

## Lab 7: Gravitational Forces

### Objectives:

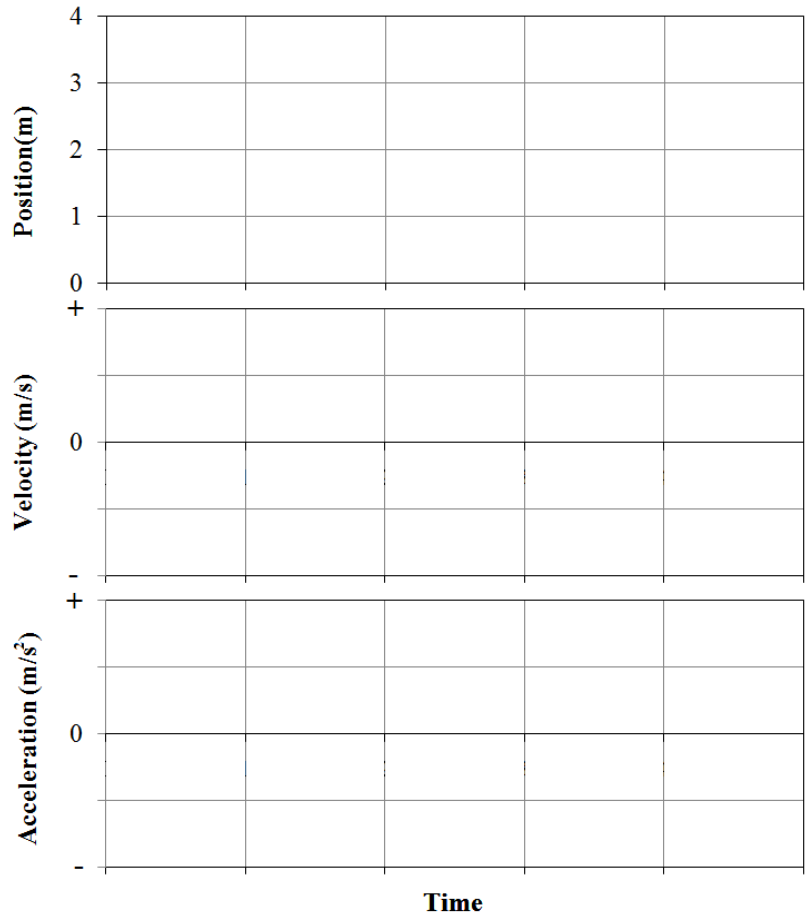
- To examine the position, velocity and acceleration of an object under the influence of the gravitational force without significant resistance
- To examine the direction of the velocity and acceleration of an object at under the influence of the gravitational force without significant resistance
- To examine the position, velocity and acceleration of an object under the influence of the gravitational force with significant air resistance
- To examine the position, velocity and acceleration of an object due to the gravitational force on an inclined ramp under the influence of gravity.

### Equipment:

- Computer-based laboratory system
- motion detector
- Real-Time physics mechanics experiment configuration files
- Baseball
- Basketball
- protection cage for the motion detector.

### Exploration 1 Motion under gravity

**Exploration 1.1.a** Consider a ball thrown in the air and returning to the same height. Sketch your prediction for the position vs. time, velocity vs. time, and acceleration vs. time graphs for the  $y$ - direction motion of the ball thrown upward and returning to the same height. Choose upward as the positive  $y$  direction.



**Exploration 1.1.b** Explain why you drew the graphs the way you did in the space below.

**Exploration 1.2** In the table below, indicate the sign (positive, negative or zero) of the velocity and acceleration of the ball at three different points:

- I. The ball is rising.
- II. The ball at its maximum height.
- III. The ball falling.

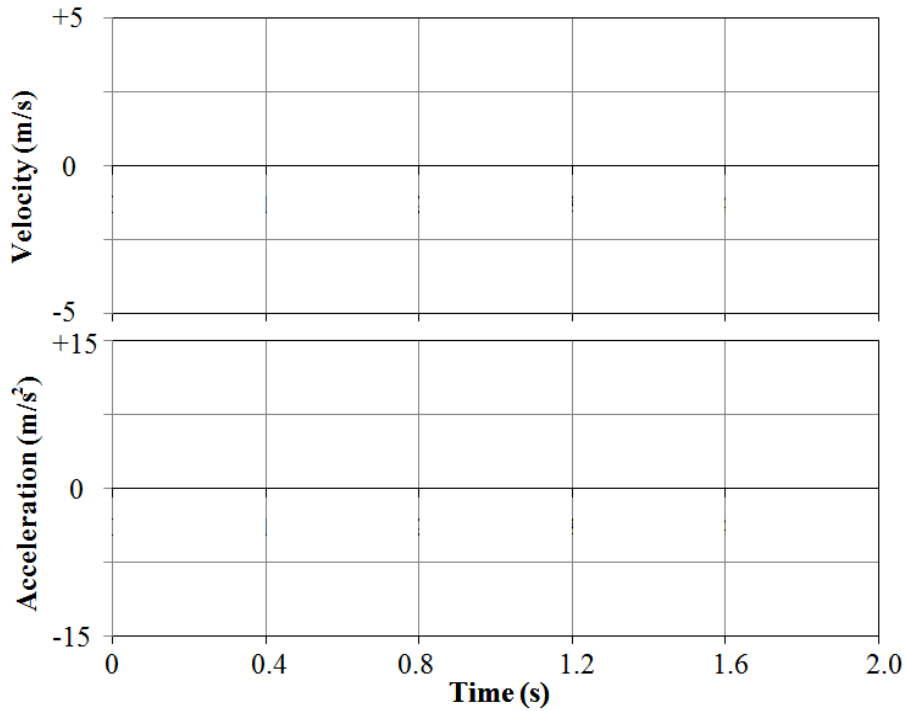
	velocity	acceleration
Ball rising		
Ball at max. height		
Ball falling		

Explain your choices at each of the three points.

**Exploration 1.3** Draw a force diagram for the ball at each of the three points described in Exploration 1.2. Are your force diagrams consistent with your answers to Exploration 1.2?

## Investigation 1 Motion under gravity

**Investigation 1.1** You are going to perform the experiment described in Exploration 1. Set up the motion detector on the floor with a cage on top of the motion detector to protect it. You are going to use a basketball to produce the motion. Open the experimental file called "**Falling Ball (L06A1-1)**" to display the axes shown below. Turn the motion detector on and take data for the ball thrown in the air and caught at the same height. Record and save the data. Sketch the velocity vs. time and acceleration vs. time graphs below.



How does the data compare to your prediction? If your prediction was incorrect, explain the experimental results in terms of the forces acting on the ball during different parts of the motion and the mathematical relationship between velocity and acceleration.

**Investigation 1.2.a** Find the average (mean) acceleration in the acceleration-time graph using statistics in the analysis feature to extract the mean.

Average acceleration:  $\text{m/s}^2$

If the true value of the acceleration of the gravity is  $9.81 \text{ m/s}^2$ , calculate the percent error in the value you measured.

**Investigation 1.2.b** Use the fit routine in the analysis feature to find the mathematical relationship between velocity and time during the same time interval in you used in Investigation 1.2.a. Write this equation and identify the slope and the intercept.

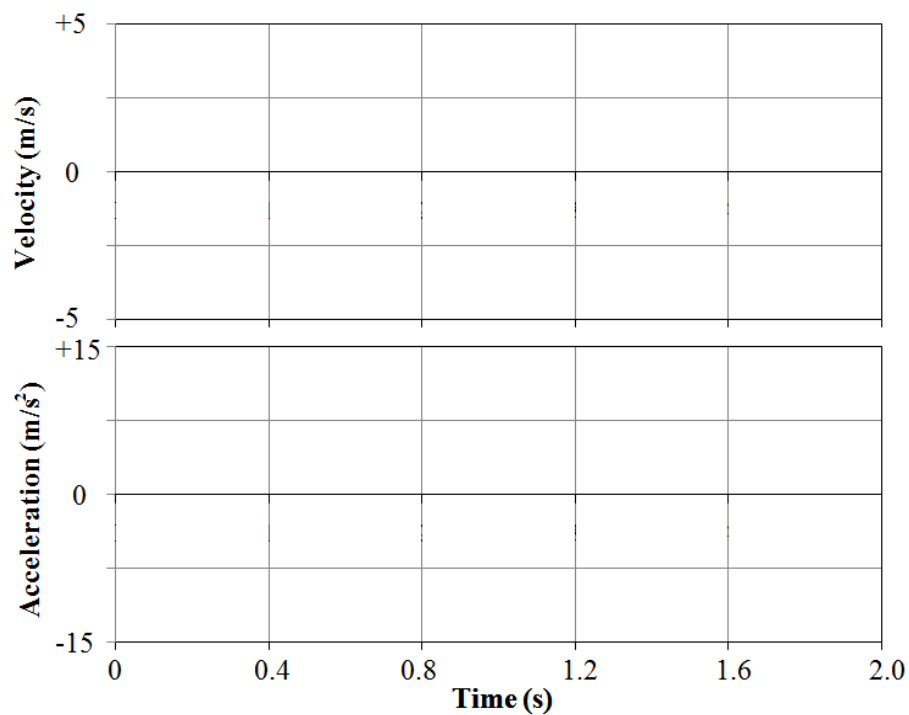
From your equation, what is the average acceleration? Compare this value with what you find in Investigation 1.2.a.

## Exploration 2 Air resistance

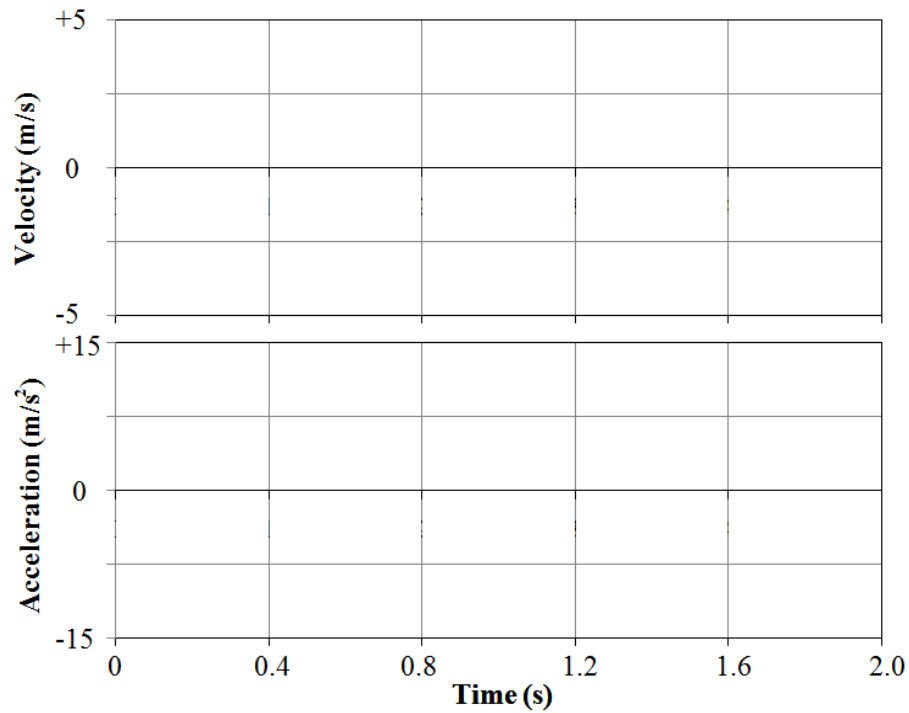
**Exploration 2.1** Consider a coffee filter and a baseball, both dropped from the same height. Will they reach the floor at the same time? Explain.

**Exploration 2.2** Try it out.

**Exploration 2.3** Sketch the velocity vs. time and acceleration vs. time based on your observation for both of the objects on the graphs below and on the next page. (There is a graph for each object. Sketch the coffee filter graphs below and the baseball graphs on the next page.)



**Coffee Filter**



**Baseball**

**Exploration 2.4** Draw a force diagram for the ball and for the coffee filter. Are your force diagrams consistent with your answers to Exploration 2.3?

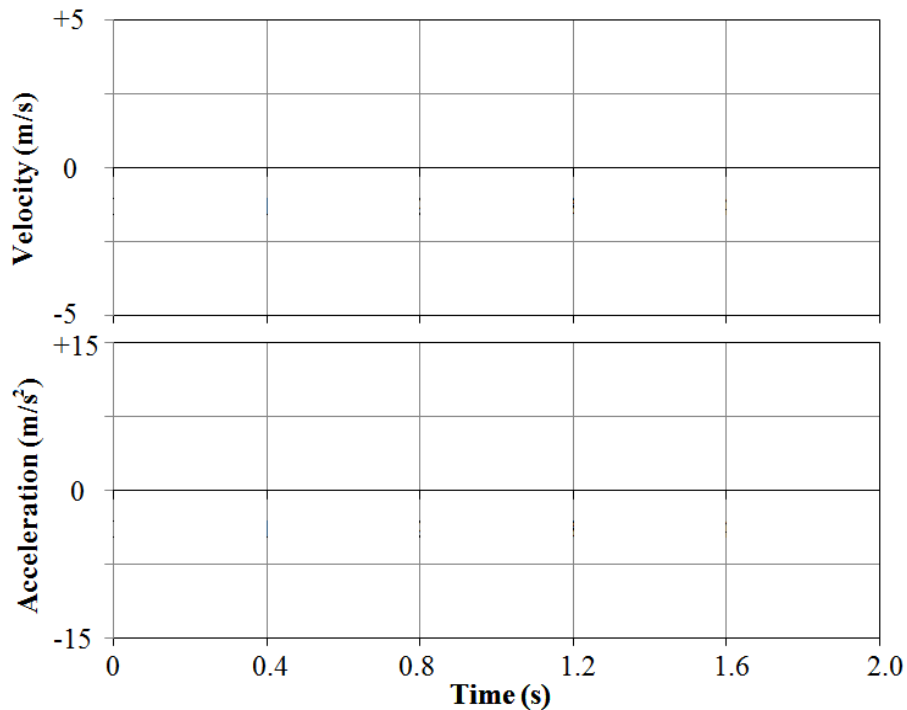
**Exploration 2.5** Explain the motion of the coffee filter and the baseball. How are the motions the same or different? When Galileo observed that the rate of fall due to the gravitational force was the same for all objects? Was he talking about these two objects? Explain.

## Investigation 2 Vertical motion with air resistance

In this part you will use the motion detector to examine the motion of a coffee filter and a baseball falling from rest.

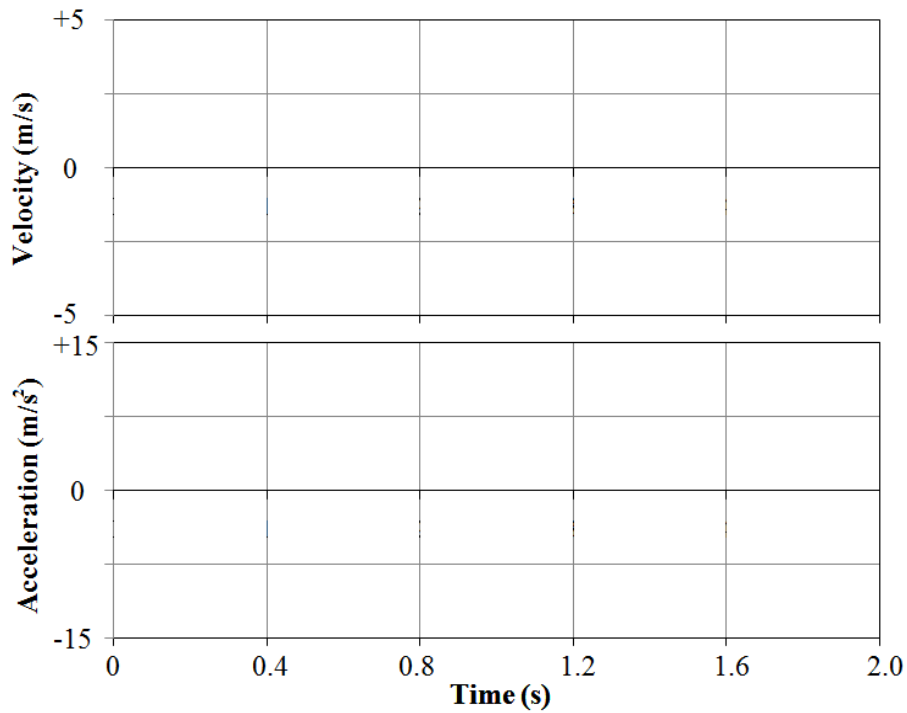
**Investigation 2.1** Set up the motion detector on the floor, and open the experimental file called "Falling Ball (L06A1-1)" to display the axes below.

Drop the coffee filter and record the data and store it. Drop the baseball from the same height, record the data and store it. Sketch the velocity vs. time and acceleration vs. time graphs for both objects on the graphs below. (There is a graph for each object. Don't put them both on the same graph.)



**Coffee Filter**





### Baseball

**Investigation 2.2** Compare between the graphs of the falling coffee filter and the baseball. How do they compare with your predictions? If the graphs are different from your predictions, explain the experimental results in terms of the forces acting on the coffee filter and the ball and the mathematical relationship between velocity and acceleration.

**Investigation 2.3** Find the average (mean) acceleration for each of the objects from the acceleration vs. time graph using statistics in the analysis feature to extract the mean.

Average acceleration of the coffee filter:  $\text{m/s}^2$

Average acceleration of the baseball:  $\text{m/s}^2$

**Investigation 2.4** Use the fit routine in the analysis feature to find the mathematical relationship between velocity and time during the same time interval in Investigation 2.3. Write this equation and identify the slope and intercept.

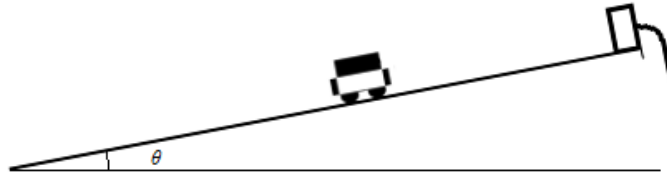
**Investigation 2.5** Find the average acceleration from the velocity graph, using the equation in Investigation 2.4. Compare this value with what you found in Investigation 2.3.

Average acceleration of the coffee filter:  $\text{m/s}^2$

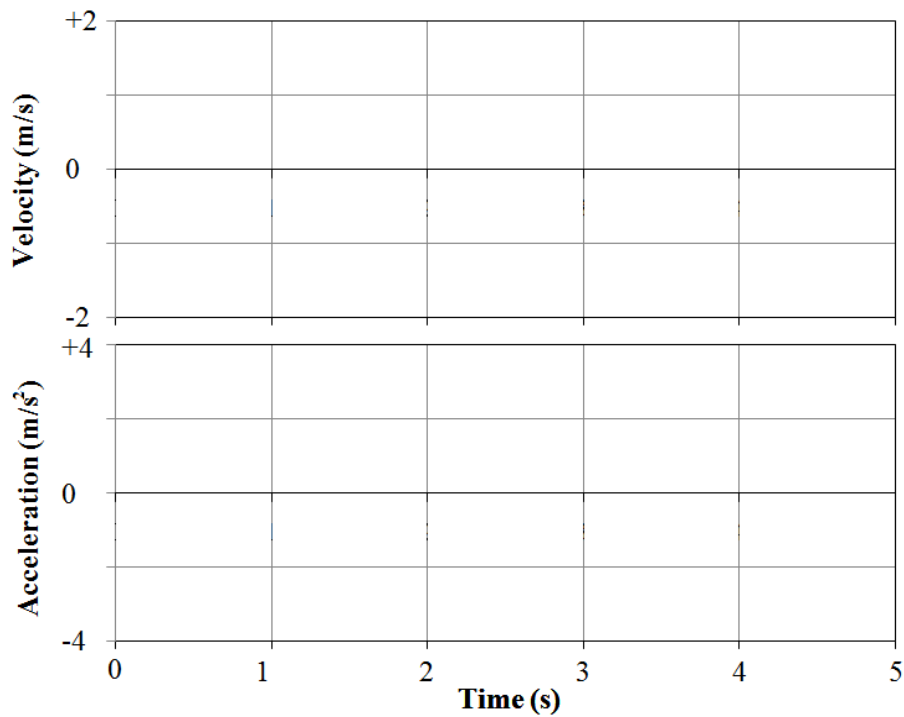
Average acceleration of the baseball:  $\text{m/s}^2$

### Exploration 3 Motion on an inclined plane

**Exploration 3.1** Consider a cart on a low friction inclined plane, as in the picture below. Suppose the cart is given a short push to start it up the ramp.



Sketch your prediction for the velocity vs. time and acceleration vs. time in the direction of the motion on the graphs below. Consider the whole motion from just after the push until the cart returns to the same height. Take *down* the ramp as positive.



**Exploration 3.2** In the table below, indicate the sign (positive, negative or zero) of the velocity and acceleration of the cart at three different points in its motion (taking *down* the ramp as positive):

- I. The cart is moving up the ramp.
- II. The cart at its maximum height.
- III. The cart is moving down the ramp.

	velocity	acceleration
Cart moving up		
Cart at max. height		
Cart moving down		

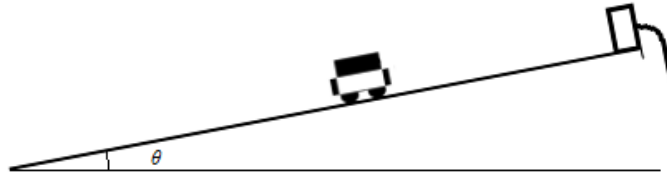
Explain your choices at each of the three points

**Exploration 3.3** Draw a force diagram for the cart at each of the three points described in Exploration 3.2. Are your force diagrams consistent with your answers to Exploration 3.2?

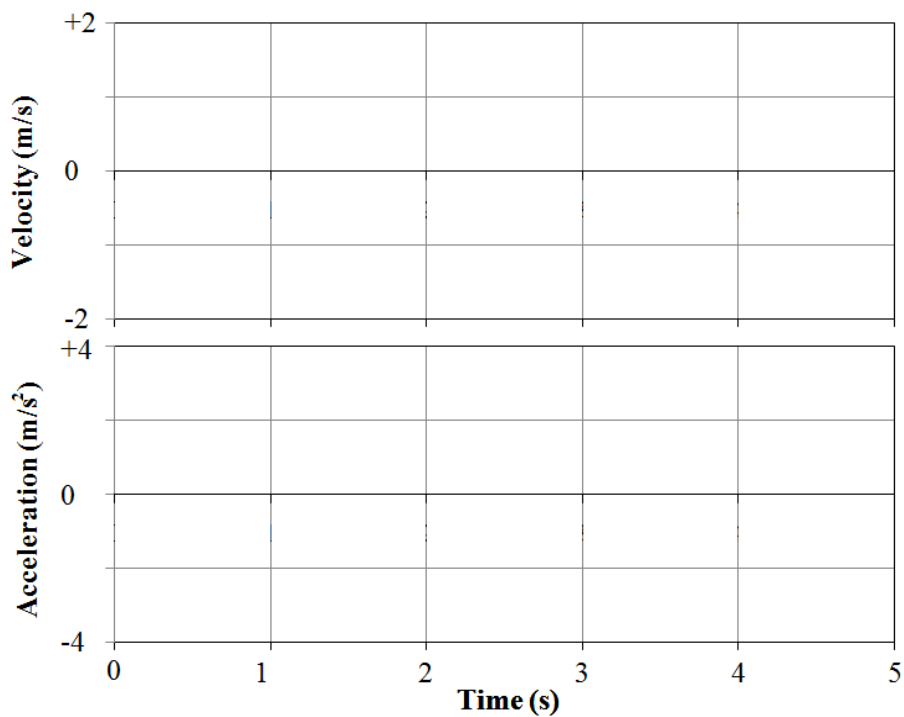
**Exploration 3.4** Calculate the acceleration of cart at one of the three points described in Exploration 3.2 in terms of the gravitational constant  $g$  and the angle of the ramp,  $\theta$ . Show your work in the space below. Is the acceleration the same or different at the other points?

### Investigation 3 Motion along an inclined ramp

**Investigation 3.1** Set up the ramp and motion detector as in the Figure below. The high end of the ramp should be elevated about 10cm.

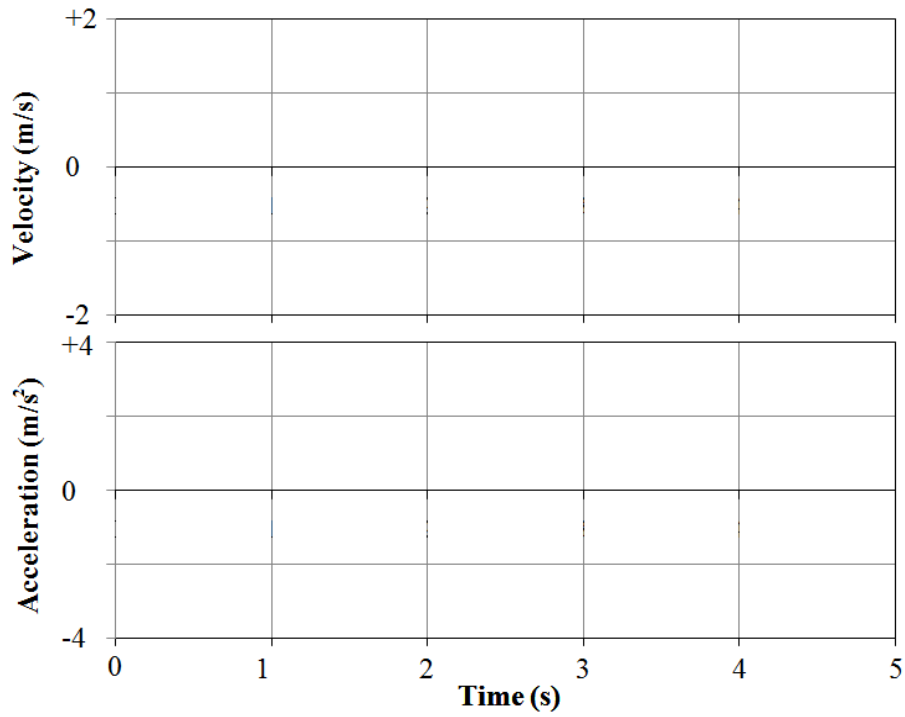


Open the experimental file called "**Inclined Ramp (L06A1-5)**" to display the axes below.



Hold the cart at the bottom of the ramp and begin graphing. When you hear the clicks of the motion detector, give the cart a short push up the ramp and release it. Save the data.

Sketch the graphs on the axes below.



**Investigation 3.2** Do the graphs agree with your predictions? If the graphs are different from your predictions, explain the experimental results in terms of the forces acting on the coffee filter and the ball, your calculation of the acceleration down the ramp and the mathematical relationship between velocity and acceleration.

**Investigation 3.3** Use the analysis and statistics features of the software to find the average acceleration of the cart during the time interval after it was released and before it was stopped at the bottom of the ramp.

Average acceleration:             $\text{m/s}^2$

Compare to your calculation in Exploration 3.4.

**Investigation 3.4** If we consider the value you calculated in Exploration 3.4 as the true value of the acceleration, calculate the percent error in the acceleration you measured in Investigation 3.3.