Lab 2 - Velocity and Acceleration Pt. I

OBJECTIVES

After successfully completing this laboratory, you should be able to:

- understand the difference between instantaneous velocity and acceleration,
- understand how position, velocity and acceleration depend on time for a motion with constant acceleration,
- understand how velocity and acceleration depend on the initial velocity and the mass,
- understand how velocity and acceleration depend on the direction of the motion.

Recommended Reading: Giancoli 2.1–2.5. Walker 2.1–2.7

EQUIPMENT

You will have a 2m track, a level, 2 wooden blocks to adjust the tilt of the track, motion sensor, frictionless cart, and a 50g mass.

PROBLEM

Because of your physics background, you have a summer job with a company that is designing a new bobsled for the U.S. team to use in the next Winter Olympics. You want to know what factors contribute to the success of the team. One factor is the initial push of the team members, i.e., how fast they can push the bobsled before they jump into the sled. Another is the total weight of the team members will contribute to the success. You need to know in more detail how the initial velocity and the weight of the athletes affect the motion of the bobsled. In particular, your boss wants you to determine if the initial velocity of the sled and the weight of the team affect its acceleration down the ramp. To solve this problem, you decide to model the situation using a cart moving down an inclined track.

WARM-UP

1. Sketch a graph of instantaneous acceleration vs. time when the cart rolls down the track after an initial push (your graph should begin after the initial push.) Compare this to an instantaneous acceleration vs. time graph for a cart released from rest. (To make the comparison easier, draw the graphs next to each other.) Explain your reasoning for each graph. Write down the equation(s) that best represents each of the graphs. If there are constants in your equations, what kinematics quantities do they represent? How would you determine the constants from your graphs?
2. Write down the relationship between the acceleration and the velocity of the cart. Use that relationship to construct an instantaneous velocity vs. time graph, after an initial push, just below each of your acceleration vs. time graphs from question 1. Use the same scale for your time axes. (The connection between the derivative of a function and the slope of its graph will be useful.) Write down the equation that best represents each graph. If there are constants in your equations, what kinematics quantities do they represent? How would you determine the constants from your graphs? Can any of the constants be determined from the equations representing the acceleration vs. time graphs?

3. Write down the relationship between the velocity and the position of the cart. Use that relationship to construct a position vs. time graph, after an initial push, just below each velocity vs. time graph from question 2. Use the same scale for your time axes. (The connection between the derivative of a function and the slope of its graph will be useful.) Write down the equation that best represents each graph. If there are constants in your equations, what kinematics quantities do they represent? How would you determine these constants from your graphs? Can any of these constants be determined from the equations representing the velocity vs. time graphs?

4. Answer questions 1 through 3 for the case when the cart is released from rest but the mass of the cart is increased.

PREDICTIONS

Do you think the cart launched down the inclined track will have a larger acceleration, smaller acceleration, or the same acceleration as the cart released from rest?

Do you think that increasing the mass of the cart increases, decreases, or has no effect on the carts acceleration?

BONUS

If the bonus part is completed and written up in the report correctly, your lowest scored section of the report will be bumped up by one category (normally 1 or 2 points). The bonus part can go over 1 page limit and should be a concise (no more than 2 paragraphs) description of your results. The bonus part doesn’t have to follow a more rigid structure of the main report (overview, prediction, results, conclusion) and should be straight to the point of answering the bonus question.

During the team practice you notice that sometimes the team members push the sled up to the top of the track and let it slide to its start position. You have an intriguing idea: will the motion of the sled be affected if the team first pushed the sled up the ramp, jumped into the sled, slided to the top and then all the way down the track?

Make a rough sketch of how you expect the acceleration vs. time graph to look for a cart with the conditions discussed in the problem. The graph should be for the entire motion of going up the track, reaching its highest point, and then coming down the track.
Do you think the acceleration of the cart moving up an inclined track will be greater than, less than, or the same as the acceleration of the cart moving down the track? What is the acceleration of the cart at its highest point? Explain your reasoning.

**EXPLORATION**

Use the level to level the track by adjusting the legs of the track. You can test that the track is level by observing the motion of the cart on a level track.

Use a wooden block to slant the track at an angle.

Determine the best way to gently launch the cart down the track in a consistent way without breaking the equipment. BE SURE TO CATCH THE CART BEFORE IT HITS THE END STOP!

Where is the best place to put the motion sensor?

What is the total distance through which the cart rolls? How much time does it take? These measurements will help you to zoom in on the useful parts of the graphs on your computer.

Write down your measurement plan. Make sure to include the measurement of the cart rolling down from rest as a reference.

After completing the first set of measurements quickly devise a measurement plan for a heavier cart. Use the masses available to you.

**ANALYSIS AND RESULTS**

Choose a function to represent the *position vs. time* graph. How can you estimate the values of the constants of the function from the graph? What kinematics quantities do these constants represent? Measure the corresponding quantities and their values of the errors.

Choose a function to represent the *velocity vs. time* graph. How can you calculate the values of the constants of this function from the function representing the position versus time graph? Check how well this works. You can also estimate the values of the constants from the graph. What kinematics quantities do these constants represent? Record the corresponding kinematic quantities and the values of the corresponding errors.

Choose a function to represent the *acceleration vs. time* graph. How can you calculate the values of the constants of this function from the function representing the position versus time graph? Check how well this works. You can also estimate the values of the constants from the graph. What kinematics quantities do these constants represent? Record the corresponding kinematic quantities and the values of the corresponding errors.

From either the *position vs. time*, *velocity vs. time*, or *acceleration vs. time* graph, determine the acceleration of the initially stationary cart as it goes down the ramp. Use the correct function representing your graph to calculate the acceleration of the cart as a function of time. Record the value of acceleration and the corresponding error. Clearly explain why you have chosen a particular graph. This is your reference measurement.

From either the *position vs. time*, *velocity vs. time*, or *acceleration vs. time* graph, determine the acceleration as the cart goes down the ramp after the initial push. Use the correct function representing your graph to calculate the acceleration of the cart as a function of time. Record
the value of acceleration and the corresponding error. Clearly explain why you have chosen a particular graph and use the same method as for the reference measurement.

Repeat the analysis on the data for your heavier cart. Extract the value of acceleration of the heavier cart and corresponding error.

CONCLUSION

Look at the graphs you produced through your analysis. How do they compare to your answers to the warm-up questions and your predictions? Explain any differences. What are the limitations on the accuracy of your measurements and analysis? How can your results be improved? Which method of determining the acceleration did you find to be the most precise?

What will you tell your boss? Does the acceleration of the bobsled down the track depend on the initial velocity the team can give it? Does the velocity of the bobsled down the track depend on the initial velocity the team can give it? Does the acceleration of the bobsled down the track depend on the weight of the team members? State your result in the most general terms supported by your analysis.

Please clean up your lab area