University of Calgary
Department of Physics and Astronomy
PHYS 211/221, Fall 2016

Labatorial 2: Measuring Motion

Preparation:
Read Knight (3rd ed.) Sections 1.1-1.6, 2.1, 2.2, 2.4

Equipment:
Vernier capable computer, Vernier motion sensor, metre stick, and 1D_Motion.cmbl.

Overview:
This labatorial will explore one-dimensional motion, position, velocity, and acceleration graphs, and the relationships between these graphs.

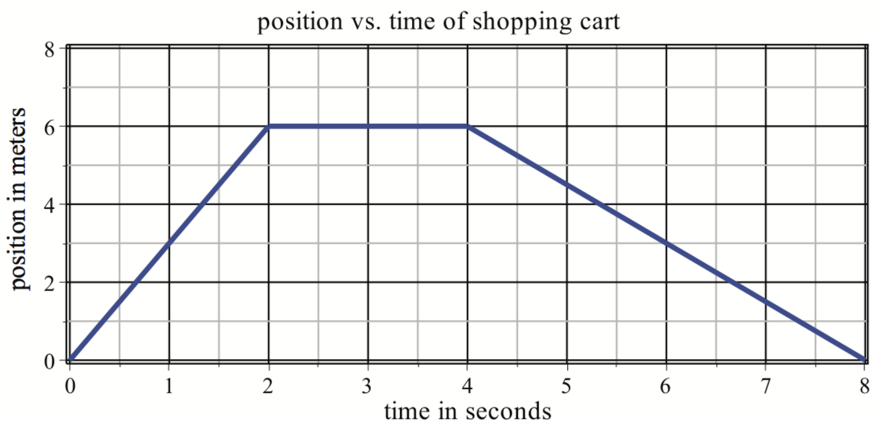
1 Position, velocity, and acceleration

Imagine you just finished stocking up on household goods at Wal-Mart and are leaving the store pushing your shopping cart to your car. As you leave the store entrance, the security alarm goes off. Having “accidentally” put a chocolate bar you didn’t pay for in your cart, you decide to ignore the alarm until a security guard requests you return to the store. At this point you stop, consider your options, and then reluctantly return. Table 1 gives the position s of your shopping cart relative to the store entrance at different moments in time t starting from when you first leave the store. Examine the data in the table, then look at the graphical representation of this data in Figure 1. Note that time is measured in seconds and position is measured in metres.

Table 1: Position vs. time of shopping cart

t (time in seconds)	s (position in m)
0	0
1	3
2	6
3	6
4	6
5	4.5
6	3
7	1.5
8	0

We will represent this one-dimensional motion with the time t on the horizontal axis and the position s on the vertical axis, as shown in the graph below. Note that this convention may be backwards from what you’re accustomed to but the purpose should become more apparent later in the labatorial.



Question 1: What is the displacement of the cart in the interval from 0 seconds to 2 seconds (include units)?

Question 2: Calculate the ratio of the displacement from Question 1 to the time interval over which that displacement occurred (include units).

Question 3: What is the displacement of the cart in the interval from 1 second to 2 seconds (include units)?

Question 4: Calculate the ratio of the displacement from Question 3 to its time interval (include units).

Question 5: What is the displacement of the cart in the interval from 1.5 seconds to 2 seconds?

Question 6: Calculate the ratio of the displacement from Question 5 to its time interval (include units).

Question 7: What do you notice about the ratio of displacement to time interval for shorter and shorter intervals?

Question 8: In the limit as the time interval gets smaller and smaller does this ratio ever change?

Question 9: What is another name for this ratio of displacement to the time interval?

Question 10: Why would "uniform motion" be a good name for the cart's motion from 0 to 2 seconds?

CHECKPOINT 1: Before moving on to the next part, have your TA check the results you obtained so far.

Question 11: The ratio $\frac{\Delta s}{\Delta t}$ in Question 9 gives the average velocity, while $\lim_{\Delta t \to 0} \frac{\Delta s}{\Delta t}$ gives the instantaneous velocity. How does the instantaneous velocity compare to the average velocity in the time interval between 0 and 2 seconds?

Question 12: Describe the motion of the shopping cart between 2.1 and 3.6 seconds. Would you say that the motion is uniform? Explain.

Question 13: For this time interval, how does the slope of the graph compare to the average velocity? Does this make sense?

Question 14: What is the average velocity, v_{avg}, for the time interval from 1 to 3 seconds? Would you say that the motion is uniform? Explain.

Question 15: Does the average velocity for the time interval from 1 to 3 seconds correspond to the instantaneous velocity, v_{inst}, at any particular moment of time? Explain.

Question 16: What is the average velocity of the cart over the entire 8 seconds?

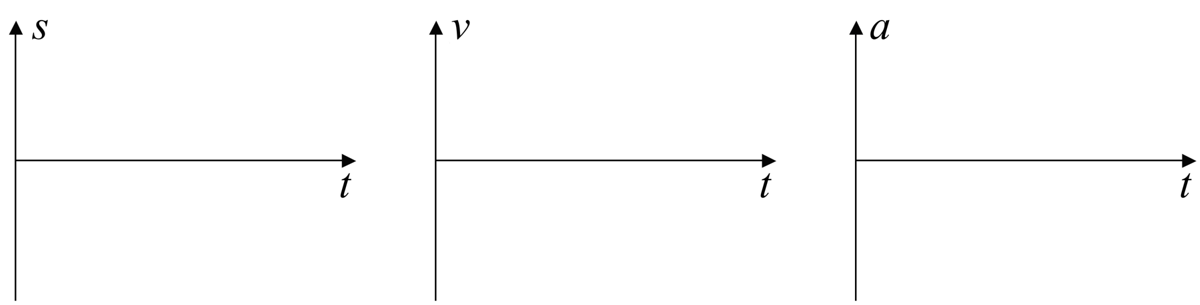
Question 17: Some high school physics textbooks use the expression: $v = \frac{s}{t}$ for velocity. Explain why using Δs and Δt instead of s and t is more accurate.

Question 18: Why would using the expression $v = \frac{s}{t}$ for velocity give the wrong answer for any moment in time greater than 2 seconds?

CHECKPOINT 2: Before moving on to the next part, have your TA check the results you obtained so far.

2 Constant Position

Question 19: Suppose an object has a constant, non-zero position. In the graphs below draw your predictions for the position, velocity, and acceleration of the motion of this object.



Question 20: Open the file "1D_Motion.cmbl" and place a textbook at a constant and non-zero position in front of the motion sensor, then press the "Collect" button: . The computer might prompt you to erase the old data and continue (erasing the old data is fine). Copy the computer generated graphs onto the same graphs that you put your predictions on, but in a different colour.

Question 21: Describe how you gave the textbook the motion to produce these three graphs.

Question 22: Explain how the data you collected match your predictions, as well as any differences from your predictions.

Question 23: Imagine two cars, car A and car B, driving on a highway. Car A pulls into the left lane to pass car B. At the moment that car A just overtakes car B, which quantity must be the same for the two cars: position, velocity, or acceleration? Explain why.

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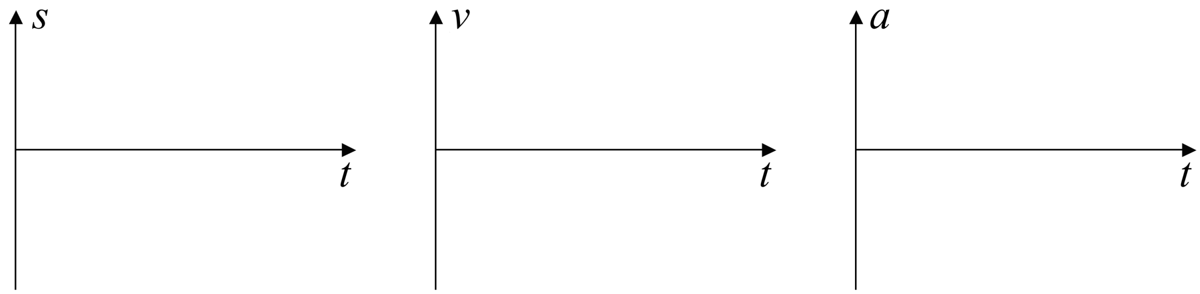
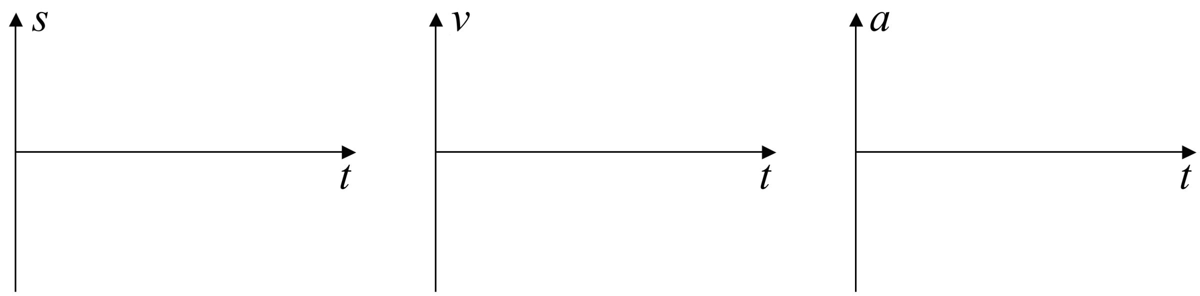
3 Constant Velocity

Question 24: Now assume that the textbook has a constant non-zero velocity. In the graphs below draw your predictions of the three graphs that represent motion with a constant non-zero velocity.



Question 25: Now select a different member of your group to hold the textbook in front of the motion sensor, and a different member of the group to operate the software. Press "Collect" and move the textbook with constant velocity. Observe the graphs generated and repeat this step if necessary. Copy the graphs generated from your data below.



Question 26: Describe how you gave the textbook this motion to produce these three graphs and explain any discrepancies between the data you collected and your predictions.

Question 27: The LoggerPro software can be used to find the best fit line to the data in a graph. To do this, click on the position vs. time graph and drag the cursor to select a desired time interval, then go to Analyze $\rightarrow$ Linear Fit. Write the equation of the best fit line in the form $s = mt + b$, where the values of m and b are found from the linear fit.

Question 28: Pick two rows from the data columns on the left of the screen and measure the average velocity. State the data points you used and show how you calculated the average velocity.

Question 29: Does the slope of the best fit line agree with this average velocity? Why, or why not? Show **how** you determined whether the two values agree.

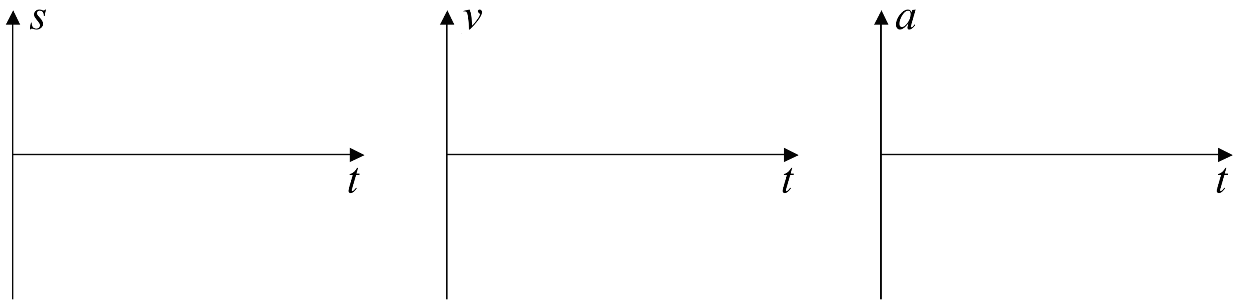
Question 30: Which direction is positive for your motion sensor, towards the motion sensor or away from it? Explain how you know.

Question 31: Where is the origin of the motion sensor? Explain how you know.

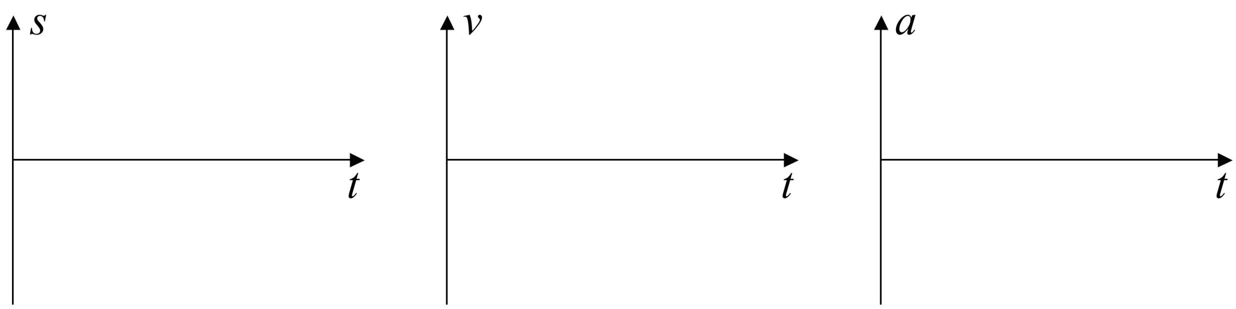
CHECKPOINT 3: Before moving on to the next part, have your TA check the results you obtained so far.

4 Constant Acceleration

Question 32: Now predict what the position, velocity, and acceleration graphs will look like for a constant non-zero acceleration. Draw your predictions on the axes below.



Question 33: Now select a different member of your group to hold the textbook in front of the motion sensor, and a different member of the group to operate the software. Press "Collect" and move the textbook with constant acceleration. Observe the graphs generated and repeat this step if necessary. Copy the graphs generated from your data below.



Question 34: Describe how you gave the textbook this motion to produce these three graphs and explain any discrepancies between the data you collected and your predictions.

Question 35: Select an appropriate time interval and find the best fit line to the velocity vs. time graph. Write the equation of the best fit line in the form $v = mt + b$.

Question 36: Highlighting a range of data on a graph and clicking the 

button will return various statistics of the data, including the mean over the selected range. Highlight the acceleration data and find the mean. Compare this average acceleration with the slope from Question 35.

Question 37: Does the slope of the best fit line agree with this average acceleration? Why, or why not? Show **how** you determined whether the two values agree.

Last Checkpoint! Clean up your area, and put the equipment back the way you found it. Call your TA over to check your work and your area before you can get credit for the labatorial.