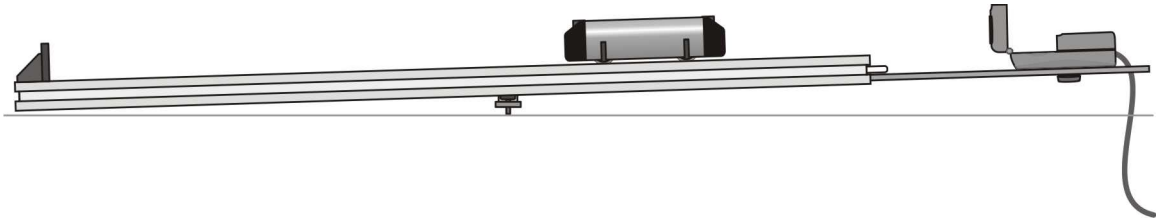
# Physics I – Laboratory #1 – Cart on a Ramp

**INTRODUCTION**

This experiment uses a ramp and a low-friction cart. If you give the cart a gentle push up the ramp, the cart will roll upward, slow and stop, and then roll back down, speeding up. A graph of its velocity *vs.* time would show these changes. Is there a mathematical pattern to the changes in velocity? What is the accompanying pattern to the position *vs.* time graph? What would the acceleration *vs.* time graph look like? Is the acceleration constant?

In this experiment, you will use a Motion Detector to collect position, velocity, and acceleration data for a cart rolling up and down a ramp. Analysis of the graphs of this motion will answer these questions.



## OBJECTIVES

- Collect position, velocity, and acceleration data as a cart rolls up and down a ramp.
- Analyze the position *vs.* time, velocity *vs.* time, and acceleration *vs.* time graphs.
- Determine the best fit equations for the position *vs.* time and velocity *vs.* time graphs.
- Determine the mean acceleration from the acceleration *vs.* time graph.

## MATERIALS

Computer
Vernier computer interface
Logger *Pro*
Vernier Motion Detector
Vernier Dynamics System

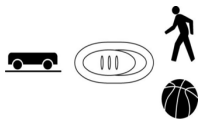
## PRELIMINARY QUESTIONS

1. Consider the changes in motion a cart will undergo as it rolls up and down a ramp. Make a sketch of your prediction for the position *vs.* time graph. Describe in words what this graph means.

2. Make a sketch of your prediction for the velocity *vs.* time graph. Describe in words what this graph means.

3. Make a sketch of your prediction for the acceleration *vs.* time graph. Describe in words what this graph means.

## PROCEDURE A



1. Connect the Vernier Motion Detector to the DIG/SONIC 1 channel of the interface. Set the motion detector switch to "Track" (the one with the picture of the cart).

2. Confirm that your ramp, end stop, and Motion Detector bracket are assembled as shown in the figure. Adjust the head of the detector so that it is pointing straight down the track, or angled up just a little (*Note: If you have trouble detecting motion of the cart, you will likely have to tweak the angle of the motion detector head, either up or down)*.

3. Open the file "03 Cart on a Ramp" from the *Physics with Vernier* folder. You can re-position the graphs so that all three are arranged across the screen.

4. Place the cart on the track near the bottom end stop. If your cart has a plunger, face the plunger away from the Motion Detector. Click Collect to begin data collection[1]. You will notice a clicking sound from the Motion Detector. Wait about a second, then briefly push the cart up the ramp, letting it roll freely up nearly to the top, and then back down. Catch the cart as it nears the end stop.

5. Examine the position *vs.* time graph. Repeat Step 4 if your position *vs.* time graph does not show an area of smoothly changing position. Check with your instructor if you are not sure whether you need to repeat data collection.

## ANALYSIS A

1. Print the three motion graphs. The graphs you have recorded are fairly complex and it is important to identify different regions of each graph. Click the Examine button, , and move the mouse across any graph to answer the following questions. Record your answers directly on the printed graphs.

   a) Identify the region when the cart was being pushed by your hand:

   - Examine the velocity *vs.* time graph and identify this region. Label this on the graph.
   - Examine the acceleration *vs.* time graph and identify the same region. Label the graph.

   b) Identify the region where the cart is rolling freely:

   - Label the region on each graph where the cart was rolling freely and moving up the ramp.
   - Label the region on each graph where the cart was rolling freely and moving down the ramp.

   c) Determine the position, velocity, and acceleration at specific points.

   - On the velocity *vs.* time graph, decide where the cart had its maximum speed, just as the cart was released. Mark the spot and record the value on the graph.
   - On the position *vs.* time graph, locate the highest point of the cart on the ramp. Note that this point is the closest approach to the Motion Detector. Mark the spot and record the value on the graph.
   - What was the velocity of the cart at the top of its motion?
   - What was the acceleration of the cart at the top of its motion?

2. The motion of an object in constant acceleration modeled by $x = v_0t + \frac{1}{2} at^2$, where $x$ is the position, $v_0$ is the initial velocity, $t$ is time, and $a$ is the acceleration. This is a quadratic equation whose graph is a parabola. If the cart moved with constant acceleration while it was rolling, your graph of position *vs.* time will be parabolic. To fit a quadratic equation to your data, click and drag the mouse across the portion of the position *vs.* time graph that is parabolic, **highlighting** the free-rolling portion.

3. Click the Curve Fit button, , select Quadratic fit from the list of models and click Try Fit. Examine the fit of the curve to your data and click OK to return to the main graph. Is the cart's acceleration

[1] Logger *Pro* tip: if a graph is currently selected, you can start data collection by tapping the Space bar.

constant during the free-rolling segment?

4. The graph of velocity *vs.* time will be linear if the acceleration is constant. To fit a line to this data, click and drag the mouse across the free rolling region of the motion. Click the Linear Fit button, . How closely does the slope correspond to the acceleration you found in the previous step?

5. The graph of acceleration *vs.* time should appear to be more or less constant during the freely-rolling segment. Click and drag the mouse across the free-rolling portion of the motion and click the Statistics button, . How closely does the mean acceleration value compare to the values of *a* found in Steps 3 and 4?

## PROCEDURE B – BOUNCING CART

1. Your cart can bounce against the track end stop using the plunger and end stop. Practice starting the cart so it bounces at least three times during the ten-second data collection.

2. Collect another set of Motion Detector data showing two or more bounces.

## ANALYSIS B

1. Determine the cart's acceleration *during the free rolling segments* using the velocity graph. How do they compare?

2. Determine the cart's acceleration *during the free rolling segments* using the position graph. How do they compare?