Unit 3 Homework Problems

Learning Goals:

F.3 Describe motion from position and velocity vs. time graphs in words, and vice-versa, using terms like standing still, constant speed, speeding up, slowing down, and moving in the positive or negative direction.

- *Complete HOMEWORK FOR UNIT* 3: *INTRODUCTION TO MOTION*, a .pdf file included on the homework web page with this assignment. Please answer the questions on the assignment itself, instead of on a separate sheet of paper.
- *Complete HOMEWORK FOR UNIT* 3: *CHANGING MOTION*, a .pdf file included on the homework web page with this assignment. Please answer the questions on the assignment itself, instead of on a separate sheet of paper.

3.1) Problem 3.9.1 from the Activity Guide.

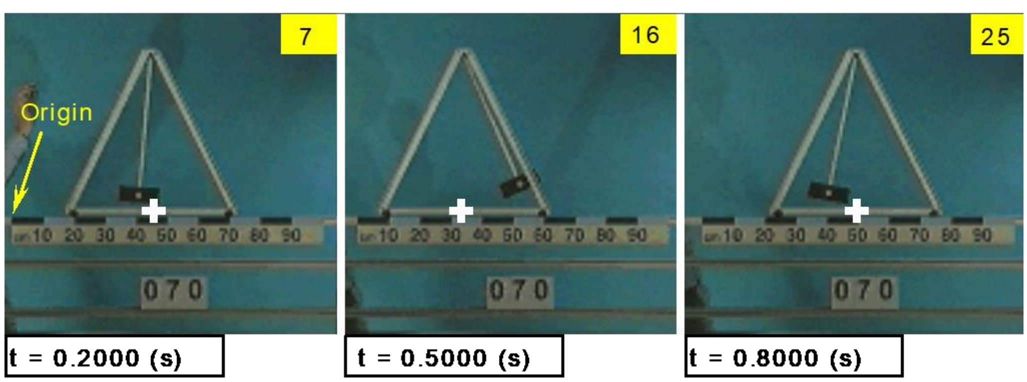
(a) Since we aren't doing calculus in this course, the two general expressions for part (a) are:

$$v(t) = \left(+0.126\,\frac{\mathrm{m}}{\mathrm{s}^2}\right) t + \left(+0.022\,\frac{\mathrm{m}}{\mathrm{s}}\right)$$

$$a(t) = \left(+0.126\,\frac{\mathrm{m}}{\mathrm{s}^2}\right)$$

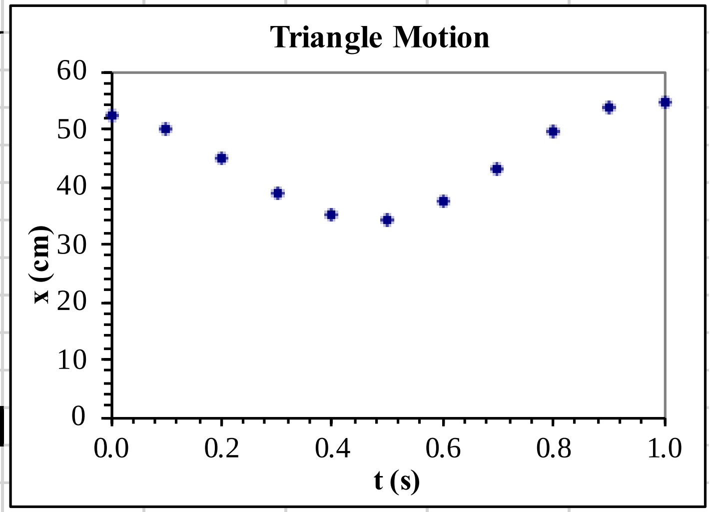
3-2) After doing a number of the exercises with carts and fans on ramps, it is easy to draw the conclusion that everything that moves is moving at either a constant velocity or a constant acceleration. Let's examine the horizontal motion of a triangular frame with a pendulum at its center that has been given a push. It undergoes an unusual motion and we would like you to determine whether or not it is moving at either a constant velocity or constant acceleration. (**Optional**: You may want to look at the motion of the triangular frame. The video (pasco070.mov) is available on the homework web page where you found this assignment.)

The images that follow are taken from the seventh, sixteenth, and twenty-fifth frames of the movie.



Your instructor collected data from the movie (what a nice person) for the position of the center of the horizontal bar of the triangle (shown as a white plus in the figure above). Data were taken every tenth of a second during its first second of motion. The origin was placed at the zero centimeter mark of a fixed meter stick. These data are shown in the figure that follows.

t **(s)**	***x*** **(cm)**	***t*** **(s)**	v_{avg} **(cm/s)**
0.000	52.1	0.050	
0.100	50.0	0.150	-53.0
0.200	44.7	0.250	
0.300	38.8	0.350	
0.400	35.0	0.450	
0.500	34.4	0.550	
0.600	37.3	0.650	
0.700	43.0	0.750	
0.800	49.4	0.850	
0.900	53.8	0.950	
1.000	54.6		



(a) Examine the position vs. time graph of the data shown above. Does the triangle appear to have a constant velocity throughout the first second? A constant acceleration? Explain the reasons for your answers.

(b) Discuss the nature of the motion based on the shape of the graph. At approximately what time, if any, is the triangle changing direction? At approximately what time does it have the greatest speed in the negative direction? The greatest speed in the positive direction? Explain the reasons for your answers.

(c) Use the data table and the definition of average velocity to calculate the average velocity of the triangle at each of the "halfway" times between t_1 = 0.000 s and t_{11} = 1.000 s. In this case you should use the method we used in class in Activity 3.7.2 and use the position just before the indicated time and the position just after the indicated time in your calculation. For example, to calculate the average velocity at $t_{1.5}$ =0.050 seconds, use x_2 = +50.0 cm and x_1= +52.1 cm along with the differences of the times at t_2 and t_1 A sample calculation of the average velocity at $t_{6.5}$ =0.55 seconds (halfway between t_6 = 0.500 s and t_7 = 0.600 s) is given by

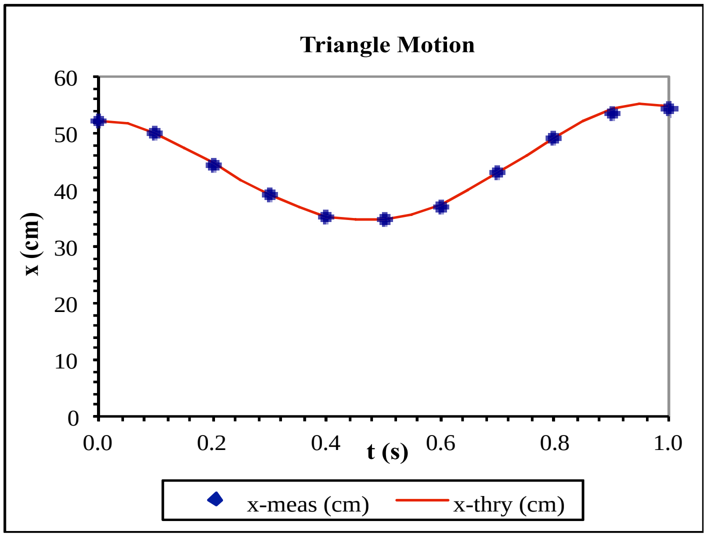
$$\langle v_{6.5}\rangle = \frac{x_7 - x_6}{t_7 - t_6} = \frac{(+37.3\text{ cm}) - (+34.4\text{ cm})}{0.600\text{ s} - 0.500\text{ s}} = +29.0\ \frac{\text{cm}}{\text{s}}$$

You should use a spreadsheet for your calculations and submit a printout of the results! An *Excel* file of the data is available on the homework web page where you found this assignment.

(d) Since people usually refer to velocity as being distance over time, it would be a lot easier to calculate the average velocities as simply x_1/t_1, x_2/t_2, x_3/t_3, etc. Is this an equivalent method for finding the velocities at the different times? Try using this method of calculation if you are not sure. Give reasons for your answer.

(e) Often when an oddly shaped but reasonably smooth graph is obtained from data it is possible to fit a polynomial to it. For example, a fifth order polynomial that fits this data pretty well is

$$x = \left(+38.5\frac{\text{cm}}{\text{s}^5}\right)t^5 + \left(-472\frac{\text{cm}}{\text{s}^4}\right)t^4 + \left(+803\frac{\text{cm}}{\text{s}^3}\right)t^3 + \left(-376\frac{\text{cm}}{\text{s}^2}\right)t^2 + \left(+9.25\frac{\text{cm}}{\text{s}}\right)t + 52.1\text{cm}$$



We can then find a polynomial for the *instantaneous* velocity by taking the time derivative of the position. I've already done this for you; the result is given by

$$v_x = \left(+193\frac{\text{cm}}{\text{s}^5}\right)t^4 + \left(-1890\frac{\text{cm}}{\text{s}^4}\right)t^3 + \left(+2410\frac{\text{cm}}{\text{s}^3}\right)t^2 + \left(-752\frac{\text{cm}}{\text{s}^2}\right)t + 9.25\frac{\text{cm}}{\text{s}}$$

Using this polynomial approximation, find the *instantaneous* velocity at $t = 0.350$ s. Please show your work carefully. Comment on how the instantaneous velocity compares to the average velocity you calculated at 0.350 s in part (c), using the spreadsheet. Are the two values close? Is that what you expect? (*Finding the % difference or % discrepancy is a good way to compare the two values.*)