Lab 2: Position, Velocity and Acceleration

Experiment for Physics 225 Lab at CSUF

What You Need to Know

Introduction:

By this time in your lecture class, you should have worked some problems with the equations for position and velocity as a function of time for one dimensional motion with constant acceleration. If you had high school physics, you would also have used these equations. In case you don't remember them, the equations are

$$v = v_0 + at$$
$$x = x_0 + v_0\, t + \frac{1}{2}\, at^2$$

Equation 1 – Kinematic Equations

Here v is the velocity at time t, v_0 the initial velocity (velocity at $t = 0$), a the acceleration, x is the position at time t, x_0 the initial position (position at $t = 0$), and t is the time measured from when the object was at position x_0 with velocity v_0. Although the equations are very simple, they do involve six variables and can be confusing. There are three major aspects of the equations that demonstrate some fundamental and useful things that we want to make sure you fully understand. In addition, we want you to become familiar with graphs of position, velocity, and acceleration as functions of time, and what they can tell you about the motion of an object. A final goal will be to help you to become familiar with dealing with data that has noise in it due to the measurement technique used.

In this lab period we will use a low friction, wheeled cart on a grooved track about two meters long, in conjunction with a sonic ranger and computer software, to acquire data for the position, velocity, and acceleration as a function of time for a moving cart. The cart has a motorized fan mounted on it with a switch to provide thrust and thus acceleration. When the fan is turned on, it provides a constant thrust and thus a constant acceleration to the cart (the thrust will eventually decrease as the fan slows down due to the batteries discharging. Be sure to turn your fans off when not taking data to conserve the battery charge for the next lab. The lab is no fun when the fan batteries are low.).

Summary of the experiment:

In today's lab, you will be making measurements with the cart and Logger Pro software for 3 important cases.

1. Constant velocity,
2. Constant acceleration with zero initial velocity, and
3. Constant acceleration with initial velocity opposite to the direction of acceleration.

For case 3. you should take data for 2 different initial velocities and compare the measured maximum distance and the calculated maximum distance using your measured values for v_0 and a for each of the two cases.

You will take screenshots of your data graphs for each case (a total of 4 screenshots) so that you can include them in your lab report.

What You Need to Do

Part 1: Zero Acceleration

Preparation

Put the cart on the track with the fan off and hold it stationary for a moment, then release it without imparting any motion. The cart should remain stationary. If it rolls in either direction, the track is not level. Please call your instructor to level the track.

Coasting

In the preparation you've already (though briefly) investigated zero acceleration and zero velocity, but this is not the only time you can have zero acceleration.

Now you'll investigate the case of zero acceleration, but non-zero velocity.

A) Open the Logger Pro software file called: "acceleration.cmbl". The display should show three graphs, as in the example figure 1 below.

B) First position the sonic ranger near the lab counter end of the track, (behind the track stop so the cart does not collide with it) and aim it towards the signal blocker on the cart (the fan should be pointed away from the ranger at all times.

C) Verify that your software is working properly:

   a. Position the cart on the far end of the track.
   b. Click the green go button at the top of the computer screen to start the data acquisition.
   c. Slowly move the cart by hand while watching the screen.
   d. The position should be changing as you move the cart towards and away from the sonic ranger.
   e. Practice a couple of times how long you wait after clicking the green go button to moving the cart so that you get nice graphs that look similar to figure 1 below. There is a brief pause after hitting the go button before the computer begins taking data, and you do not want to launch the cart until the first data shows up on the screen.

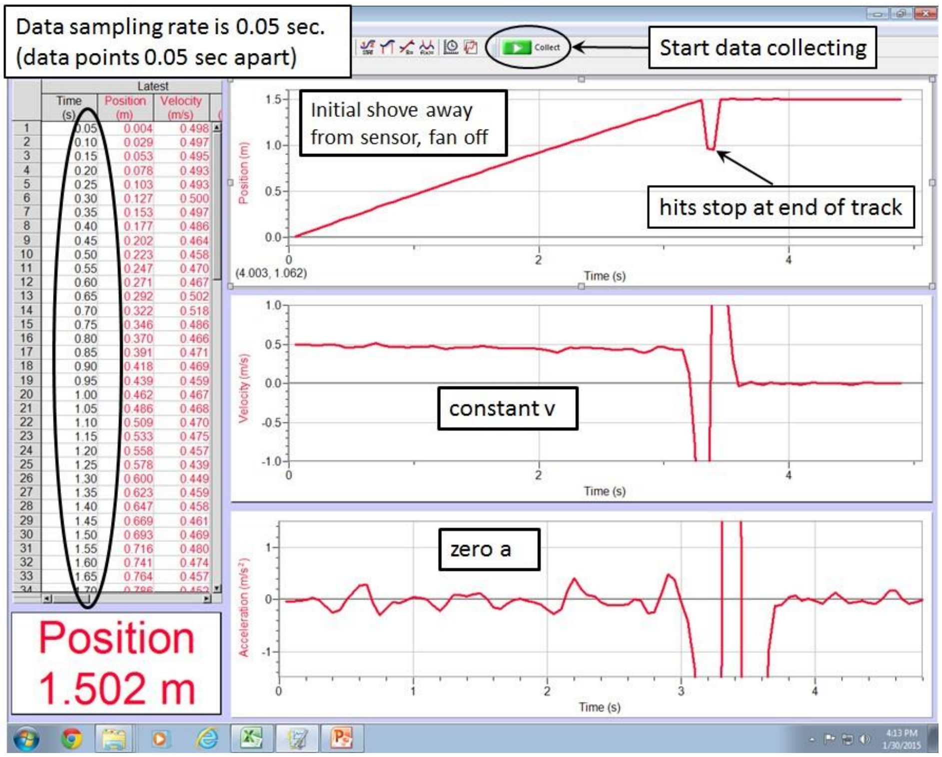

Figure 1 – Screen shot of acceleration.cmbl with sample data collected.

D) Collect some data:

f. Return the cart to the end of the track and prepare to gently launch it.

g. When you launch be sure to keep body parts from moving in the vicinity of the sensor, or you will get data with a lot of variation in the velocity

h. Practice releasing the cart with a gentle shove of two fingers behind the cart with your fingers kept low and out of the sensor beam until you get data that shows a smooth, linearly increasing position vs. time graph similar to figure 1.

i. With the fan off and the cart on the sensor end of the track, give your cart an initial (gentle!) push and record the data until the cart hits the stop at the other end.

E) Take a screenshot of the data and paste it into your report. Be sure to label what the data is and save each time you paste these or you'll have to repeat any section you lose.

Part 1 Screenshot

Question 1:

Was the velocity of the cart constant? If so, what was its value and over how big a region was it constant? Explain how you can tell.

Checkpoint 1:

If the velocity of the cart was not constant, what are some possible sources of difference and their effect. (hint: wheel friction, wheel shape irregularities, track groove irregularities, etc.)

Question 2:

Was the acceleration zero? Report its (average) value. Discuss why the acceleration is not perfectly constant or zero.

Part 2: Constant Acceleration with Zero Initial Velocity.

Now you'll investigate an object that is stationary experiencing a constant non-zero acceleration in one direction. This is the same type of motion as Free Fall from Rest.

A) One lab partner position the cart near the end of the track farthest away from the sonic ranger, with the propeller in the back of the cart facing so that when the fan is turned on, the cart will accelerate towards the sonic ranger.

B) Turn on the fan:

   a. You can turn on the fan by briefly pressing the small button on the side.

   b. Briefly pressing the button again will cycle through different speed settings.

   c. Press and hold the button to turn it off.

C) Another lab partner prepare to catch the cart once it approaches the track stop near the signal bouncer.

D) With the fan on, move your fingers in front of the cart out of the way so as to release the cart from rest and it accelerates towards the sonic ranger until you have enough data then catch and stop the cart.

BE SURE TO CATCH AND STOP THE CART BEFORE IT HITS THE STOP OR IT MAY DROP AND DANGEROUSLY SHATTER.

E) Inspect your data and repeat the measurement until you have a "good" set of data. "Good" data shows:

   a. A good curvature in the position vs. time graph.

   b. A nearly linear decrease in the velocity vs. time graph

F) Take a screenshot of the data and paste it into your report. Save the document.

Part 2 Screenshot

G) Consider the following questions:

Question 3:

Was the acceleration of your cart "constant"? Take an approximate average value for the acceleration and report that number.

Note: The up and down fluctuations in the acceleration are an artifact of taking a numerical second derivative of the position vs. time graph for a fairly small acceleration, and also under sampling the data. (ideally, if there was sufficient time in the lab, one would take a segment of the a vs. t data which is horizontal on average, import that data in a spreadsheet and then take the mean and standard deviation.)

Checkpoint 2:

Qualitatively describe the position vs. time graph. Is it what you would expect for this situation? Write down the equation that describes it using the value for the acceleration found in Question 4. (Hint: this equation is exactly the same as the equation for position vs. time for free fall of an object starting from rest)

Part 3: Constant Acceleration in Opposite Direction of Initial Velocity.

Now you'll investigate motion where a constant acceleration is applied opposite of a velocity. This is the same motion as throwing a ball straight up in the air.

A) Position the cart at the end of the track nearest the sonic ranger with the fan thrust pointing towards the sonic ranger.

B) Turn on the fan.

C) Practice your launch by using two fingers to give the cart a very gentle push for an initial velocity that is opposite to the direction of the fan thrust.

D) Repeat until your push is enough to get the cart almost half way down the track before it stops and comes back.

The point where the cart velocity is zero and turns around is called a turning point of the motion, and is an important concept in mechanics.

This is the same kind of position vs. time motion that happens when you toss a ball vertically upwards in the air, it reaches its maximum height, which is a turning point, reverses velocity, and then returns to its initial position when you catch the ball at the same height it was released from.

E) Once you've got the technique, take a good data set where the cart goes slightly less than half way down the track.

F) Take a screenshot of the data and graph and include it in your report.

Part 3 Screenshot 1

G) Do it again for another data set with a different initial velocity, this time get the cart to go nearly to the end of the track, at least ¾ the way down. BE SURE A LAB PARTNER IS READY TO CATCH IT, DO NOT LET THE FAN FALL.

H) Verify this data is good then screenshot and include this second set in your report.

Part 3 Screenshot 2

Question 4:

Was the acceleration constant for the two different v_0 values? Determine the region where it was constant and report the average values of the acceleration.

Question 5:

Compare the values from Question 4 to the acceleration you found in part 2. What do you expect the relationship between the three values to be? Do your results agree with what you expect?

Question 6:

From the velocity vs. time graphs:

a) Locate the position of the turning point (i.e. the corresponding time). Find the position of the cart at this value of the time and record it for both of your v_0 values. Also record the v_0 values.

b) From the v_0 and *a* values, determine a formula for the expected position of the distance away from the release point where the cart turns around.

(Hint: this is the same formula used to calculate the maximum height of a ball tossed in the air, and you substitute the carts acceleration for the acceleration of gravity, and the horizontal position of the cart for the vertical position of the ball.)

c) Using the values for v_0 and *a* that you determined in Part 3 and your formula from this question part b), calculate the position of the turning point of the cart for the two different initial velocities.

d) Compare these values with the measured values by calculating % differences. Are the values in approximate agreement?

Note: Your graph of position vs. time is a parabola (at least it should be if you took the data correctly), thus one dimensional motion with constant acceleration is sometimes called parabolic motion, even though it is only one dimensional.

Additional Questions for consideration:

Checkpoint 3:

Why were the velocity and acceleration graphs not smooth when they were supposed to be?

Checkpoint 4:

Why was the acceleration fluctuating up and down so much more than the velocity when it was supposed to be constant?

Checkpoint 5:

Describe what effects the data sampling rate of 0.05 seconds has on the accuracy of the position, velocity, and acceleration.

Checkpoint 6:

Include in the write-up a brief discussion of the simple finite difference approximation for the first and second derivatives.

Checkpoint 7:

The position sensor is a sonic ranger and measures distance $x(t)$ from the round-trip time of flight of a sequence of very short acoustic pulses that are reflected from the target on the moving cart. What do you think happens when there are additional reflections from other nearby objects that are moving or stationary? Can you do a simple experiment to test your hypothesis?

Conclusion

Follow the lab report guide to write a conclusion on this lab.

Submit any excel or graphical analysis data your instructor requests along with your report.

Conclusion

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