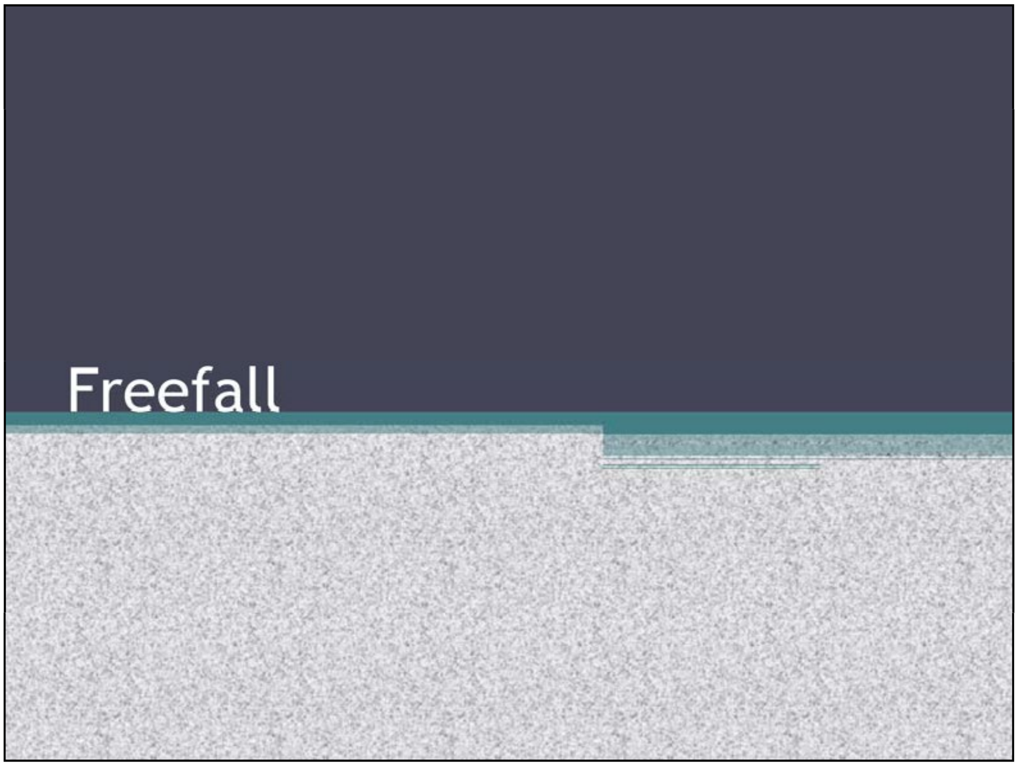


Freefall

In this lesson we will examine freefall.

We want to know if freefall is an example of constant acceleration to see if we can apply the kinematics equations to this new situation.

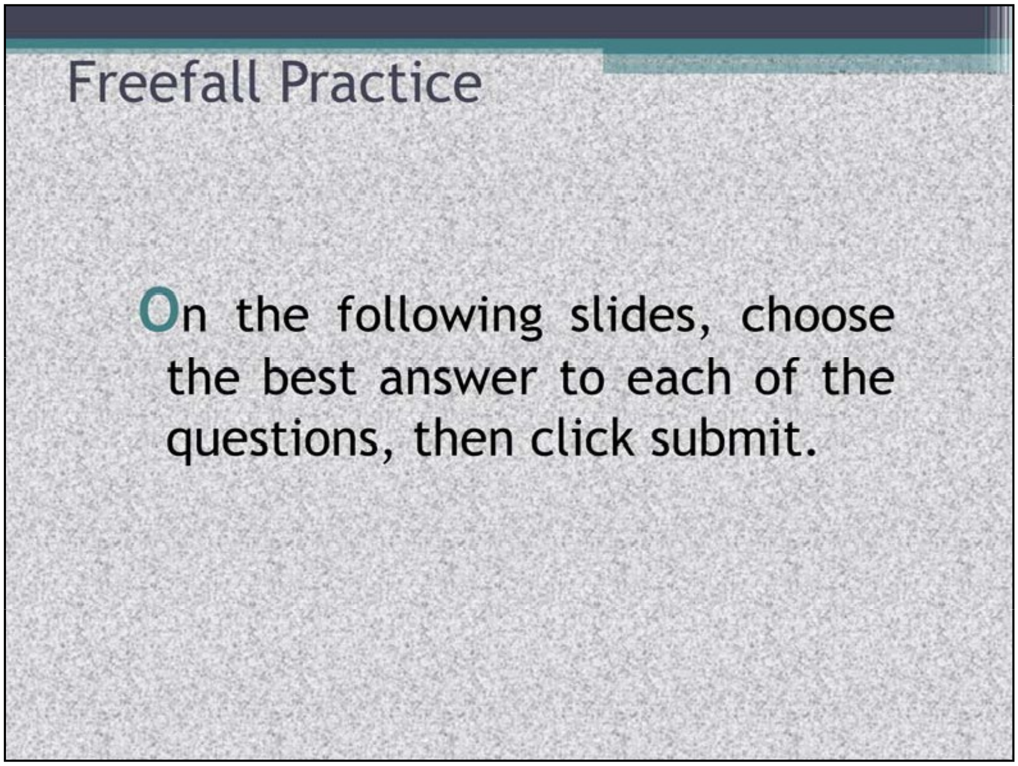
In this topic we will study the motion of a gymnast on a trampoline to learn freefall concepts.

In this topic, we will highlight Olympic Gymnastics trampoline.

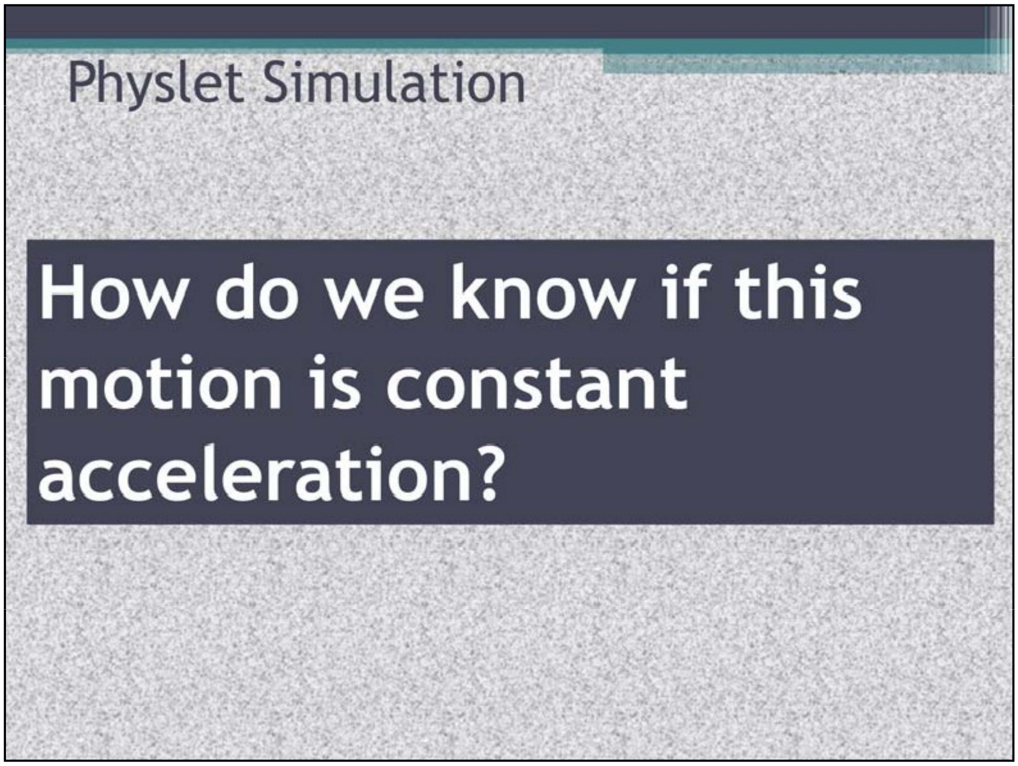
Did you know that trampoline was made part of Olympic Gymnastics in 2004? Gymnasts must perform a series of skills, one skill on every bounce off of the trampoline. Gymnasts must jump high enough to have time to complete difficult skills such as flips and twists.

This video from usa-gymnatics.org will open in a new window to show you some trampoline routines.

You can learn more about trampoline and the U.S. Olympic team at their website. Now, see how you do answering a few questions about the gymnast's motion.



On the following slides, choose the best answer to each of the questions, then click submit.



As you use the sport of trampoline to learn about freefall, you will use this simulation of a falling ball as a model of the falling gymnast.

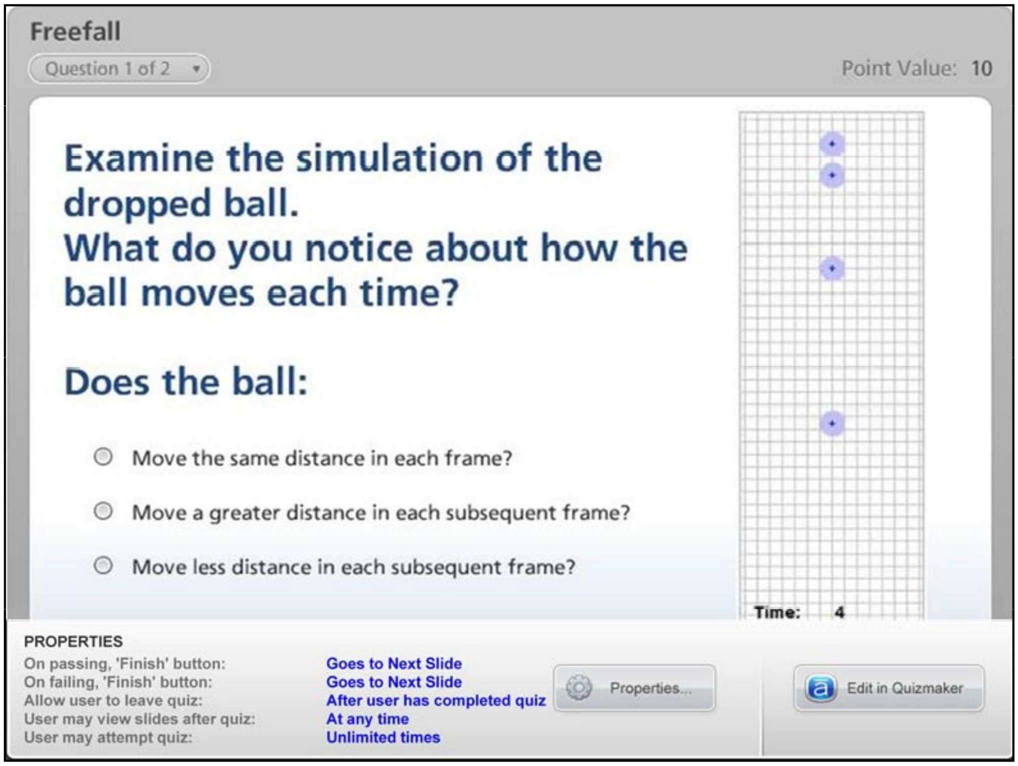
Then, examine the velocity vectors in each frame of the physlet window you already opened. You should notice the velocity vector starts as a dot (zero) and then gradually increases in the negative direction, becoming longer and longer. Use the step button on the physlet controls to examine the velocity of the ball in each frame.

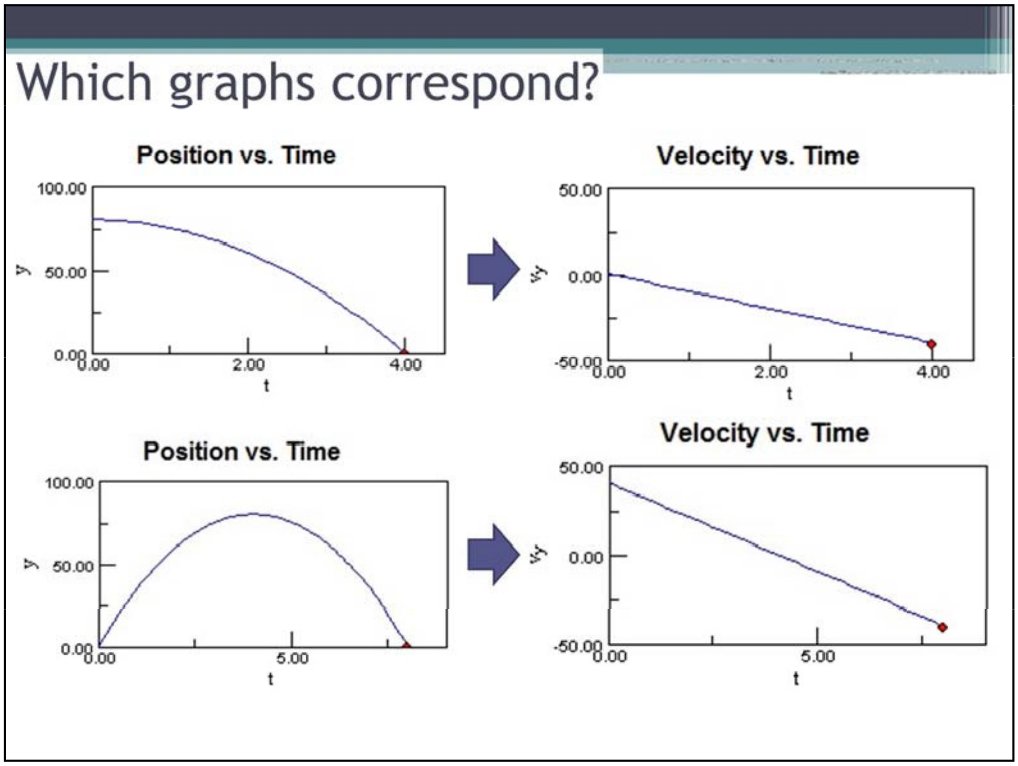
How is this motion similar to what we have studied previously in this topic?

We have seen many examples of motion with constant acceleration in previous topics within this module. We want to know if freefall is also an example of constant acceleration.

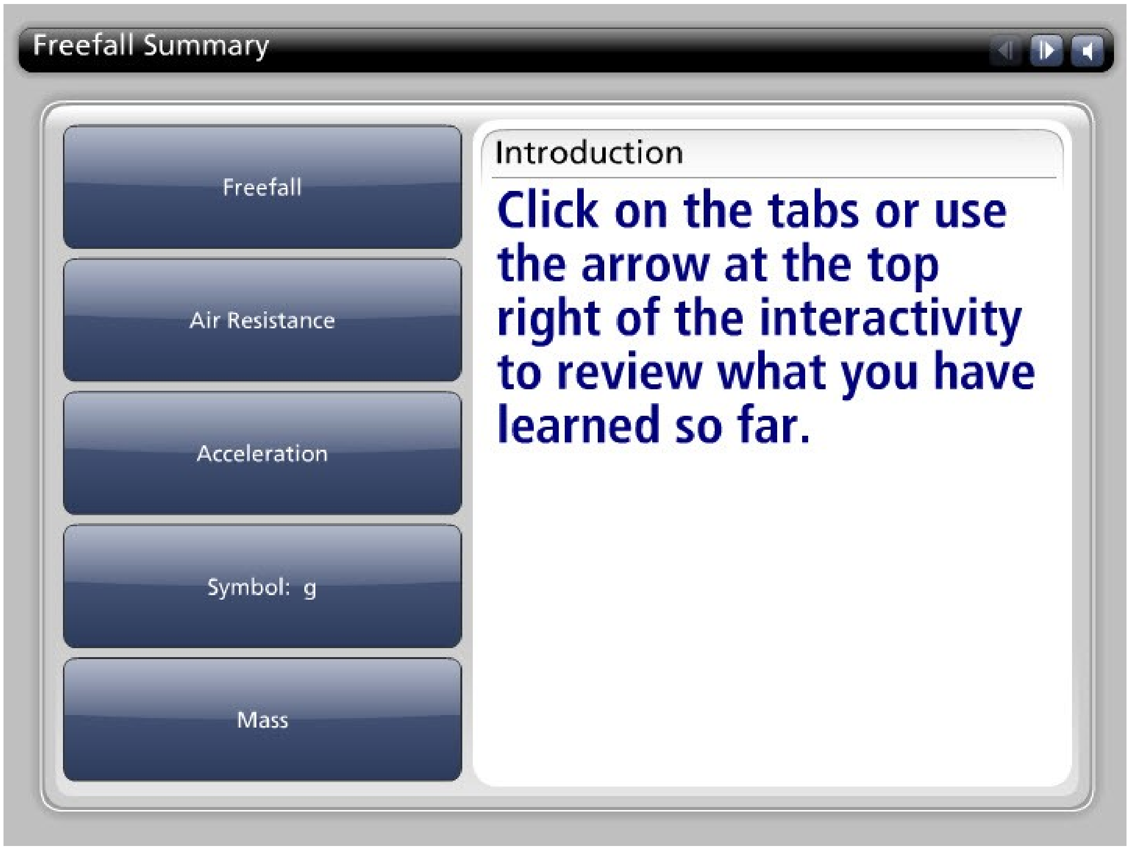
How can we know if constant acceleration models apply here? We will examine the position and velocity graphs to find out if this motion fits the constant acceleration model.

Now, you will answer some questions about the physlet simulation.

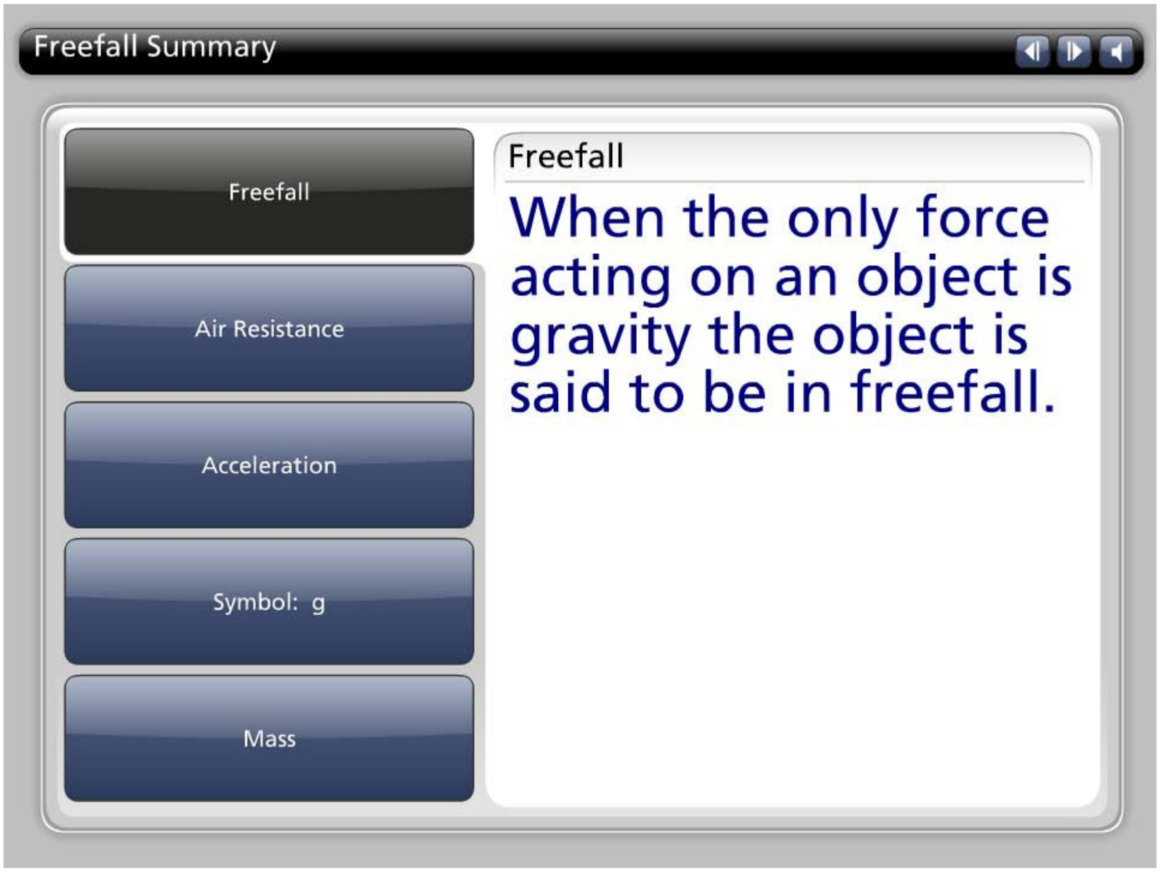

Freefall
Question 1 of 2
Point Value: 10
Examine the simulation of the dropped ball.
What do you notice about how the ball moves each time?
Does the ball:
Move the same distance in each frame?
Move a greater distance in each subsequent frame?
Move less distance in each subsequent frame?
Time: 4
PROPERTIES
On passing, 'Finish' button: Goes to Next Slide
On failing, 'Finish' button: Goes to Next Slide
Allow user to leave quiz: After user has completed quiz
User may view slides after quiz: At any time
User may attempt quiz: Unlimited times
Properties...
Edit in Quizmaker



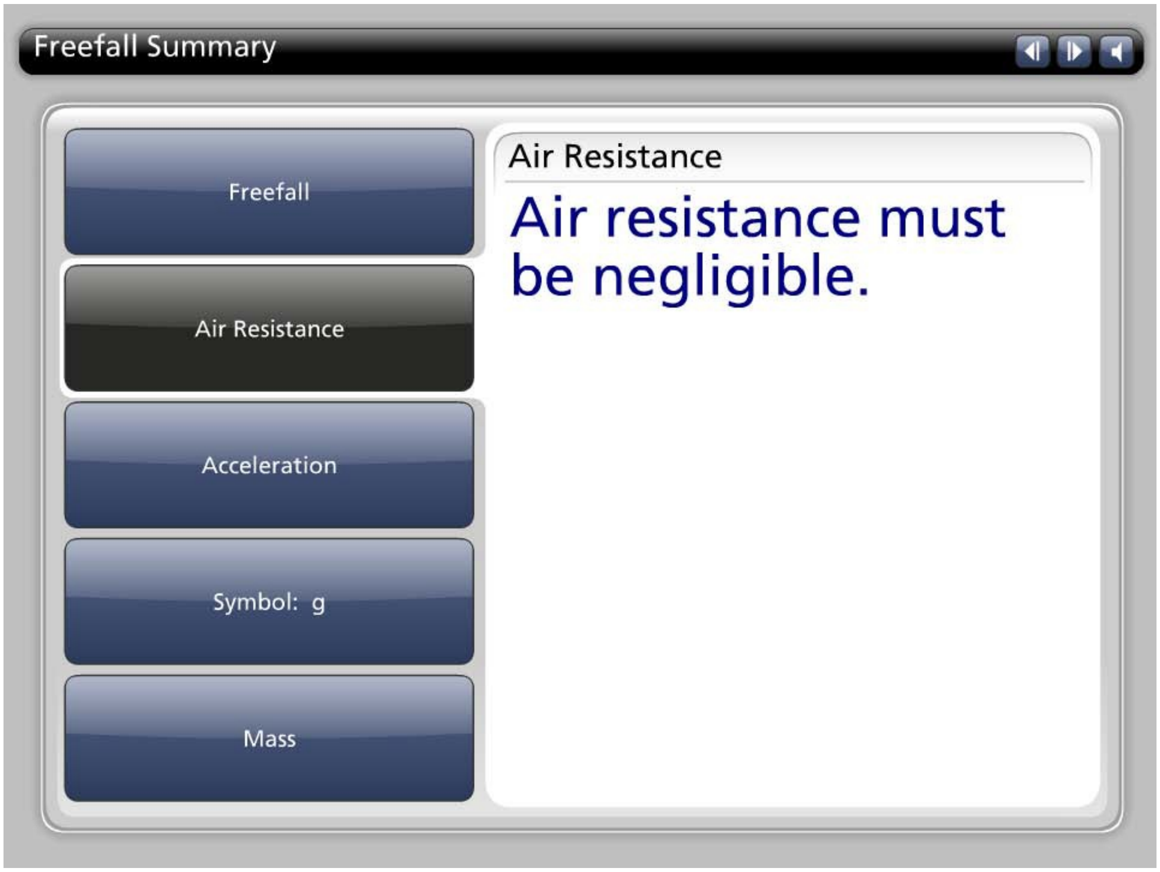
For these graphs, you should look at the slope of the position-time graph to figure out the velocity at that time. The first position-time graph starts out with zero slope, so initial velocity is zero. The second position-time graph starts out with a positive slope, so initial velocity is positive.



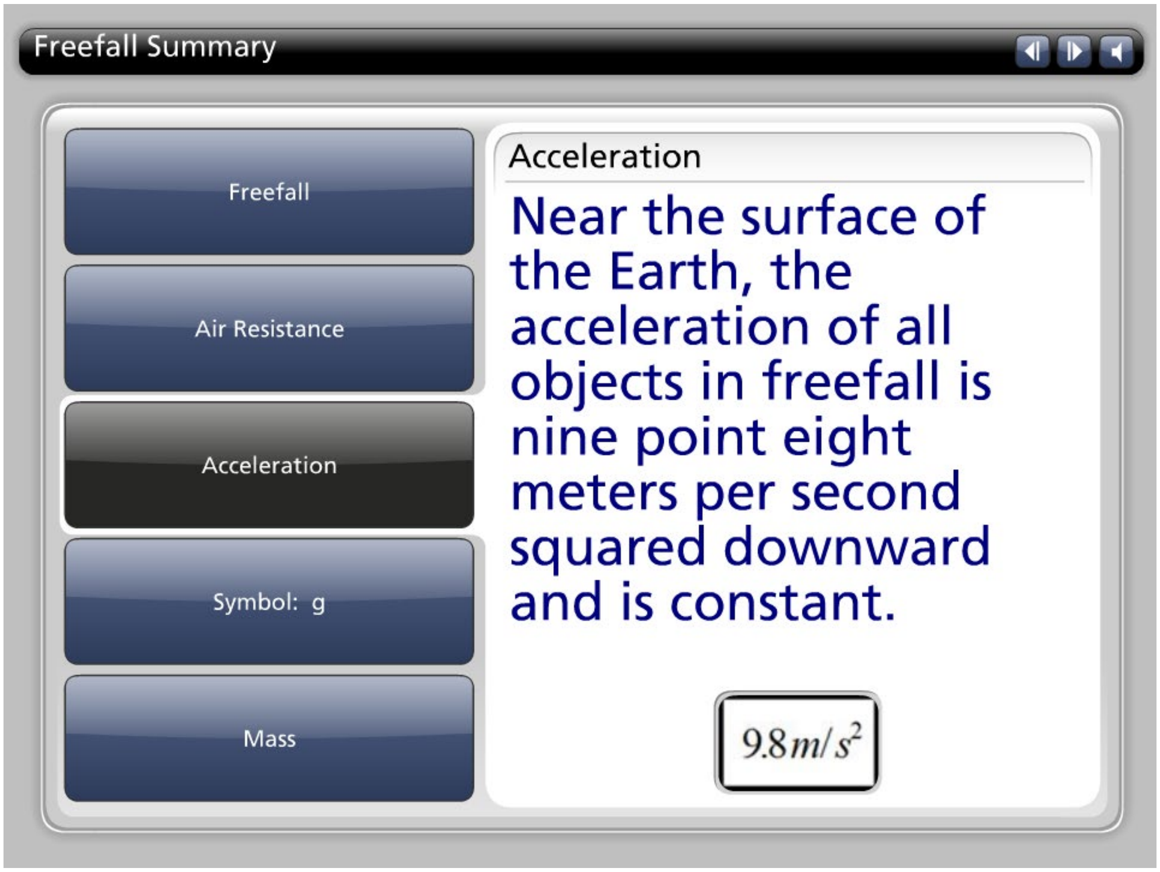
Let's summarize what you have learned so far in this lesson.



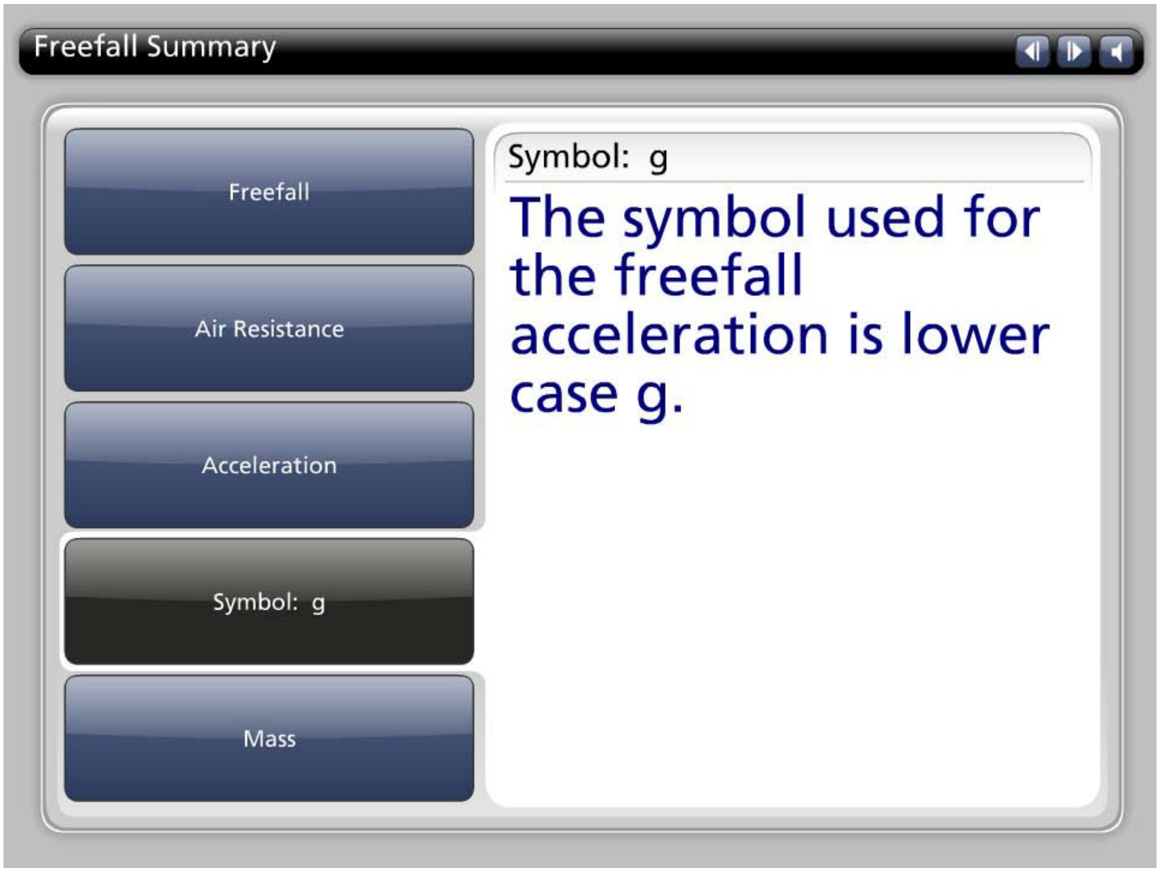
When the only force acting on an object is gravity the object is said to be in freefall.



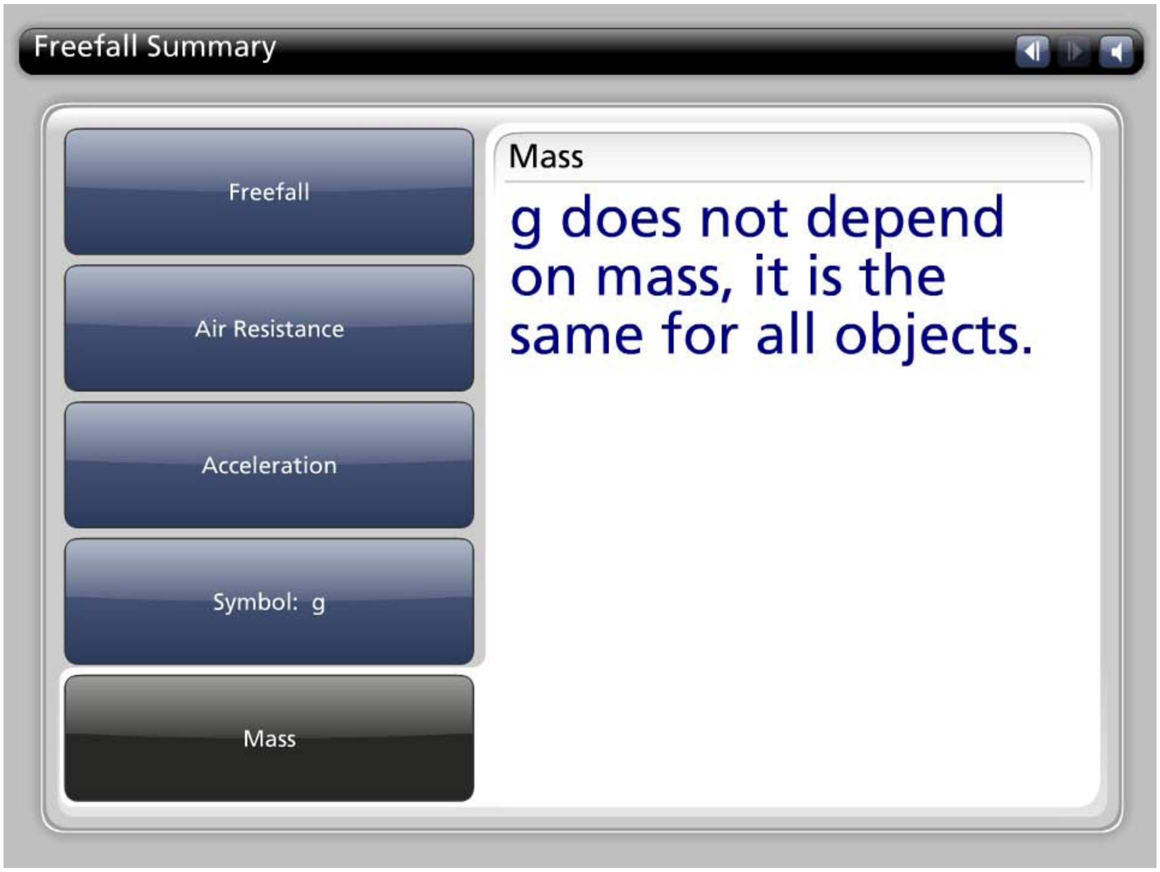
Air resistance must be negligible.



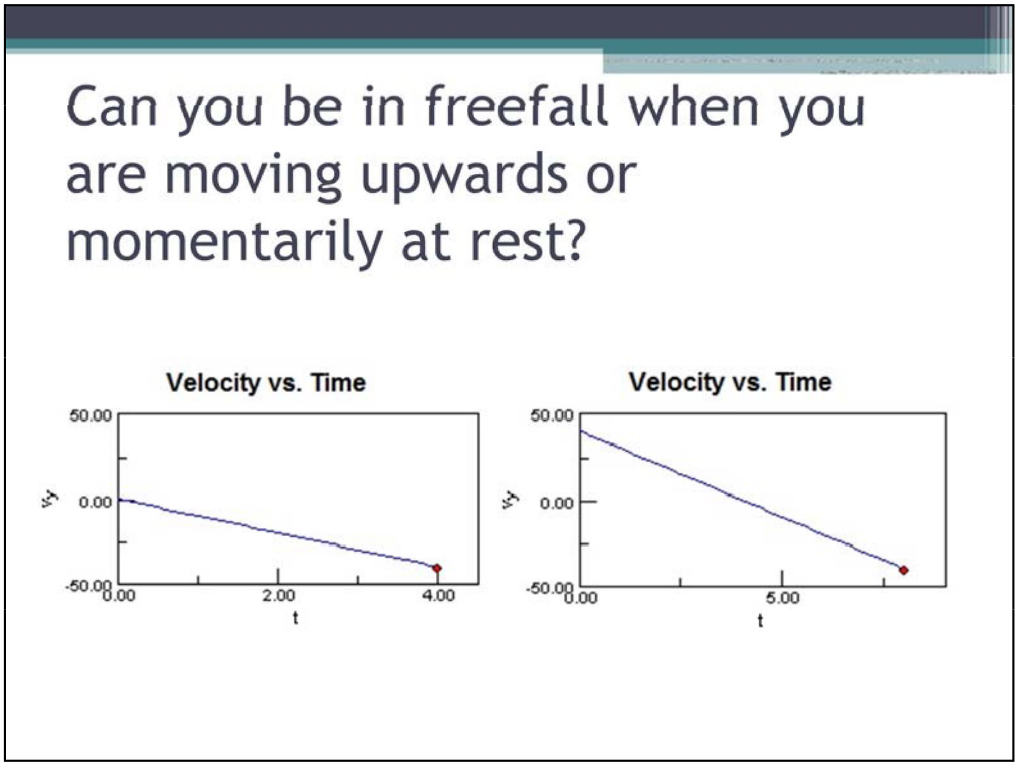
Near the surface of the Earth, the acceleration of all objects in freefall is nine point eight meters per second squared downward and is constant.



The symbol used for the freefall acceleration is lower case g.



g does not depend on mass, it is the same for all objects.



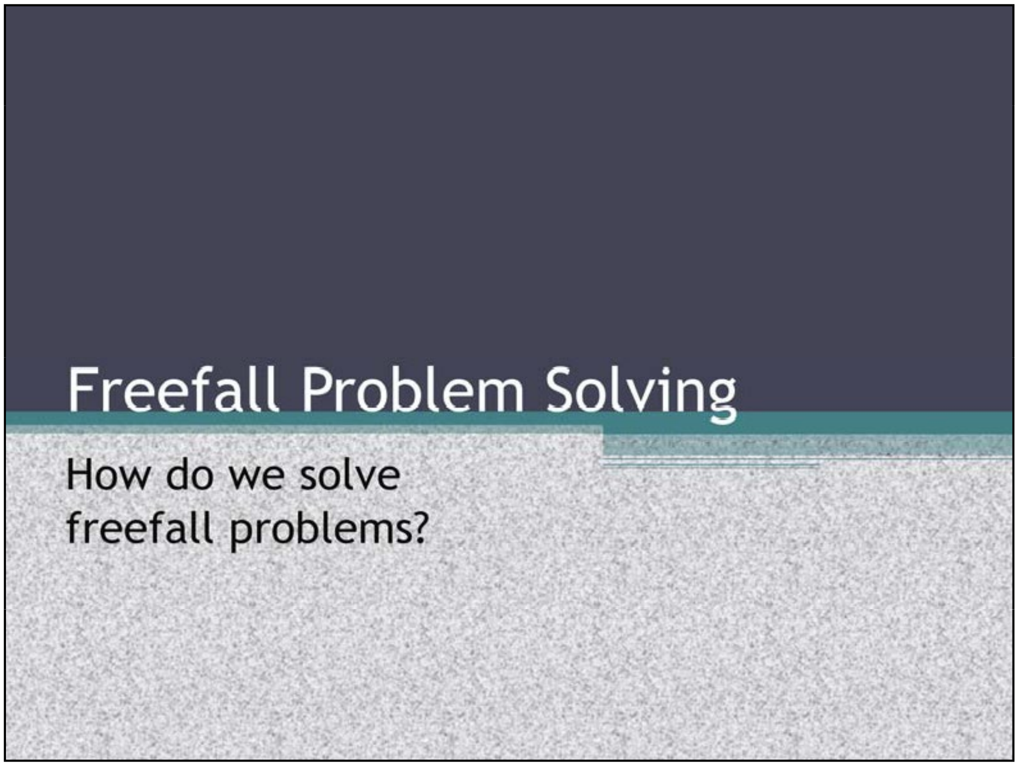
Can you be in freefall when you are moving upwards or momentarily at rest?

In everyday language, freefall is thought of as when something is falling downward. But in physics language, the gymnast is in freefall during the entire time he is not in contact with the trampoline. On the way up, at the top, and on the way down, the gymnast is still in freefall. How can we verify this from our observations?

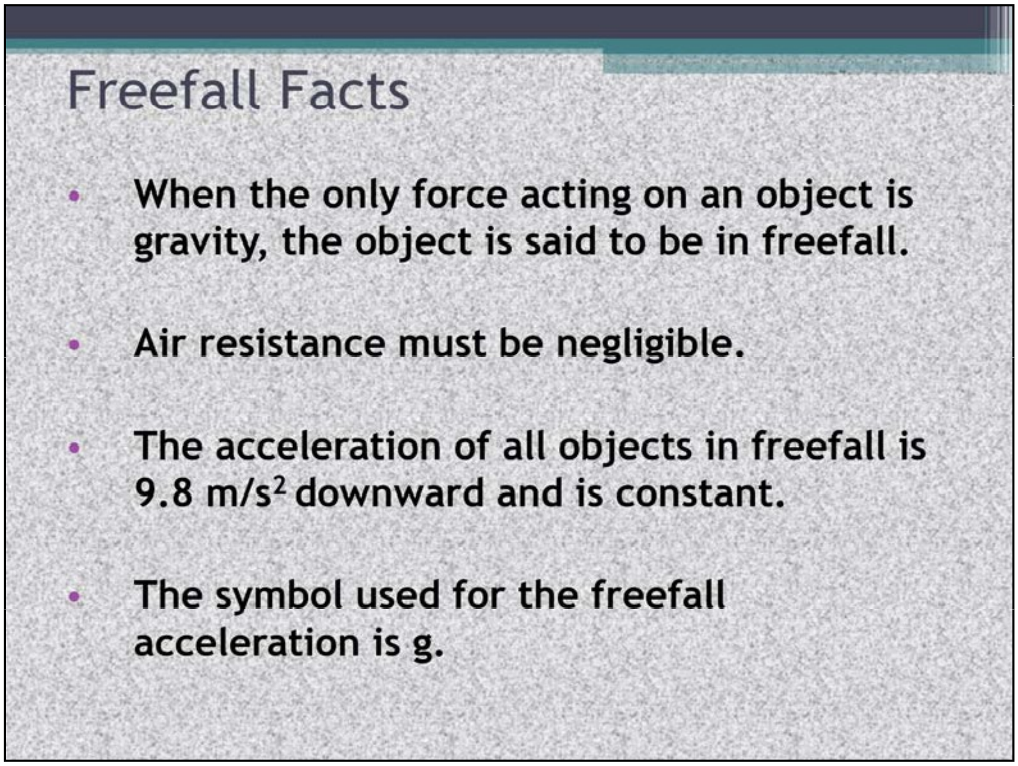
Go back to the animations for ball dropped from rest and ball projected upward from the ground in the physlet window you have open.

Compare the graphs for the two motions. Look at the velocity-time graph of the two motions. Both graphs are lines with the same constant, negative slope of negative nine point eight meters per second squared.

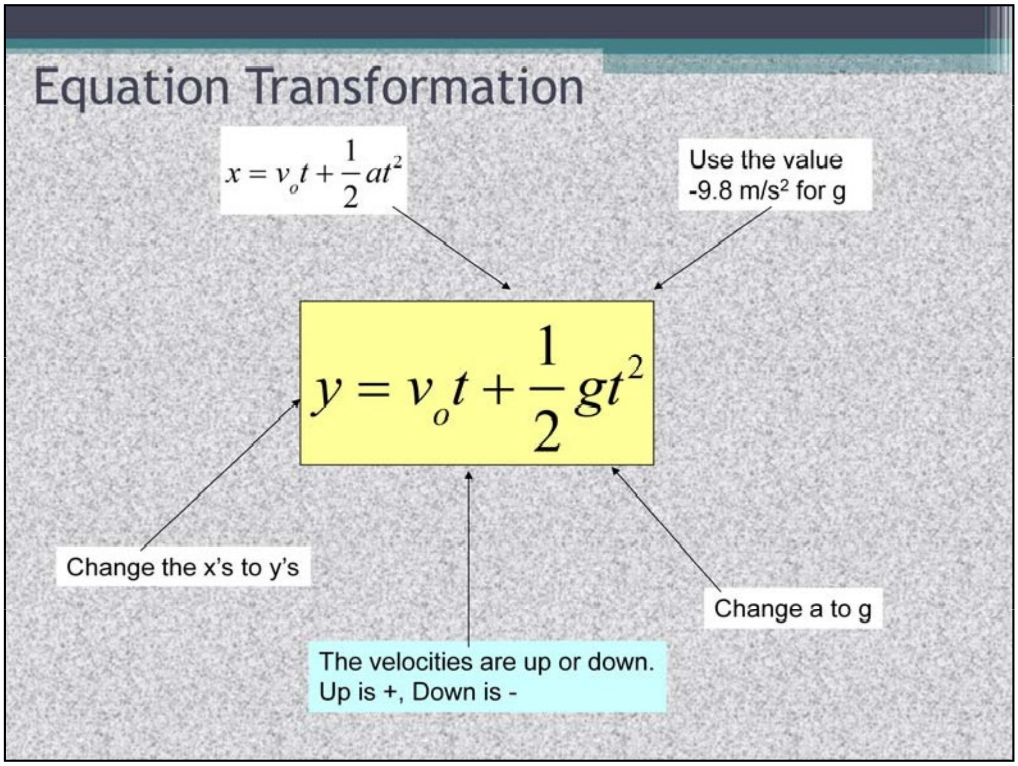
What property of the velocity-time graph tells us that the motion is constant acceleration the entire time? If you said the slope of the graph, then you are correct! The velocity-time graph of the balls motion has a constant slope, which tells us the acceleration is constant during the jump. So, even when objects are moving upward or momentarily at rest at the top of the jump, the acceleration is still nine point eight meters per second squared downward. The ball is in freefall the entire time it is in the air, just like our gymnast is in freefall when he is not touching the trampoline. Whether moving upwards and slowing down to a momentary stop, or moving downwards while speeding up, the acceleration is constant and negative.



Now let's do some free fall problem solving! In this lesson we will learn how to solve problems involving freefall.



Previously, we observed a few facts about freefall. First, the definition of freefall is when the only force acting on an object is gravity. If air resistance is present, it is not freefall. The acceleration due to gravity on Earth is nine point eight meters per second squared downward. This is also called the freefall acceleration and has the symbol lower case g.



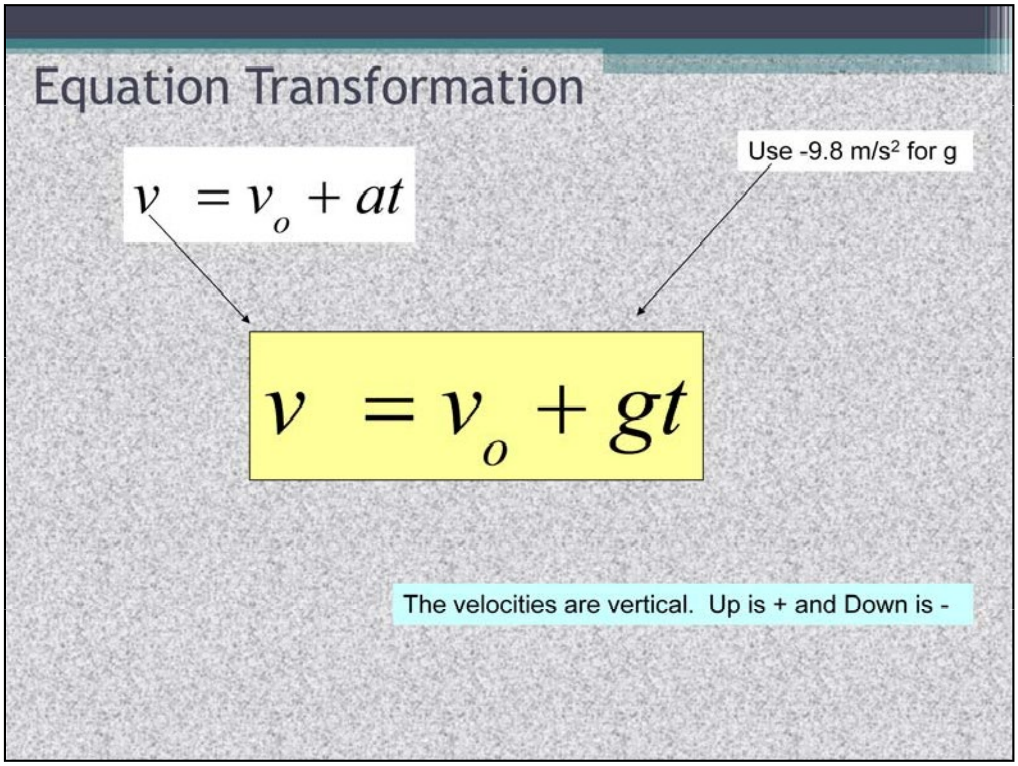
We will be using the kinematics equations to solve freefall problems. We need to make a few adjustments to the equations.

Here we are examining kinematics equation number 2.

Gravity only affects vertical velocities, so we change all of the accelerations, a, to acceleration due to gravity, g.

Later we will insert the value of g.

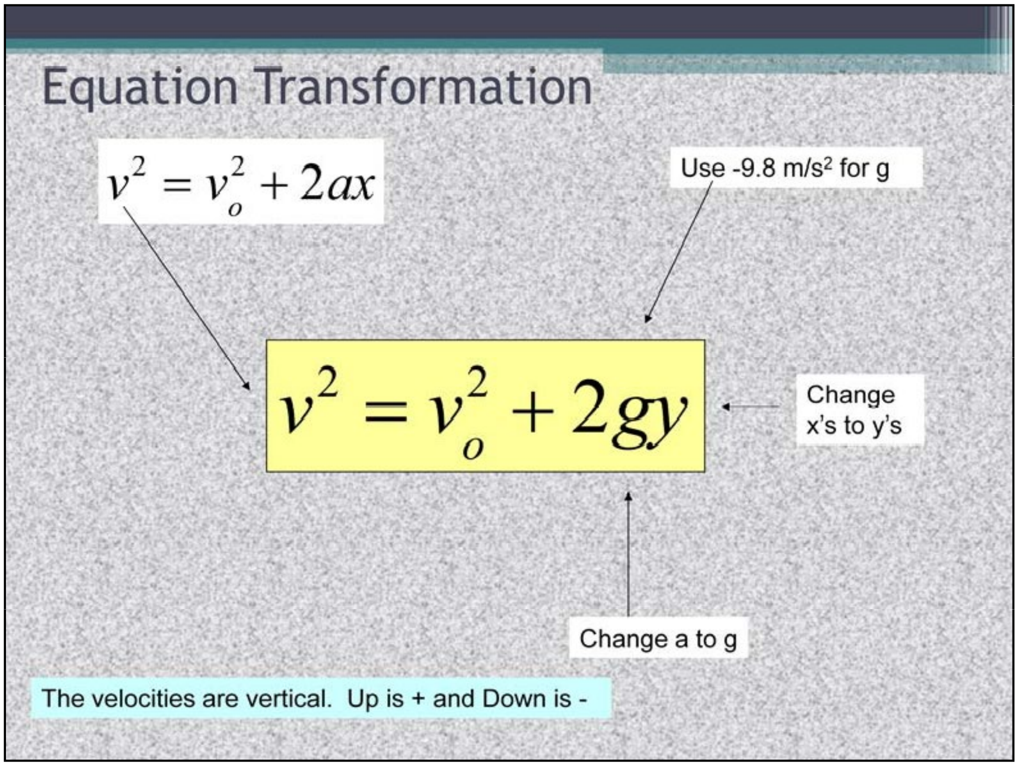
The displacement will be in the vertical direction, so we use the letter y instead of x.



We make similar changes to the first kinematics equation.

Gravity only affects vertical velocities, so we change all of the accelerations, a, to acceleration due to gravity, g.

Later we will insert the value of g

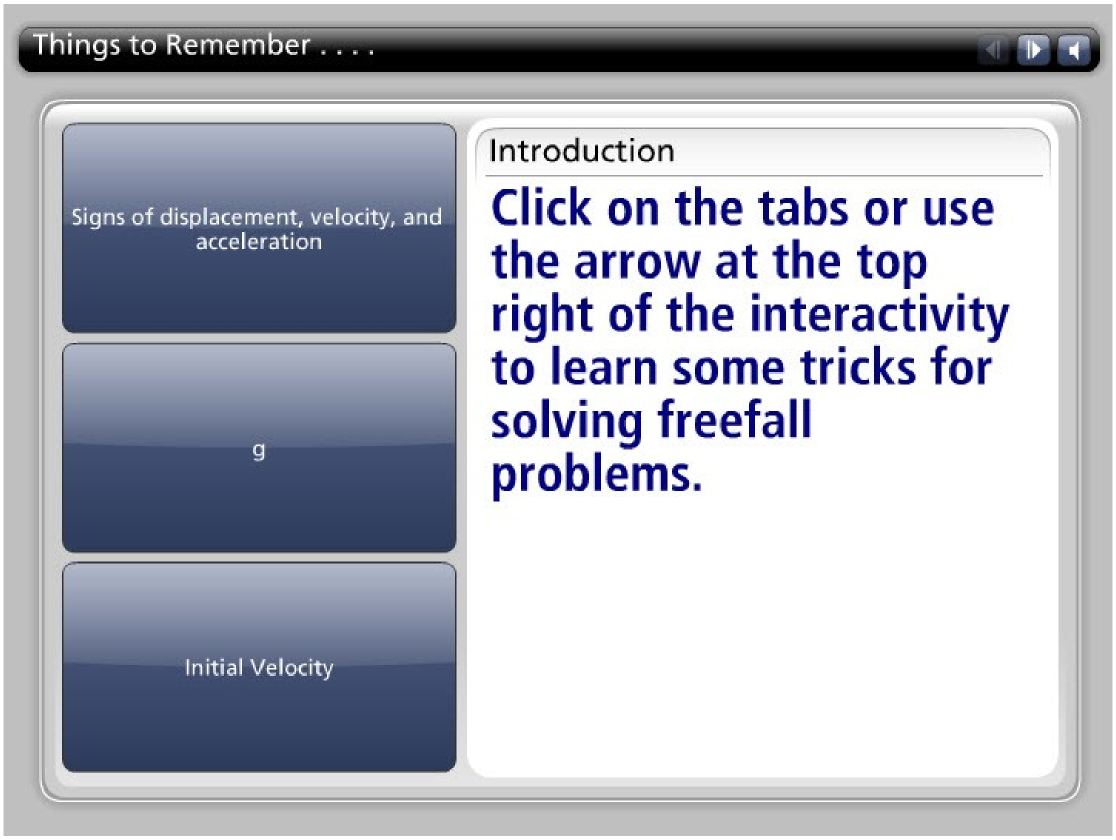


We make the same changes to the last kinematics equation.

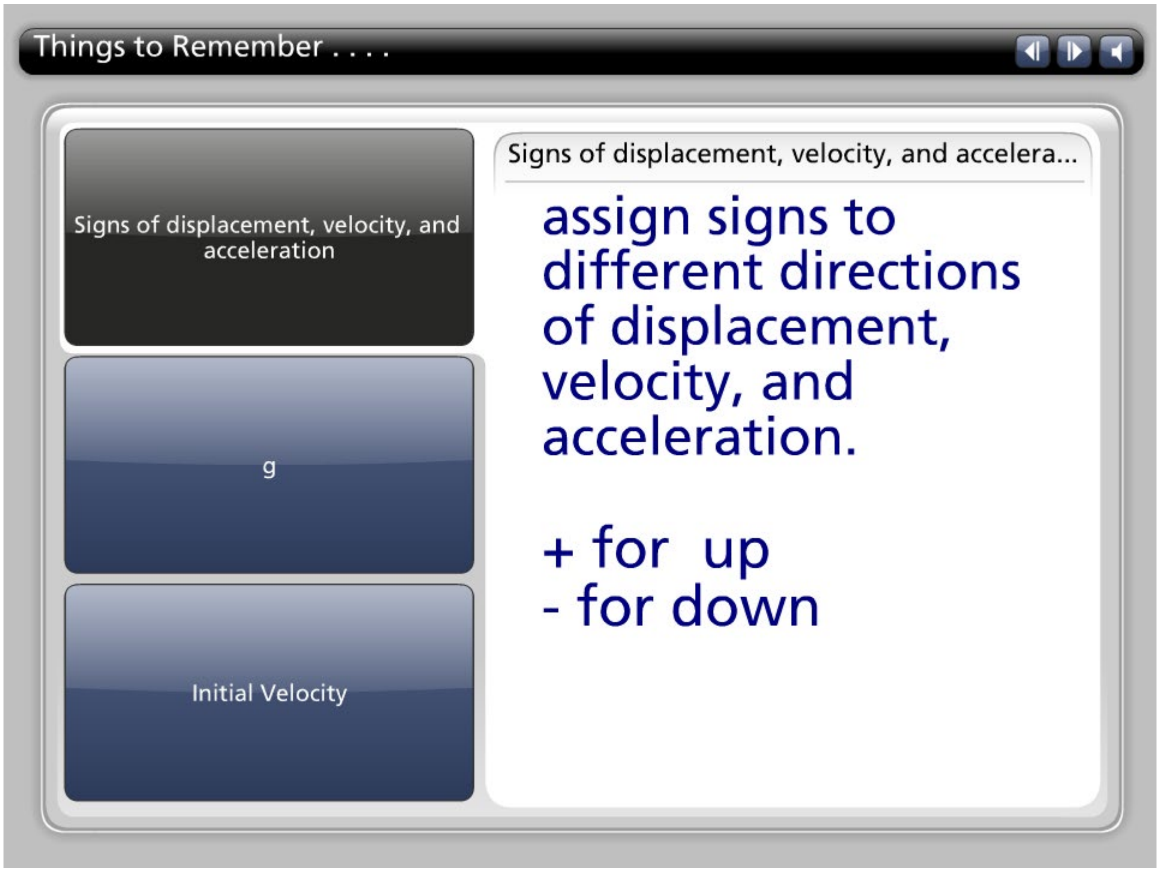
Gravity only affects vertical velocities, so we change all of the accelerations, a, to acceleration due to gravity, g.

Later we will insert the value of g.

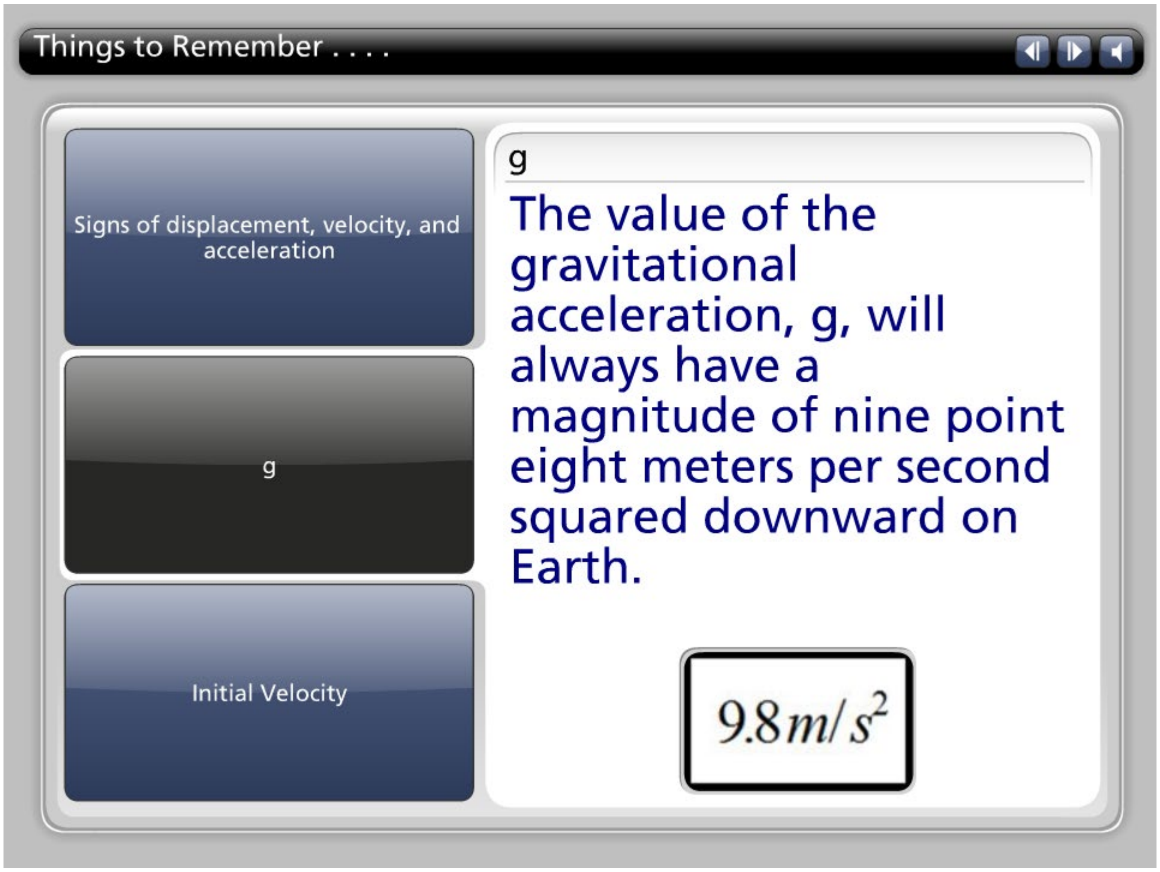
We change the x's to y's since the motion is in the vertical, or y , direction.



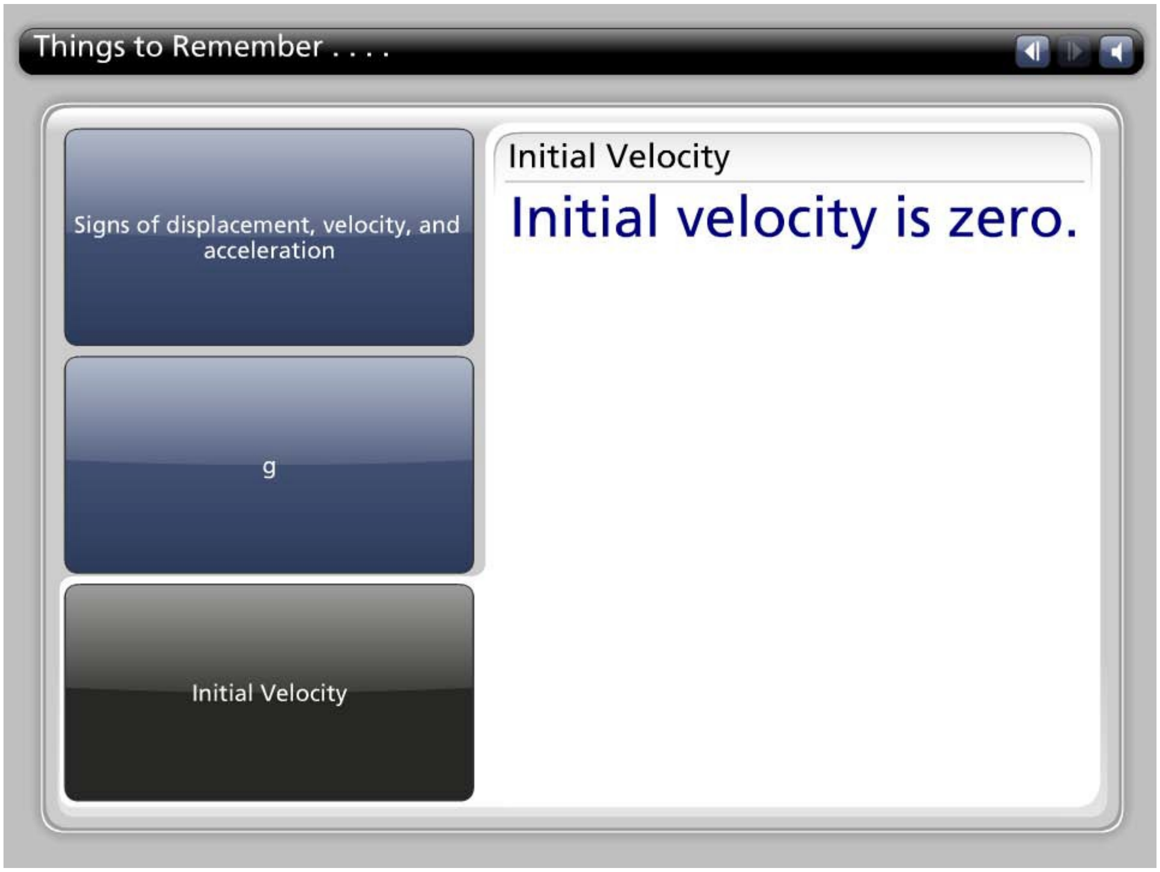
You need to remember some tricks for solving freefall problems.



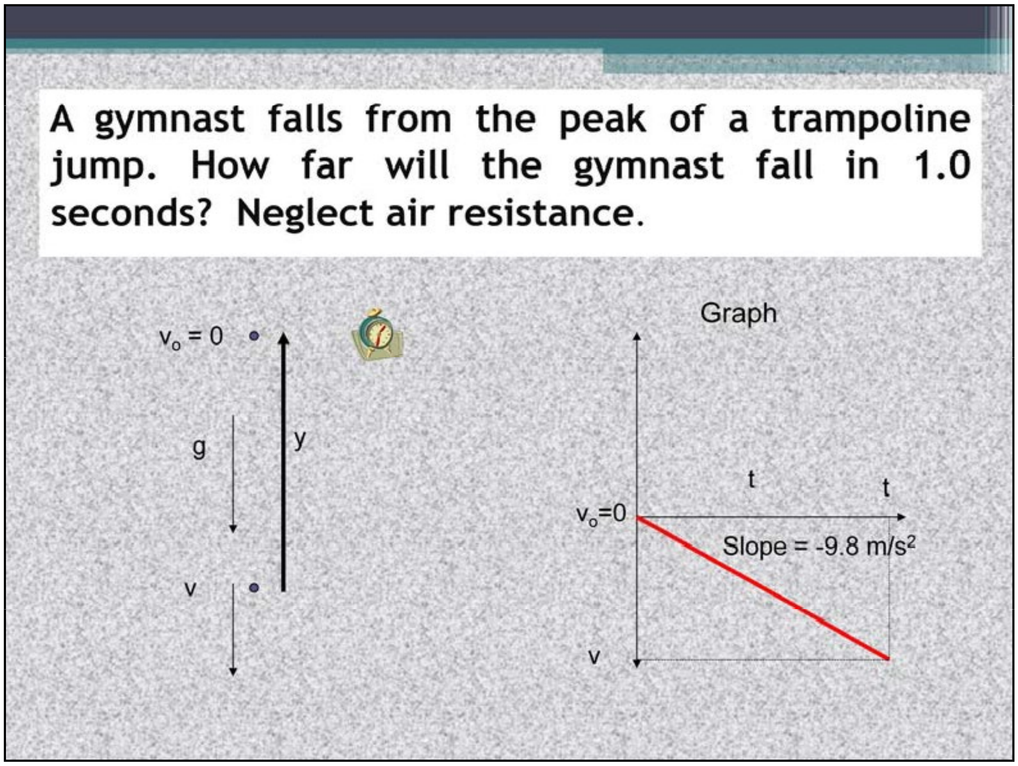
The signs of displacement, velocity and acceleration are important. You will use the convention that up is positive and down is negative.



The value of the gravitational acceleration, g, will always have a magnitude of nine point eight meters per second squared downward on Earth. In practice, you will label the downward direction as the negative direction. This makes the acceleration negative.



You also need to know that if something is dropped that means its initial velocity is zero only when the object starts from rest (dropped objects).



In this problem, a gymnast falls from the peak of a trampoline jump. We are asked to find how far the gymnast falls in one second.

It is good practice to draw diagrams when solving problems, so this will be our first step. Sometimes we can find the answer from the diagram without any equations.

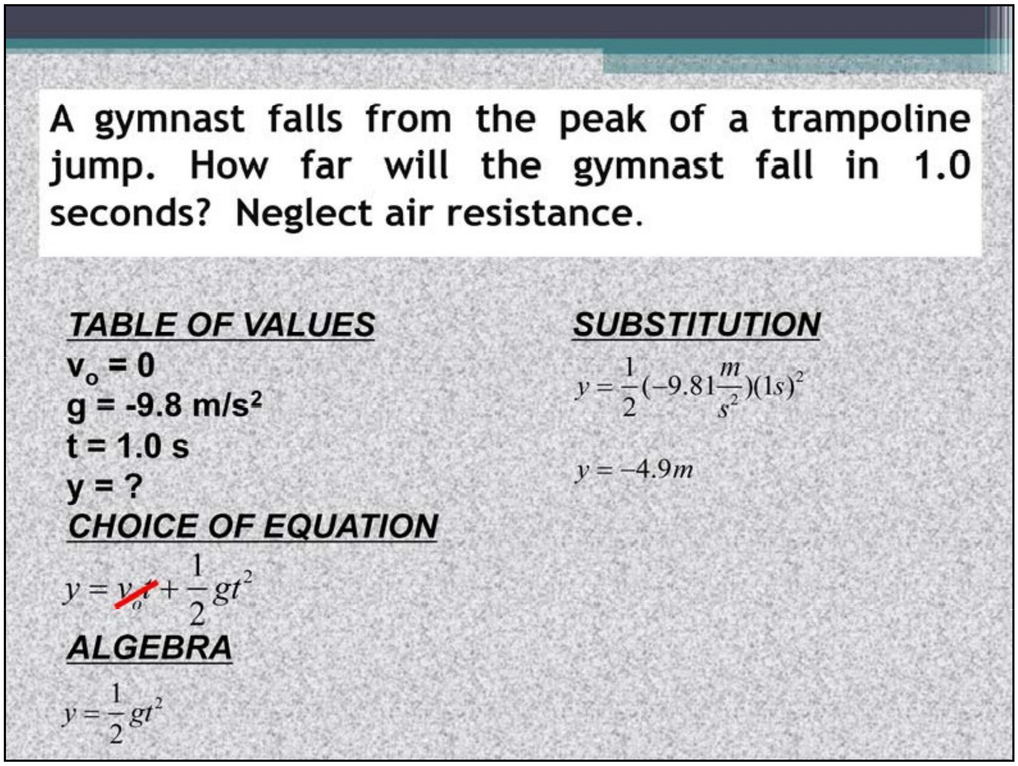
In this situation, we know the initial velocity is zero and the final velocity is unknown. Since air resistance is negligible, we can use the freefall acceleration, g.

We know the time of the fall, one second.

Here is a sketch of what the velocity-time graph would look like for this situation. Starting at zero, the velocity steadily becomes more negative.

The slope of the velocity-time graph is the acceleration due to gravity, negative nine point eight meters per second squared.

This information helps us to fill out a table of values for this problem.



The next four steps are: create a table of values, choose an equation, simplify the equation, and substitute values into the equation.

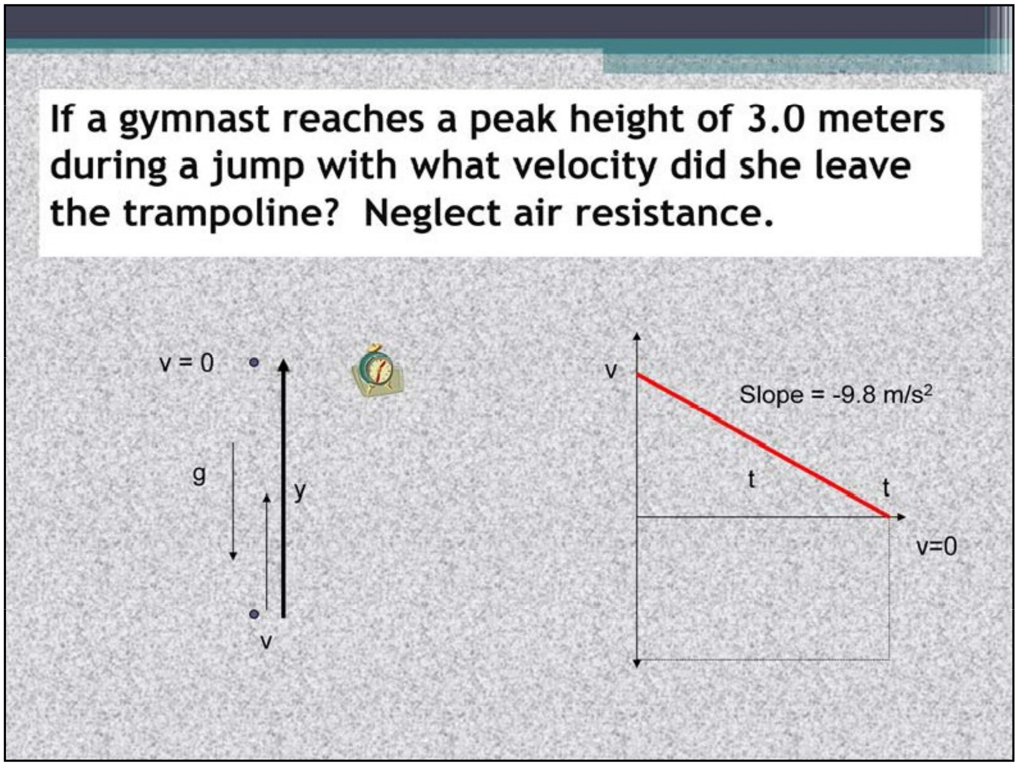
To solve this problem, first we will create a table of values. We need to identify the given information from the question. What do we know about the gymnast at the peak of the jump? We know that the initial velocity is zero there. We also know the gymnast is in freefall, since we are told to neglect air resistance. We can write the acceleration as negative nine point eight meters per second squared. We also see that the time is given, so we write down the time as one second. What are we trying to find? We are trying to find how far the gymnast falls, this is displacement, or y.

Next we choose an equation from the kinematics equations. Look at the list of equations, which one has initial velocity, acceleration, time and displacement? If you said the first kinematics equation, you are correct! We write down the original equation y equals initial velocity times time plus one half acceleration due to gravity times time squared.

Next we will simplify the equation by crossing off any terms that are zero. In this problem, initial velocity is zero.

Now we are ready to substitute the given information into the equation and calculate the answer. Substituting the values from the table of values, we get an answer of y equals negative four point nine meters.

It is a good idea to check to see if your answer makes sense. Does a negative displacement make sense? If you said yes, you are correct! Since the gymnast is moving downward, the displacement is in the negative direction.



In this problem, a gymnast leaves the trampoline with an unknown initial velocity. We are asked to find this initial velocity.

It is good practice to draw diagrams when solving problems, we will do this first.
In this situation, we know the final velocity is zero. Since air resistance is negligible, we can use the freefall acceleration, g.

We know the height of the jump, three meters.

This is a sketch of what the velocity-time graph would look like for this situation.

Starting at an unknown positive value, the velocity steadily becomes moves toward zero. The slope of the velocity-time graph is the acceleration due to gravity, nine point eight meters per second squared. This information helps us to fill out a table of values for this problem.

If a gymnast reaches a peak height of 3.0 meters during a jump with what velocity did she leave the trampoline? Neglect air resistance.

TABLE OF VALUES

$v_o = ?$

$y = 3.0\ m$

$g = -9.8\ m/s^2$

$v = 0$

CHOICE OF EQUATION

$$v^2 = \cancel{v_o^2} + 2gy$$

ALGEBRA

$$v_o = \sqrt{-2gy}$$

SUBSTITUTION

$$v_o = \sqrt{-2(-9.8\frac{m}{s^2})(3.0m)}$$

$$v_o = 7.7\frac{m}{s}$$

Now we will create a table of values. We need to identify the given information from the question. What do we know about the gymnast at the peak of the jump? We know that the final velocity is zero there. We also know the gymnast is in freefall, since we are told to neglect air resistance. We can write the acceleration as negative nine point eight meters per second squared. We also see that the height is given, so we write down y equals three meters. The displacement is positive because she moves upwards. What are we trying to find? We are trying to find the velocity that the gymnast left the trampoline with, the initial velocity.

Next we choose an equation from the kinematics equations. Look at the list of equations, which one has initial and final velocities, acceleration, and displacement? If you said the last kinematics equation, you are correct! We write down the original equation final velocity squared equals initial velocity squared plus 2 times the acceleration due to gravity times displacement.

Next we will simplify the equation by crossing off any terms that are zero. In this problem, final velocity is zero.

Now we are ready to substitute the given information into the equation and calculate the answer. Substituting the values from the table of values, we get an answer of initial velocity equals seven point seven meters per second. Note that in this case we are taking the square root of positive number. The square root of a positive number can be positive or negative. It is a good idea to check to see if your answer makes sense. Does a positive velocity make sense? (Yes or No) If you said yes, you are correct! Since the gymnast is moving upward, the velocity is in the positive direction.