In this lab, you will make and analyze an iPad video of a cart as it travels up a ramp and then comes back down. The goal is to determine whether the motion is actually an example of constant acceleration.

1. Watch directions on how to use the Vernier Video Physics app at <https://www.youtube.com/watch?v=XLU2v1rgTAk> (~9 minutes long). Write a brief (1-2 sentences) description of what this app does and how you will use it in the lab.
2. Watch directions on how to use the Vernier Graphical Analysis app at <https://www.youtube.com/watch?v=XWNBmJknYfs> (~9 minutes long). Write a brief (1-2 sentences) description of what this app does and how you will use it in the lab.

A person gives a cart a quick push up a ramp. After the cart loses contact with the person’s hand, the cart slows down, and eventually comes back down the ramp. For the following predictions, consider what happens ***only while the cart is rolling freely***- that is, from *just after* the cart is released until *just before* it is caught.

1. On the axes below, sketch what you think a graph of ***velocity*** versus time for the cart will look like.



1. Do you think the cart’s velocity will be zero at any moment during the run? If so, when? Explain.
2. Do you think the cart’s acceleration will be zero at any moment during the run? If so, when? Explain.

The big question:

Is a cart traveling up and then down a ramp an example of constant acceleration?

Procedure:

1. Make the video of the motion using Vernier’s Video Physics app on the iPad. Some suggestions for making video that’s easy to analyze follow. Make sure that
* the cart shows up well against the background
* the iPad camera is stationary
* the iPad is held parallel to the track
* the cart’s motion fills a majority of the screen (use landscape orientation for the iPad). You may need to practice your initial push before shooting video to get good video on the first try
* The angle is not too big- pictures get blurry if the cart moves too fast

Measure the angle your track makes with the horizontal. Don’t use a protractor- it’s more accurate to use a ruler to measure some distances and apply your knowledge of trig. Briefly record the angle of the ramp and how you figured it out in the space below:

Angle of ramp (and supporting data, diagrams)

**Note:** You will be using the cart as the reference object. (A reference object is an object you know the size of. This is what the software uses to calculate distances). Measure the length of your cart and record it here:

Length of cart = \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

1. Open up Video Physics and view your video. Check to make sure it’s good enough for analysis. Is the object clear (not blurry)? Is there a spot on the object that’s easy to mark? Does the motion fill most of the screen? Is the action all in a plane that’s parallel to the iPad? If your video isn’t good, now’s the time to reshoot it.
2. Once you think your video is good enough, it’s time to track/mark the motion of the object using Video Physics. Adjust the axes so that the motion of the object is along the x-axis. Use the software to mark the length of your reference object. Check your graphs in Video Physics to make sure that y-velocity and y-acceleration are both zero throughout the motion. (If not, adjust your axes slightly and recheck). Note: You may not need (or want) to record the position of the cart in every frame. In particular, when the cart is moving slowly, you might want to skip a frame, or even multiple frames to save time (and still get good graphs).
3. Once you’ve marked the motion of the object, check the quality of the graphs. Do the graphs show a consistent trend? Is there enough data in all parts of the graph? If not, now’s the time to add those data points (if you skipped them during the tracking process).
4. Analyze the motion using Vernier’s Graphical Analysis app on the iPad. ***Only consider the part of the motion where the cart is moving freely***- that is, from *just after* the cart is released until *just before* it is caught.
	1. Analyze the velocity-time graph to answer the following questions:
* Sketch the velocity-time graph on the axes below. On the graph, indicate when the cart turns around.



* Compare the graph above to your prelab prediction. Describe and account for any differences.
* Is velocity ever zero? If so, when? Explain how you can tell from the velocity graph.
* Is acceleration ever zero? If so, when? Explain how you can tell from the velocity graph.
* Does acceleration ever change sign? If so, when? Explain how you can tell from the velocity graph.
* Is acceleration constant throughout the motion? Explain how you can tell from the velocity graph. [Hint: Check to make sure that the acceleration on the way up is the same as the acceleration on the way down].
* What is the numerical value of acceleration? (If the acceleration is changing, describe the changes and calculate appropriate numbers). Show how you calculated the acceleration value(s).
	1. ***Export the velocity graphs*** with all of your analysis (linear fits, etc.) as an ***image file***. ***Share*** this file with yourself and your lab partners. (Your instructor will tell you how to do this).
	2. Analyze the position-time graph to answer the following questions.
* Sketch the position-time graph on the axes below. On the graph, indicate when the cart turns around.



* Is the position-time graph linear? If not, what type of curve fit is appropriate to analyze the position-time graph? Explain.
* Use the type of curve fit you think is correct to analyze the position-time graph. Write the equation for the best fit curve below.
* Explain how you can figure out the value of acceleration from the fit equation you just found. What is this numerical value of acceleration? Show how you calculated the acceleration value(s) from the position graph.
* Compare the acceleration value(s) obtained from the position graph to those obtained from the velocity graph. Are they similar? Exactly the same? (If they are vastly different, redo your analysis- something’s wrong!)
* In a world where friction can be ignored, theory predicts that the acceleration of the cart will be equal to $g\sin(θ)$ throughout the entire motion. (In this equation, $θ$ is the angle the ramp makes with the horizontal and $g=9.8 \frac{m}{s^{2}}$). How well do your results match this theoretical prediction?
	1. ***Export the position graphs*** with appropriate fits as an ***image file***. ***Share*** this file with yourself and your lab partners. (Your instructor will tell you how to do this).
1. Write the report, using your analysis according to your instructor’s guidelines. Make sure you have the image files from Graphical Analysis to include in your report.