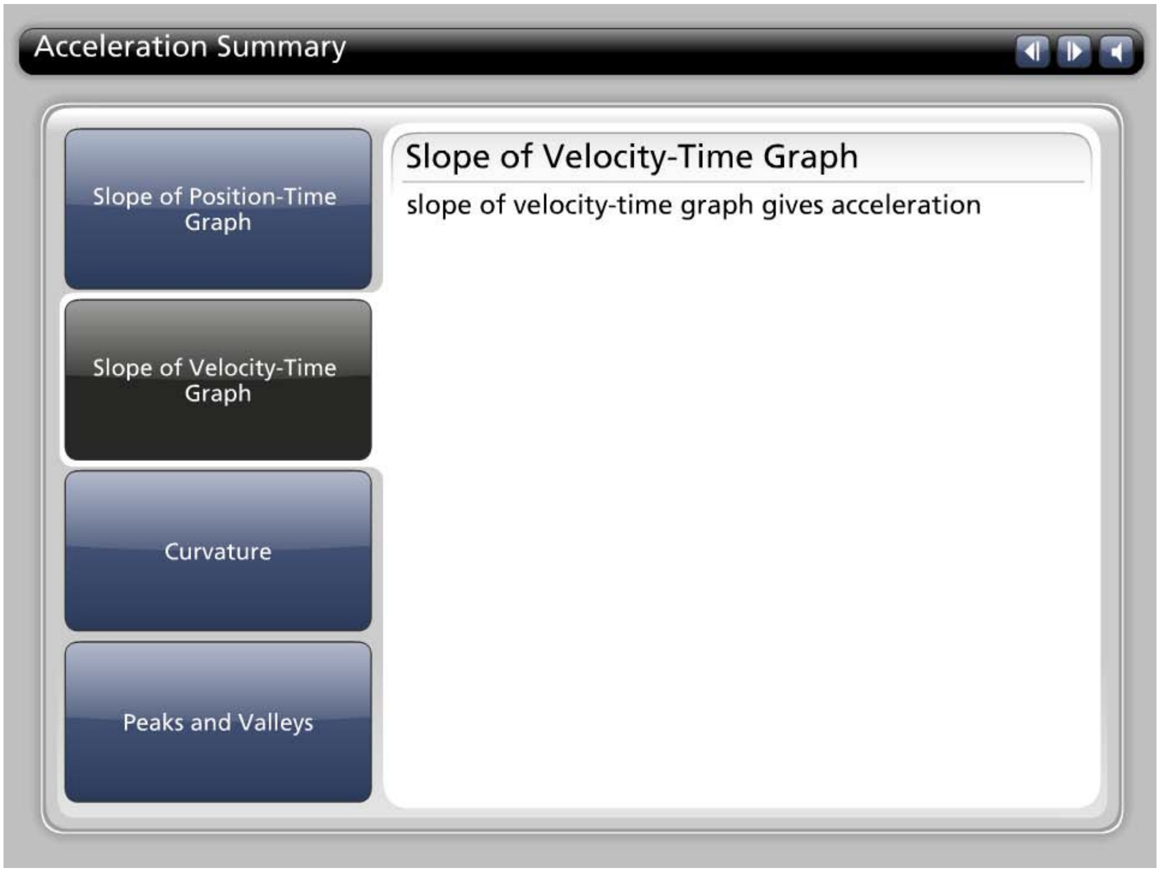


What does acceleration look like on these graphs?

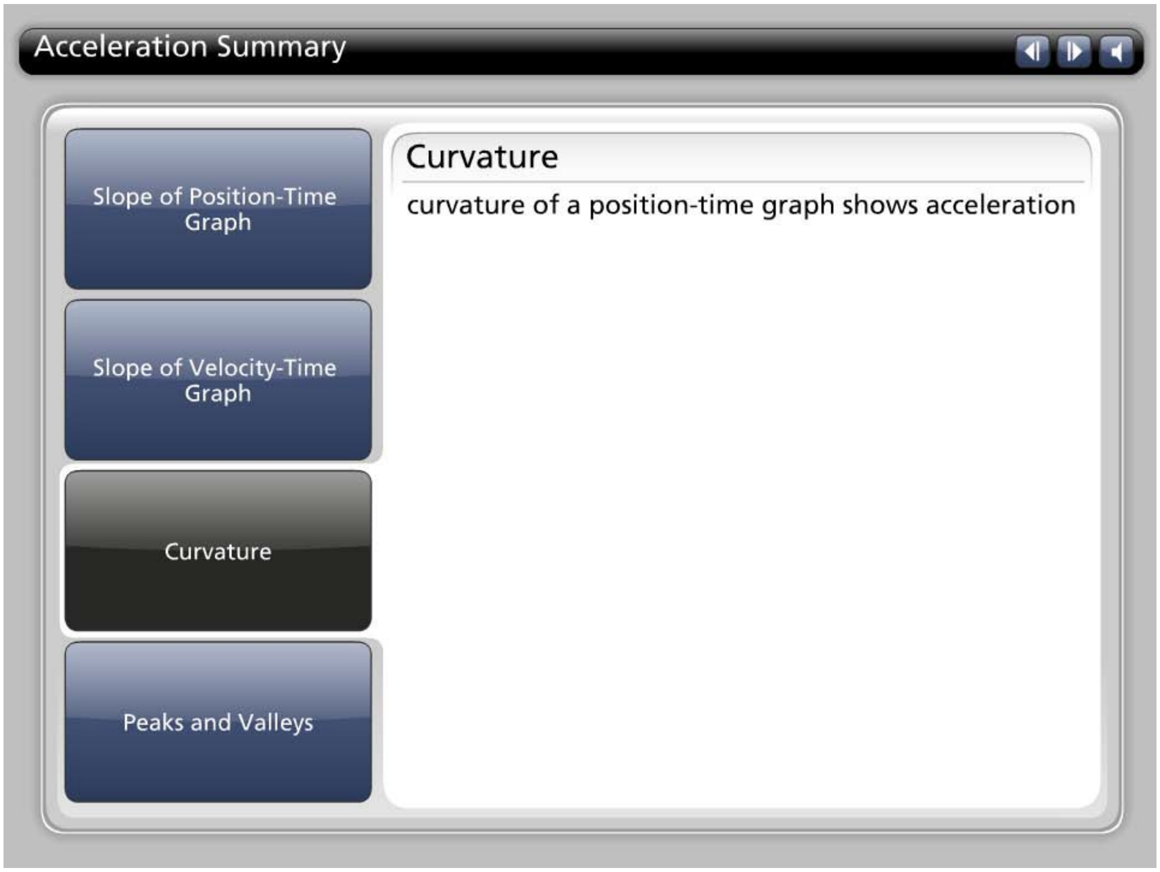
Remember that just like velocity is change in position over time, acceleration is change in velocity over time. The slope of a position-time graph gave us velocity, so the slope of a velocity-time graph must give us acceleration.



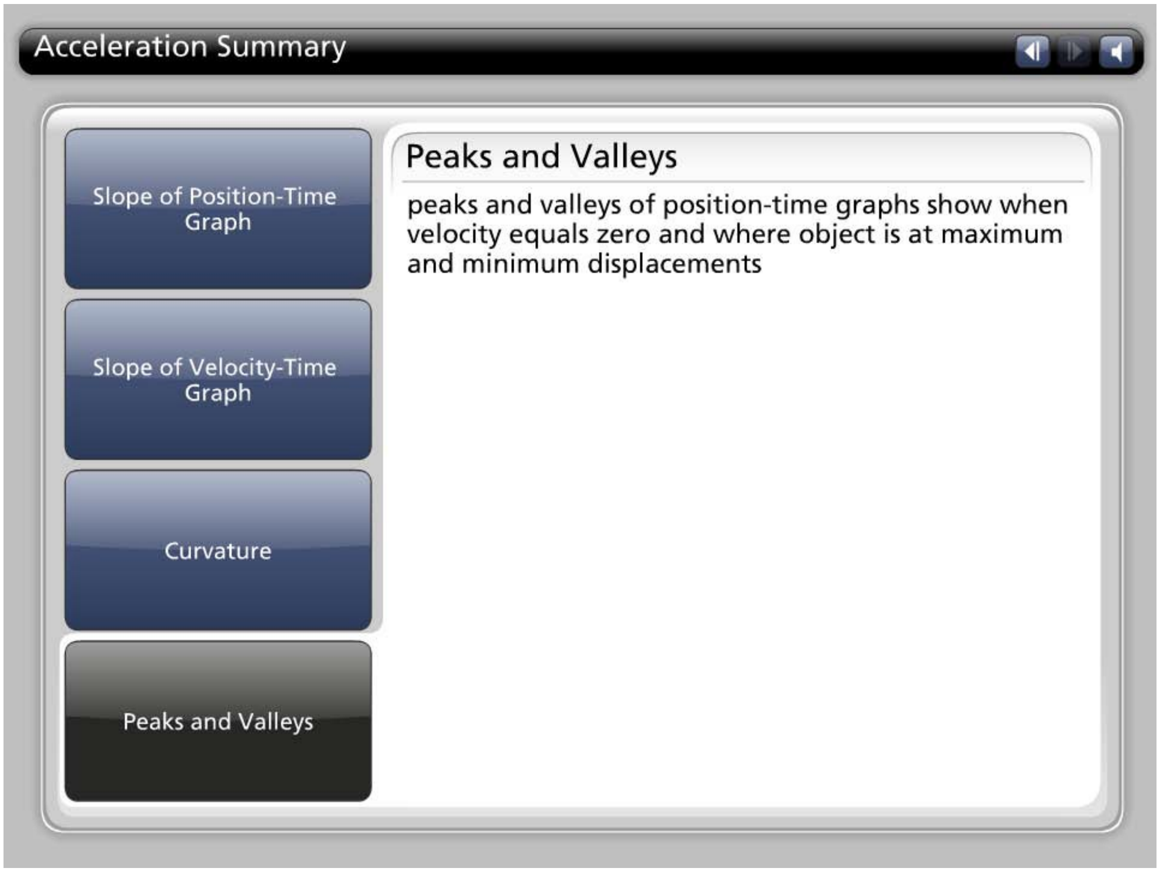
The slope of a position-time graph indicates the velocity of the object.



The slope of the velocity-time graph indicates the acceleration of the object.



The curvature of the position-time graph indicates the acceleration of the object, with positive, “smile” curvature indicating positive acceleration and negative, “frown” curvature indicating negative acceleration.



The peaks and valleys of a position-time graph indicate where the velocity momentarily passes through zero and the object is at rest. This is also where the object reaches local maximum and minimum displacements.