

Equations of Motion for Constant Acceleration

Introduction

The motion of a Smart Cart as it accelerates down an incline is measured using Capstone software. Graphs of position and velocity are studied and comparisons are made to the standard equations of motion using User-Defined curve fits. Further analysis compares values found from the position graph to those found from the velocity graph.



Figure 1: Smart Cart on Inclined Track

Equipment

Qty	Items	Part Number
1	Smart Cart Blue	ME-1241
1	Dynamics Track Feet (Pair)	ME-8972
1	Dynamics Track End Stops (Only 1 needed)	ME-8971
1	1.2m Starter Dynamics Track	ME-9493
1	250g Cart Mass (Pair)	ME-6757A
1	Elastic Bumper (Elastic & 1 pair brackets needed)	ME-8998
Required, but not included:		
1	PASCO Capstone software	

Set-up

1. As illustrated in Figure 1, install the two Track Feet on the underside of the Dynamics Track, and then place the Cart Masses under the track feet on one side to incline the track.
2. Install the fixed End Stop at the top of the incline (see Figure 1), and an Elastic Bumper (see Figures 1 & 2) at the bottom.
3. Turn on the Smart Cart, and then wirelessly connect it in Capstone. On the bottom toolbar, change the sample rate of the Position Sensor to 40 Hz.
4. Recording conditions: In Capstone, on the lower toolbar, open Recording Conditions. Create a Start Condition: Position is above 0.10. Create a Stop Condition: Position is above 0.70. With these settings, after you click Record, data recording begins only when the cart has traveled 0.10 m (by which point the acceleration will be steady, making for a nicer graph), and ends when the cart is at 0.70 m (before the cart hits the elastic bumper).

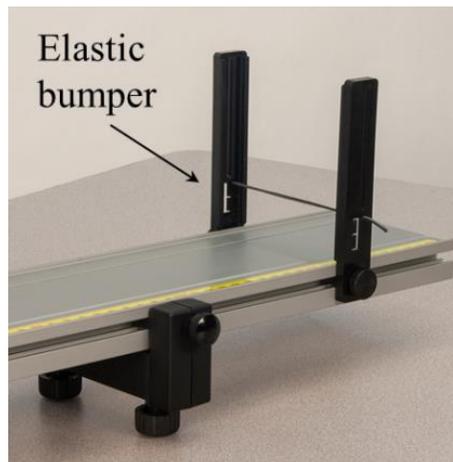


Figure 2: Elastic Bumper

You can adjust the Recording Conditions as needed to suit your experiment.

5. In Capstone, create a graph of Position vs. Time.

Procedure

1. Place the car on the track, and hold it at rest near the end stop at the upper end of the track. Make sure the +x-direction (printed on the top of the Smart Cart) is pointing down the track.
2. Start recording. Let the cart accelerate down the track. Recording should stop automatically after the cart has gone 0.70 m.
3. Repeat as needed until you get a smooth run. Use the Delete run button at the bottom toolbar if needed.

Position Equation

1. Turn on the curve fit tool on the graph toolbar, and then select User-Defined from the list.
2. Open the Curve Fit Editor on the left toolbar. If it tells you to select a curve fit, click on the curve fit annotation box on the graph.
3. The default user-defined curve fit is: $y = A*t + B$

Edit the right side to read: $X_0 + V_0*t + (1/2)*a*t^2$.

To make the zero subscripts, right-click at that point in the curve fit equation, and then select the subscript.

Click on Apply.

4. From the curve fit, record the initial position, X_0 . How does this compare to the Start Condition (remember, this is at position of 0.10 m)?
5. Also from the curve fit, record the initial velocity, V_0 , and the acceleration, a .

Velocity Equation

1. Create a graph of Velocity vs. Time.
2. Select a User-Defined Curve Fit from the graph tool palette.
3. Open the Curve Fit Editor on the left toolbar. If it tells you to select a curve fit, click on the curve fit annotation box on the graph.
4. Edit the right side of the curve fit equation to read:

$$V_0 + a*t$$

Click on Apply.

5. From the curve fit, record the initial velocity, V_0 . How does this compare to the initial velocity found from the position graph curve fit?
6. Also from the curve fit, record the acceleration, a . How does this compare to the acceleration found from the position graph curve fit?

Comparing Instantaneous Velocities

1. At 0.2 seconds:

Click on the position graph to make that graph active. Select the Slope tool and then move the tool to 0.2 s on the graph. Record the slope at this time.

Click on the velocity graph to make that graph active. Add a Coordinates tool, and move the tool to 0.2 s on the graph. Record the velocity at this time.

2. Repeat for 0.6 s and 1.0 s.
3. The velocity of the cart is equal to the rate of change of its position. (In calculus, we say the velocity is the derivative of position vs. time.) On the graphs that means: At any time, the slope of the position graph is equal to the value of the velocity. How well does your data support this statement?

Comparing Displacements

1. Interval from 0 to 0.4 s:

Click on the position graph to make that graph active. Add a Coordinates/Delta tool and turn on the Delta tool. Use the delta tool to measure from 0 to 0.4 seconds on the graph. Record the value of the displacement, Δx , for this interval.

Click on the velocity graph to make that graph active. Then select the Highlight tool, and highlight the velocity graph data from 0 to 0.4 s. Then click the Area tool, which should find the area under the velocity graph from 0 to 0.4s. (Note: This finds the area **between the velocity graph and the time axis**, not the area of the highlighter rectangle.) Record the area.

2. Repeat for the interval from 0.4 to 1.0 s. (Rather than adding new graph tools, it may be easier if you simply move the existing tools to this new interval.)
3. Repeat for the interval from 0 to 1.0 s.
4. The displacement of the cart for any time interval is equal to the area under the velocity vs. time graph for that time interval. (In calculus, we say the displacement is the integral of velocity vs. time.) How well does your data support this statement?