LAB 3: VELOCITY AND ACCELERATION GRAPHS (TPL1)

Goals:

- **Investigate acceleration vs. time graphs**
- **Predict acceleration graphs from velocity graphs**
- **Investigate acceleration as slope of velocity vs. time graph**

Part 1 - Making Velocity-Time Graphs

Preliminary activities

1. Prepare equipment. Connect the motion sensor through USBLink to your laptop. It is very helpful to look at the online help page for this lab. Start the DataStudio software.

2. Load the experiment file. Download the DataStudio file **`Lab03_VelocityGraphs.ds`** from the lab schedule webpage, and open it in DataStudio.

3. Prepare program for graphing. Make sure the graph layout is set to display one graph - Velocity vs. Time. [See the graph layout help page for graphing information in DataStudio.]

4. Starting the graphing process. When you are ready, click the 

button in DataStudio to start data recording.

We will now make specific velocity-time graphs to look at changes in walking speed and direction of motion. This is an important activity, because it connects the motion with the graphical display.

A) Accelerating away. Start at 50 cm from the detector, and walk away from the detector with your speed increasing steadily. Draw the graph on the Data/Question sheets.

B) Decelerating away. Start at 50 cm from the detector, and begin to walk away quickly and then slow down and stop (speed decreasing steadily). Draw the graph on the Data/Question sheets.

C) Accelerating toward. Start at 2 m from the detector, and walk toward the detector with a speed that increases steadily. Draw the graph on the Data/Question sheets.

D) Decelerating toward. Start at 2 m from the detector, and walk toward the detector quickly at first and then slow down steadily and stop (velocity decreasing steadily). Draw the graph on the Data/Question sheets.

Part 2 - Predicting Velocity -Time Graphs

Refer to the Data/Question Sheet for this section.

Part 3 Acceleration Graphs - Cart on a Ramp

We have experienced our own human-powered velocity and acceleration curves, but it is difficult to maintain a steady acceleration. For a constant acceleration, we will turn to an inclined track and a cart that rolls up and down on it.

1. <u>Preparation.</u> Set the motion detector on the top end of the track, and clamp it in place, please refer to the pictures in the Online Help Page. Use the pole and clamp at the end of the track to raise one end – start with a low tilt to the track (about 4-5 cm from the table). When you start the cart, make sure it is at least 0.5 meters from the detector. Load the file **Lab03_CartTrack.ds** file. Make sure the time axis in the data graph is set to at least 5 seconds.

2. <u>Graphing the cart rolling down the ramp and speeding up.</u> Let the cart start from rest (0.5 meters from the sensor). Click 

and then release the cart when the clicking sound starts. Make sure that the program is graphing **before** you let go of the cart. (Also, make sure the detector doesn't "see" your hands.)

3. <u>Store graphs.</u> Your goal is to find a nice smooth graph of the motion. This means the velocity graph should have a straight-line region, and the acceleration should have a smooth horizontal region. When you have a nice clean curve, name them (such as "low tilt").

4. <u>Higher tilt to track.</u> Increase the tilt of the track a little (a few more centimeters higher at the far end). Perform the experiment again until you get a clean curve. Name this data also (named "high tilt"?).

5. <u>Sketching the graphs.</u> After you have adjusted the scales (to maximize the picture), sketch your graphs neatly on the axes shown below.

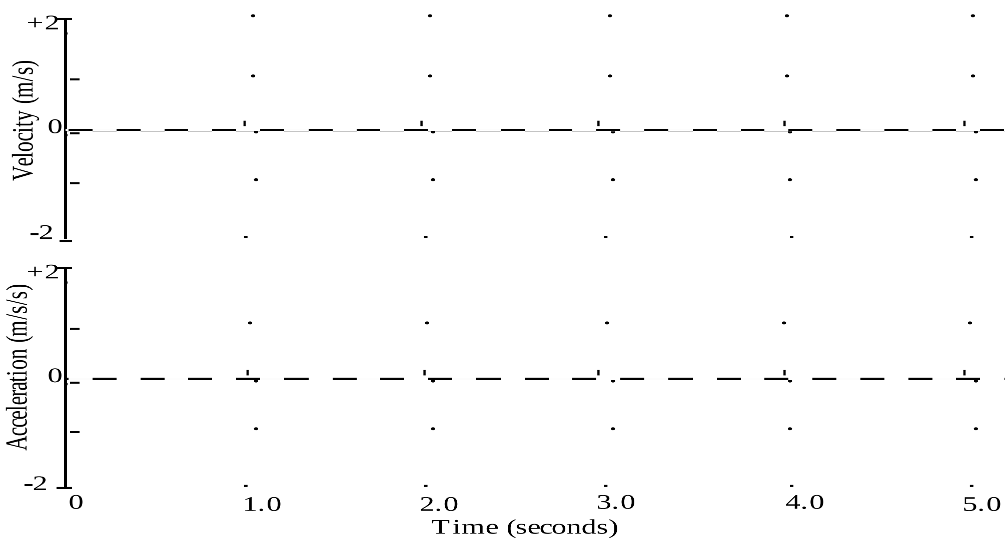


Figure 1 – Motion of a cart for two different tilts of the track

<u>Low Tilt Graph</u>

6. <u>Finding the average acceleration of the cart from your acceleration graph.</u> Under the 

menu on the graph, hide the "high tilt" run (so only the "low tilt" run is visible). Locate a region of the low tilt graph where the acceleration is reasonably constant (a horizontal section of the acceleration curve, or a straight-line portion of the velocity curve). Using the SMART TOOL , identify about 10 values (roughly equally spaced in time) of the acceleration. (Only use values from the portion of the graph after the cart was released and before it hit the end of the track -- during the constant acceleration region.)

Record these numbers on the Data/Question sheet, and then calculate the average value of the acceleration.

7. Finding the average acceleration from your velocity graph. You will calculate the slope of your velocity graph (which should be the average acceleration over that interval). Using the SMART TOOL , read the velocity and time coordinates for two typical points on the velocity graph. For a more accurate answer, use two points as far apart in time as possible but still during the time the cart was speeding up (it should be during the straight-line portion of the velocity graph. Record these values on the Data/Question sheet.

8. Find the slope (the average acceleration). Calculate the change in velocity between those two chosen endpoints. Also calculate the corresponding change in time (time interval). Divide the change in velocity by the change in time. This is the average acceleration. Show your calculations on the Data/Question sheet.

9. Calculating the "mean" acceleration. Click in the Acceleration graph, and using the SMART TOOL , select a region of the acceleration graph where the acceleration is constant (basically the same area from which you took the 10 points). Using the Σ menu on the graph – display the MEAN value for that data run. Record the mean acceleration of that "low tilt" section on the Data/Question sheet.

Questions Answer these questions on the Data/Question sheet.

a) Is the acceleration positive or negative? Is this what you expected? (Explain your answers.)

b) Does the average acceleration you just calculated agree with the average acceleration you calculated from the acceleration graph? Do you expect them to agree? How would you account for any differences? (Explain your answers.)

High Tilt Graph

10. Find the average acceleration of the cart from your acceleration graph. Hide the "low tilt" run and SHOW the "high tilt" run. Using the SMART TOOL , find 10 values during the constant acceleration region. Then calculate the average value of the acceleration on the Data/Question sheet.

11. Finding the average acceleration from your velocity graph. Calculate the slope of your velocity graph. Using the SMART TOOL , read the velocity and time coordinates for two typical points. Remember to use two points as far apart in time as possible. Record these on the Data/Question sheet.

12. Calculate the average acceleration. Following the steps in Part 5.7, calculate the average acceleration for the "high tilt" portion of the graph.

13. Calculating the "mean" acceleration. Following the steps in Part 5.8, calculate the mean acceleration for the "high tilt" portion of the graph. Record the mean acceleration on the Data/Question sheet.

Questions Answer on the Data/Question sheet.

a) Does the average acceleration calculated from velocities and times agree with the average acceleration you calculated from the acceleration graph, and the mean acceleration from the program? How would you account for any differences? (Explain your answers.)

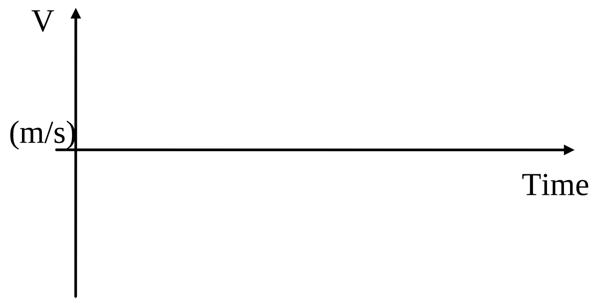
b) Compare this average acceleration to that with the Low Tilt. Which is larger? Is this what you expected? (Explain your answers.)

14. Print the "High/Low" graph. Show both runs (low and high), and print the graph from this section to include with your lab report. (See the printing with DataStudio help page for assistance.)

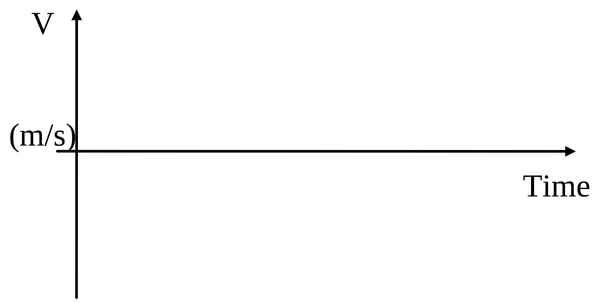
DATA/QUESTION SHEET FOR LAB 3: VELOCITY AND ACCELERATION GRAPHS

Part 1 - Making Velocity-Time Graphs

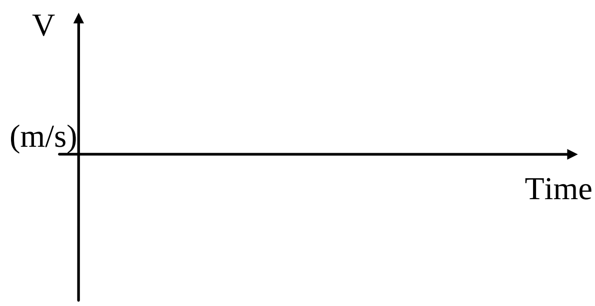
2. Accelerating away. Start at 50 cm from the detector, and walk away from the detector with your speed increasing steadily.



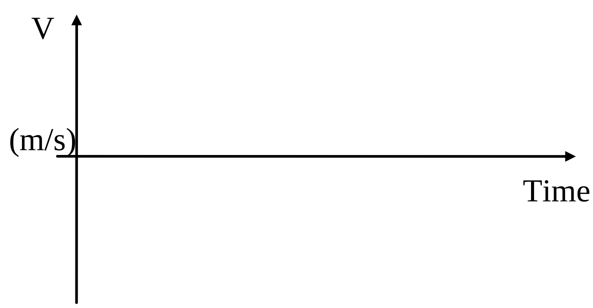
3. Decelerating away. Start at 50 cm from the detector, and begin to walk away quickly and then slow down and stop (speed decreasing steadily).



4. Accelerating toward. Start at 2 m from the detector, and walk toward the detector with a speed that increases steadily.



5. Decelerating toward. Start at 2 m from the detector, and walk toward the detector quickly at first and then slow down steadily and stop (velocity decreasing steadily).



Part 2 - Predicting Velocity-Time Graphs

Prediction Predict the graph produced when a person starts at the 0.5-meter mark, accelerates away from the detector steadily (speed increases) for 4 seconds, then slows down for 6 seconds (deceleration with a smaller magnitude than the acceleration) and stops and then accelerates toward the detector. Draw your prediction on the left graph below using a dotted line.

Compare predictions with the rest of your group. See if you all agree. Draw your group's prediction on the left graph using a solid line. (Do not erase your original prediction.) *Write the prediction* ***before*** *performing the experiment.* Points are not taken off for wrong predictions!

PREDICTION

RESULT

1. Do the experiment. Move in the way described and graph your motion. When you are satisfied with your graph, draw your group's final result on the graph on the right.

Question If the final results differed from the prediction, explain why. If the final result is the same, explain the characteristics of the graph and why you chose them.

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Part 3 Acceleration Graphs - Cart on a ramp

Low Tilt Graph

6. Finding the average acceleration of the cart from your acceleration graph. (Only use values from the portion of the graph after the cart was released and before it hit the end of the track -- during the constant acceleration region.)

Accelerations from graph (m/sec^2): _____ _____ _____ _____ _____ (These values should be
_____ _____ _____ _____ _____ very similar!)

Average acceleration (mean): ________m/sec^2 **(Low Tilt)**

8. Find the slope (the average acceleration) between two points on the velocity graph.

Point 1 Velocity _______ m/sec Time ________ sec
Point 2 Velocity _______ m/sec Time ________ sec

Change in velocity: _______ m/sec Change inTime: _______ sec

Average acceleration: _______ m/sec^2 **(Low Tilt)**

9. Calculating the "mean" acceleration.

Mean acceleration = __________ m/sec^2

Questions a) Is the acceleration positive or negative? Is this what you expected? (Explain your answer.)

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b) Does the average acceleration you just calculated agree with the average acceleration you calculated from the acceleration graph? Do you expect them to agree? How would you account for any differences? (Explain your answer.)

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High Tilt Graph

10. Finding the average acceleration of the cart from your acceleration graph.

Accelerations from graph (m/sec^2): _____ _____ _____ _____ _____ (These values should be
_____ _____ _____ _____ _____ very similar!)

Average acceleration (mean): ________m/sec^2 (High Tilt)

11. Finding the average acceleration from your velocity graph.

Point 1 Velocity _______ m/sec Time ________ sec
Point 2 Velocity _______ m/sec Time ________ sec

12. Calculate the average acceleration.

Change in velocity: _______ m/sec Change in Time: _______ sec

Average acceleration: _______ m/sec^2 (High Tilt)

13. Calculating the "mean" acceleration.

Mean acceleration = __________ m/sec^2

Questions a) Does the average acceleration calculated from velocities and times agree with the average acceleration you calculated from the acceleration graph, and the mean acceleration from the program? How would you account for any differences? (Explain your answer.)

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b) Compare this average acceleration to that with the Low Tilt. Which is larger? Is this what you expected? (Explain your answers.)

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Return equipment to instructor and to the box from where you have removed it. Please insure a good experience for the next lab group by cleaning up your lab station.

Questions/Suggestions → Dr. Changgong Zhou – czhou@ltu.edu