  Graphical Analysis 3

Cart on a Ramp

(Motion Detector)

This experiment uses an incline and a low-friction cart. If you give the cart a gentle push up the incline, 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 does 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 an incline. Analysis of the graphs of this motion will answer the questions above.

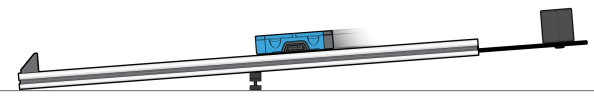


Figure 1

objectives

* Collect position, velocity, and acceleration data as a cart rolls freely up and down an incline.
* Analyze 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

Chromebook, computer, or mobile device

Graphical Analysis 4 app

Go Direct Motion

Vernier Dynamics Track

Adjustable End Stop

Motion Detector Bracket

Vernier Dynamics Cart with plunger

Preliminary questions

1. Consider the changes in motion a Dynamics Cart will undergo as it rolls up and down an incline. 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

Part I

1. Prepare the Dynamics Track and motion detector for data collection.
   1. Attach the Motion Detector Bracket to the track as shown in Figure 1.
   2. Attach the motion detector to the Motion Detector Bracket.
   3. Adjust the position of the Motion Detector Bracket so the motion detector is 0.25 m from the end of the track.
2. Set up the motion detector and Graphical Analysis.
   1. Launch Graphical Analysis.
   2. Connect the motion detector to your Chromebook, computer, or mobile device. Click or tap Sensor Channels.
   3. Select the check box for Motion (cart). Click or tap Done.
3. Place the cart on the track near the Adjustable End Stop. Face the plunger away from the motion detector. Click or tap Collect to start data collection. You will notice a clicking sound from the motion detector. Wait about a second, then briefly push the cart up the incline, letting it roll freely up nearly to the top, and then back down. Catch the cart as it nears the end stop.
4. Examine the position vs. time graph. Repeat Step 3 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.
5. Answer the Analysis questions for Part I before proceeding to Part II.

Part II

1. Your cart can bounce against the end stop with its plunger. Practice starting the cart so it bounces at least twice during data collection.
2. Collect another set of motion detector data showing two or more bounces. Note: The previous data set is automatically saved.
3. Proceed to the Analysis questions for Part II.

Analysis

Part I

1. Export, print, or sketch the three motion graphs. To view the acceleration vs. time graph, change the y-axis of either graph to Acceleration. The graphs you have recorded are fairly complex and it is important to identify different regions of each graph. Record your answers directly on the printed or sketched graphs.
   1. Identify the region when the cart was being pushed by your hand:
      * Examine the velocity vs. time graph and identify the region. Label it on the graph.
      * Examine the acceleration vs. time graph and identify the same region. Label the graph.
   2. Identify the region where the cart was rolling freely:
      * Label the region on each graph where the cart was rolling freely and moving up the incline.
      * Label the region on each graph where the cart was rolling freely and moving down the incline.
   3. Determine the position, velocity, and acceleration at specific points:
      * On the velocity vs. time graph, decide where the cart had its maximum velocity, 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 incline. 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 is modeled by the equation   
   x = ½ at2 + v0t + x0, where x is the position, a is the acceleration, t is time, and v0 is the initial velocity. 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.
   1. Select the data in the parabolic region of the position graph.
   2. Click or tap Graph Tools, , for the position graph and choose Apply Curve Fit.
   3. Select Quadratic as the curve fit and click or tap Apply.
   4. Record the parameters of the fitted curve (the acceleration).

Is the cart’s acceleration constant during the free-rolling segment?

1. The graph of velocity vs. time is linear if the acceleration is constant. Fit a line to the data.
   1. Select the data in the linear region of the velocity graph.
   2. Click or tap Graph Tools, , for the velocity graph and choose Apply Curve Fit.
   3. Select Linear as the curve fit and click or tap Apply.
   4. Record the slope of the fitted line (the acceleration).

How closely does the slope correspond to the acceleration you found in the previous step?

1. Change the y-axis to Acceleration. The graph of acceleration vs. time should appear approximately constant during the freely-rolling segment.
   1. Select the data in the region of the graph that represents when the cart was rolling freely.
   2. Click or tap Graph Tools, , for the acceleration graph and choose View Statistics.

How closely does the mean acceleration compare to the values of acceleration found in Steps 2 and 3?

Part II

1. Determine the cart’s acceleration during the free-rolling segments using the velocity graph. Are they the same?
2. Determine the cart’s acceleration during the free-rolling segments using the position graph. Are they the same?

extensions

1. Use a free-body diagram to analyze the forces on a rolling cart. Predict the acceleration as a function of incline angle and compare your prediction to your experimental results. For a trigonometric method for determining θ, see the experiment, "Determining g on an Incline," in this book.
2. Even though the cart has very low friction, the friction is not zero. From your velocity graph, devise a way to measure the difference in acceleration between the roll up and the roll down. Can you use this information to determine the friction force in newtons?