SP211 Lab 1
Calculus in Motion: Graphical 1D Kinematics

Equipment

You will need the following equipment to complete this lab. Quantities needed are listed inside of the parenthesis.

LabQuest Mini (1)
Motion Sensor (1)
Cart (1)
Track (1)
Fan (1)
Small Harmonic Spring (1)
Table Clamp with Long Rod and Spring Holder (1)
Rubber Stopper with Hook (1)

You will also need the Vernier Graphical Analysis software, which can be downloaded here or from the Software Center, and Google Gemini to complete this lab.

Experiment 1: Using the Motion Sensor to Understand Position, Velocity, and Acceleration

1) Connect the motion sensor to the LabQuest Mini and the LabQuest Mini to your computer. Open the Vernier Graphical Analysis software. The software should automatically detect the motion sensor and display appropriate graphs. The motion sensor will also slowly click and display a green light when connected to the software correctly.

2) On the motion sensor, make sure the switch set to the position showing the person and basketball (not the cart).

3) Play around collecting data with the motion sensor while you walk towards and away from it at different speeds until you are comfortable with how different scenarios are displayed on the position and velocity graphs. In particular, ask yourself "Does position increases or decreases on the plot as you walk toward and away from the motion sensor? What does slow versus fast look like?" Once you believe you understand what differing scenarios look like on the graphs, use Figure 1 to answer Questions 1 through 4 on the attached worksheet.

4) Take your own data to qualitatively reproduce the graph displayed in Figure 2. You may want to lengthen the amount of time for which the motion sensor takes data. To do so,

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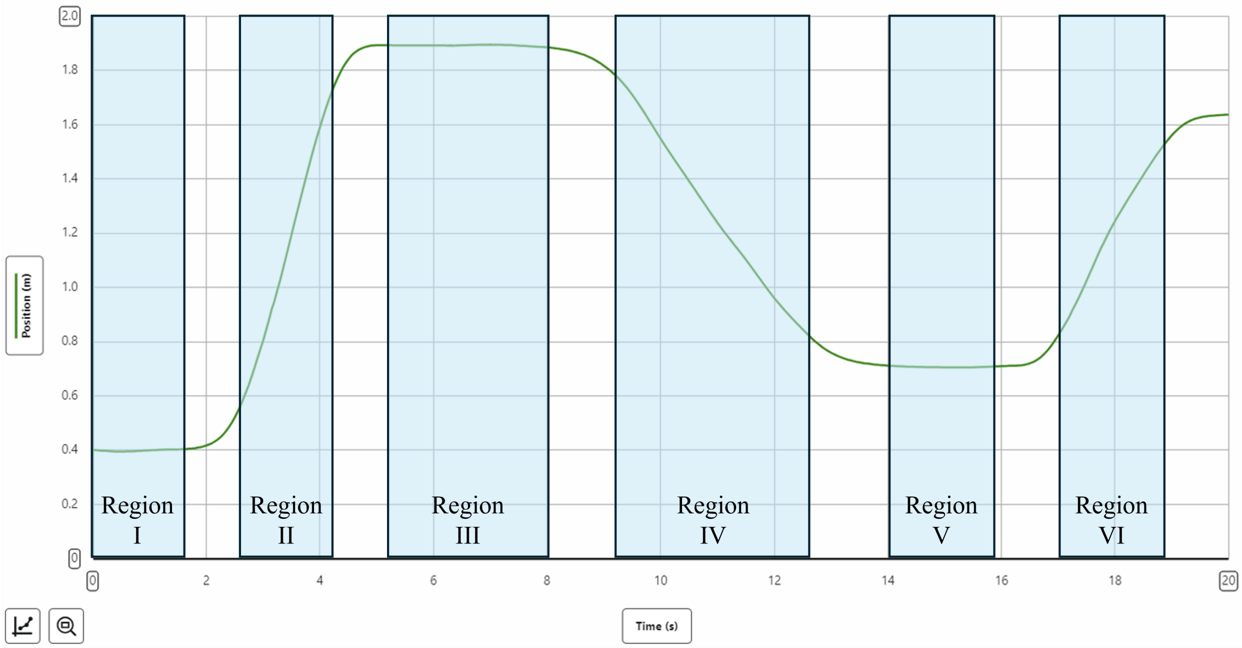

Figure 1: A plot of position versus time taken of a person moving towards and away from a motion sensor. Six different regions are highlighted in light blue.

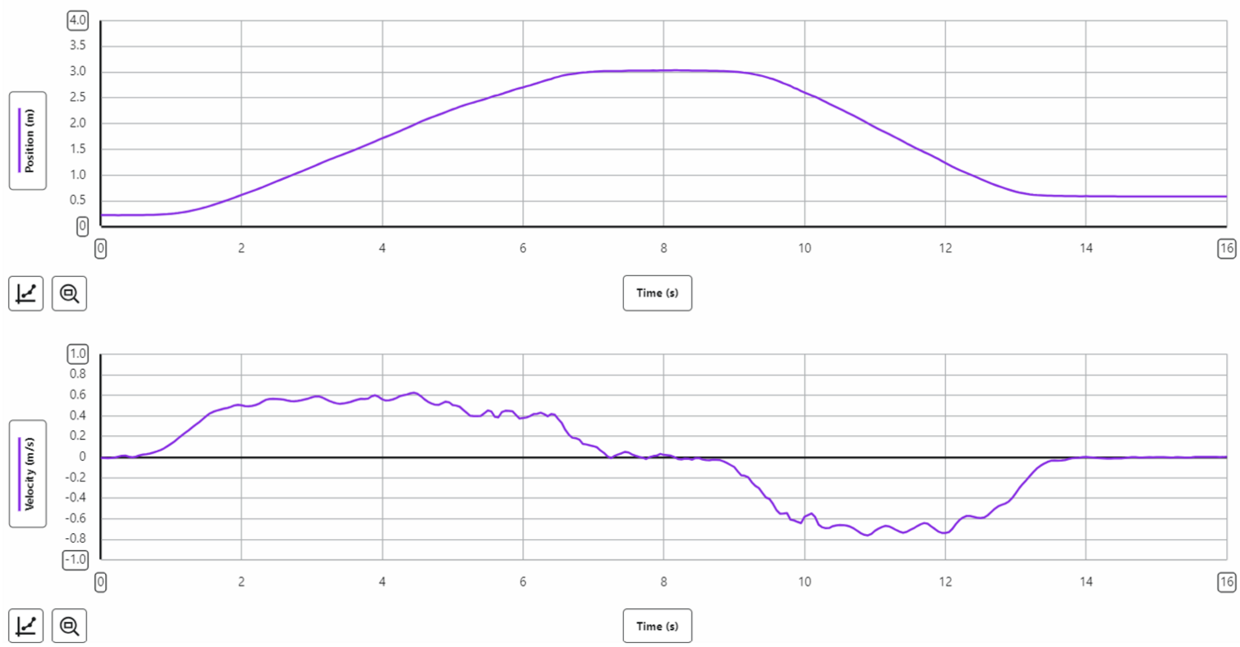

Figure 2: Plots of position (top) and velocity (bottom) versus time taken of one of your instructors walking away from the motion sensor and then toward the motion sensor. Note, you can see this professor's steps as small squiggles in the velocity data.

click on the Mode/Rate button in the lower left corner (see Figure 3) and change the "End Collection" time. It should be very clear from the graph when you are moving and when you are stopped with little to no noise. You may wish to change the scaling on the axes by clicking on their minimum and maximum numbers. Use your data to answer Questions 5 through 7 on the attached worksheet.

Figure 3: The red oval indicates where to click to change the collection settings for the motion sensor. The arrow points towards where additional graphs and data tables can be added to the display.

5) Cut and paste your velocity versus time data into Google Gemini. You can access the table of your data by clicking on the boxes in the upper right hand side of the window (see Figure 3). Make sure it understands the quantities you gave it and their units. Use your uploaded data to answer Questions 8 and 9 on the attached worksheet.

CHECK POINT: ☐

Experiment 2: Kinematics with a Constant Acceleration

1) Add an acceleration graph to what is displayed in the Vernier Graphical Analysis software by clicking on the boxes in the upper right hand side of the window (see Figure 3).

2) Change the setting on the motion sensor to the cart and place it at one end of a horizontal level track. Attach the fan to the cart and place the cart on the track so that the fan pushes the cart away from the motion sensor while you are collecting data. Please catch the cart and fan before they fall to the floor. Keep adjusting your setup and retaking data until you feel you have collected good data, with little noise.

3) Use your collected data to answer Questions 10 through 13 on the attached worksheet.

CHECK POINT: ☐

5-day section break point ____________________

Experiment 3: Kinematics with a Non-constant Acceleration

1) Change the setting on the motion sensor back to the person and place it on the floor directly underneath a rubber stopper hanging from a spring.

2) Collect data of the stopper bouncing up and down. Keep retrying this until you get clean data of several bounces. Small bounces work better than large bounces.

3) Use your collected data to answer Questions 14 through 16 on the attached worksheet.

CHECK POINT: ☐

Clean Up

Please return your lab station and the drawer of equipment to a clean and organized form. Follow any directions your instructor gives you about where to return equipment to when you are finished with the lab.

LAB 1 Worksheet

Name(s) and Alpha(s) Date

Experiment 1: Using the Motion Sensor to Understand Position, Velocity, and Acceleration

Question 1: Figure 1 displays a graph of data taken while a person walked towards and away from a motion sensor. Identify in which region(s) of the graph the person is walking

(a) toward the motion sensor

(b) away from the motion sensor

(c) stopped

(d) the fastest

(e) the slowest

Question 2: Using your equation sheet and your knowledge of velocity, estimate what the average velocity of this person was in regions II, IV, and VI. Include whether those velocities are positive or negative.

Question 3: On the graph paper below, sketch what the velocity graph should look like for the data displayed in Question 1. Make sure you include important parts of the graph: draw in and label axes, include units where appropriate, etc.

Question 4: Does a negative velocity correspond to a person walking away from the motion sensor or towards the motion sensor?

Question 5: Using your collected data, calculate your total displacement. Show your work.

Question 6: Using your collected data, calculate the total distance you walked. Show your work.

Question 7: Using your velocity graph and your equation sheet, predict the at which times the magnitude of your average acceleration was greatest.

Question 8: In class we learned that velocity is the derivative of position and acceleration is the derivative of velocity. Therefore, one must integrate to go the opposite direction mathematically. Have Google Gemini determine the distance you traveled and your total displacement from the velocity data you uploaded. Work with Google Gemini until both you and the computer agree on your displacement and the distance you traveled. Hint: Think about what it means graphically to integrate and ask Google Gemini to perform that mathematical operation.

(a) What distance did Google Gemini determine you traveled?

(b) What did Google Gemini determine your displacement was?

(c) If the output from your first attempt to get Google Gemini to determine the distance you traveled and your displacement didn't match your answer to Questions 5 and 6, what went wrong?

Question 9: Have Google Gemini generate a graph of your acceleration versus time from the data you uploaded. Digital data is inherently noisy and you may need to ask Google Geminit to smooth it.

(a) At what times was the magnitude of your acceleration the greatest according to Google Gemini?

(b) Did you predict the correct times in Question 7? Do you believe Google Gemini's acceleration graph? Why or why not?

(c) In terms of velocity, what were you physically doing when you accelerated the most?

Experiment 2: Kinematics with a Constant Acceleration

Question 10: The motion of the fan pushing the cart should be smooth, but your graph likely begins and ends abruptly with strange recorded behavior. What specific events correspond to the ends where the behavior isn't smooth?

Question 11: Qualitatively, what happened to the cart's velocity and what kind of mathematical function describes that behavior?

Question 12: Calculate the slope of the velocity graph using two data points that are far apart and record it here. What is the physical meaning of this slope?

Question 13: Copy and paste your position, velocity, and acceleration versus time data into Google Gemini and make sure it understands the quantities and their units.

(a) Work with Google Gemini to determine the average acceleration of your data that was taken between the two points in time you used in Question 12. Record that value here and explain why you are satisfied that it produced the correct number.

(b) Ask Google Gemini to fit a polynomial curve ($x(t) = At^2 + Bt + C$) to your position data between the two points you used in Question 12. Have it make a plot of its fit equation over top of the original data. Work with Google Gemini until you are satisfied with the fit displayed in the plot. Once you are satisfied, have Google Gemini output the A, B, and C coefficients from the fit and record them here. What equation(s) on the equation sheet have the same form as the equation from Google Gemini?

(c) How does the A coefficient, your answer to part (a) of this question, and your answer to Question 12 relate to each other?

Experiment 3: Kinematics with a Non-constant Acceleration

Question 14: Find a time when the acceleration of the mass is at a maximum.

(a) Considering the range in possible positions for the mass, where qualitatively is the mass at this point in time?

(b) What is the velocity of the mass at this point?

Question 15: Find a time when the velocity of the stopper is at a maximum.

(a) Considering the range in possible positions for the mass, where qualitatively is the mass at this point in time?

(b) What is the acceleration of the mass at this point?

Question 16: Copy and paste your position versus time data into Google Gemini. Ask Google Gemini to fit a function to this dataset and record that function here. Is it a polynomial?