Unit 3 Homework Problems

- *Complete HOMEWORK FOR UNIT 3: INTRODUCTION TO MOTION,* a .pdf file included on the homework web page with this assignment. You may have to return to the classroom outside of class time to complete the activities, but this problem and the rest of the homework can be done anywhere.

- *Complete HOMEWORK FOR UNIT 3: CHANGING MOTION,* a .pdf file included on the homework web page with this assignment. You may have to return to the classroom outside of class time to complete the activities, but this problem and the rest of the homework can be done anywhere.

3-1) One of the great folk legends in Physics is that of Galileo in the 16th century dropping a wood ball and an iron ball from the top of the Leaning Tower of Pisa to refute an Aristotelian belief that heavier objects fall faster. Although historical research indicates that this event probably never took place, the Tower itself is an interesting and famous work of architecture. It has a lean that is increasing slowly over the years as a result of the ground under one side settling faster than the ground on the other side. The following photograph of the tower was taken from an advertisement found in a 1994 airline magazine. Note that the photo of the man talking on the telephone to the left is not part of the original photograph.

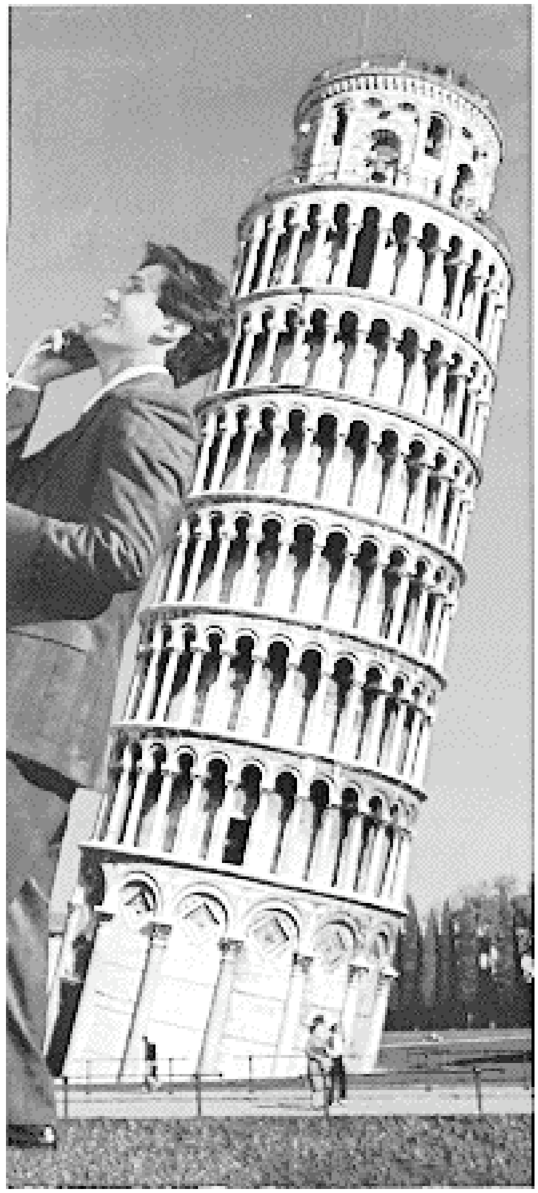
(a) Examine the photograph. Take the measurements in centimeters that are needed to find a scale factor that enables you to estimate the length of the Tower in meters (i.e. its height if it were standing up straight.) Use only evidence in the photograph. No other data are allowed. Then estimate the tower length in meters.

(b) According to data published in Sir Bannester Fletcher's <u>A History of Architecture</u> (U. of London Athlone Press, 1975, p. 470) the diameter of the lower part of the Tower is 16.0 m. Using this data find another scale factor for estimating the length of the tower, and then re-estimate the length of the tower using this new scale factor.

(c) Which of the scale factors (a) or (b) do you think will give the best estimate of the length of the Tower? Explain the reasons for your answer.

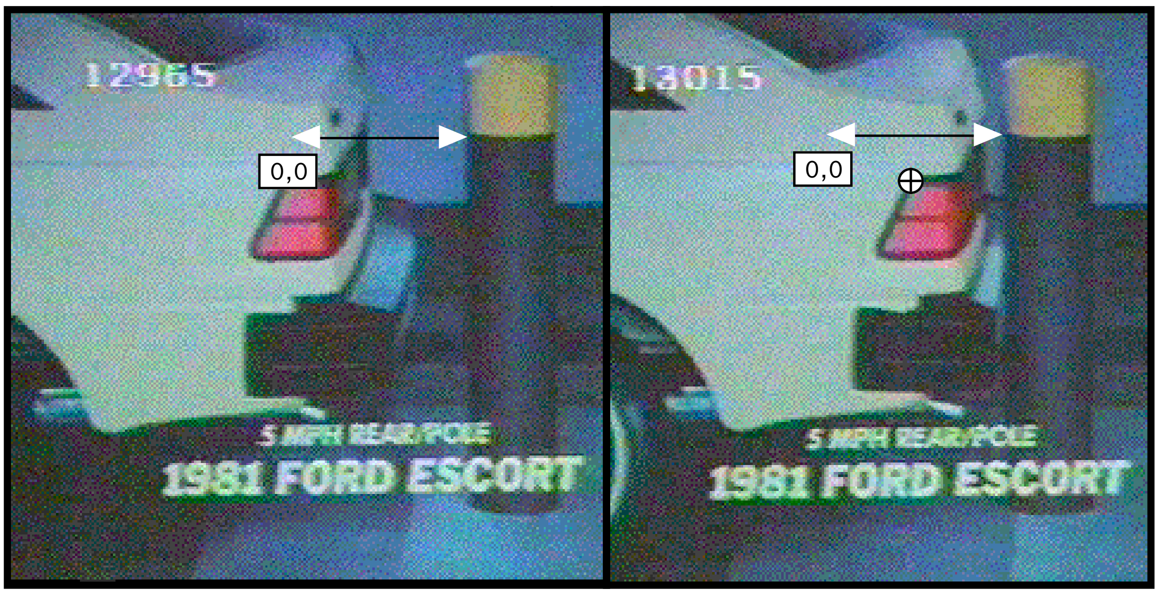
(d) Using the scale factor you found in part (b) what is the length of the Tower without the Belfry or narrow top segment. (i.e. just consider the bottom 7 stories.)

(e) Based on data also reported by Fletcher the top of the wide part of the Tower (with the narrow top segment omitted) overhangs the bottom by 4.2 meters as of 1975. Question: Is the lean of the tower exaggerated in the photo used in the ad? Are the little people in front of the tower dubbed in? Discuss this question and provide appropriate calculations and/or measurements to support your opinions.



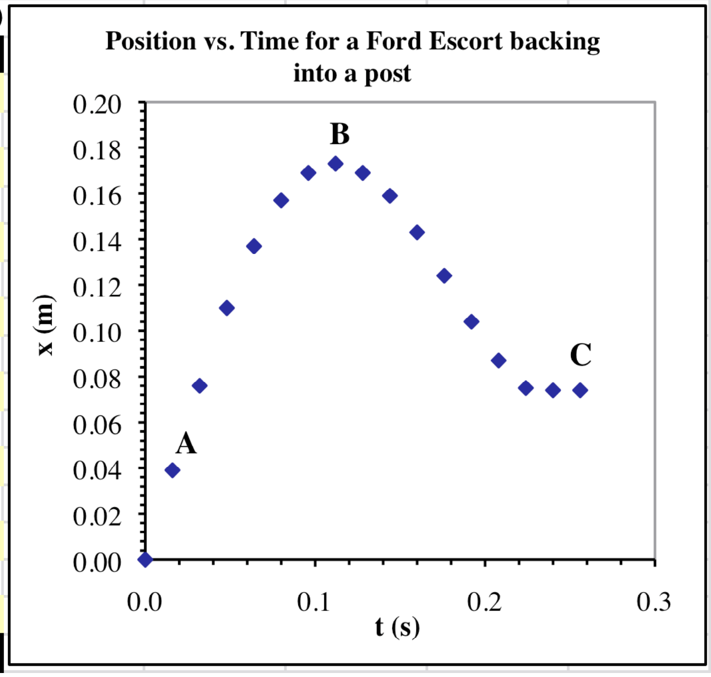
3-2) After doing a number of the exercises with carts and fans on ramps, it is easy to draw the conclusion that vehicles like the carts always move either at constant velocity or a constant acceleration. Let's examine the motion of a car undergoing a low velocity collision to see if it is moving at either a constant velocity or constant acceleration. The Ford Motor Co. has arranged to test the resiliency of the rear bumper on its 1981 Escort. The Escort is backed into a 3" high concrete filled metal post at approximately 5 mph. This collision is filmed at 500 frames per second.* (Optional: You may want to look at the slow motion film of the collision using the *VideoPoint* Software. To do this, open the movie entitled Bumper. (C:/Physics/Movies/Unit 3/bumper.mov) The video is also available on the homework web page where you found this assignment.

In the first view shown below the rear bumper is several inches away from the post and in the last view 50 frames later (i.e. 0.100 seconds later) the rear bumper has already hit the post and is compressing.



Your instructor collected data from the movie for the location of the top left corner of the Escort's tail light as the car moved from left to right toward its collision with the post. These data have been "idealized" a bit for clarity. The origin was fixed as the location of the upper left corner of the tail light in the first frame of the movie. Data were taken from every 8th frame of the 500 frames/second movie so the elapsed time between one frame and the next is only 0.016 s. These data are shown in the figure that follows.

t (s)	*x* (m)	v_{avg} (m/s)
0.000	0.000	
0.016	0.039	
0.032	0.076	2.22
0.048	0.110	
0.064	0.137	
0.080	0.157	
0.096	0.169	
0.112	0.173	
0.128	0.169	
0.144	0.159	
0.160	0.143	
0.176	0.124	
0.192	0.104	
0.208	0.087	
0.224	0.075	
0.240	0.074	
0.256	0.074	



(a) Examine the position vs. time graph of the data and discuss its characteristics: (1) Does the graph show the car having a constant velocity between t= 0.000 s and t= 0.300 s. Why or why not? (2) Does the graph show the car having a constant acceleration between t= 0.000 s and t= 0.300 s. Why or why not? (3) Describe what you think the car is doing at points A, B. and C on the graph.

(b) Use the data table and the definition of average velocity to calculate the average velocity of the car at each of the times between 0.016 s and 0.240 s. In this case you should use a "leap frog" method 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_2 =0.016 seconds, use x_3 = 0.076 m and x_1= 0.000 m along with the differences of the times at t_3 and t_1 Hint: Only use times and positions in the gray boxes to get a velocity in a yellow box and only use times and positions in the white boxes to get a velocity in a white box. A sample calculation of the average velocity at t_3 =0.032 seconds is given by

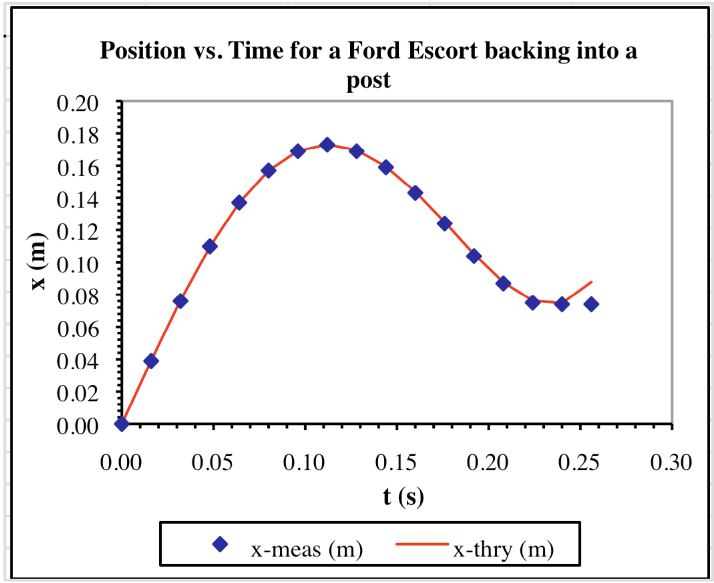
$$\langle \vec{v} \rangle = \frac{0.110\text{ m}\,\hat{x} - 0.039\text{ m}\,\hat{x}}{0.048\text{ s} - 0.016\text{ s}} = 2.22\,\frac{\text{m}}{\text{s}}\,\hat{x}$$

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.

(c) 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.

(d) 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 fourth order polynomial that fits this data pretty well (except at the last two times) is given by

$$\vec{x} = \left(342\frac{\text{m}}{\text{s}^4}\hat{x}\right)t^4 - \left(127\frac{\text{m}}{\text{s}^3}\hat{x}\right)t^3 + \left(1.87\frac{\text{m}}{\text{s}^2}\hat{x}\right)t^2 + \left(2.45\frac{\text{m}}{\text{s}}\hat{x}\right)t$$



We can find a polynomial for the *instantaneous* velocity by taking the time derivative of the position. The result is given by

$$\vec{v} = \left(1368\frac{\text{m}}{\text{s}^4}\hat{x}\right)t^3 - \left(381\frac{\text{m}}{\text{s}^3}\hat{x}\right)t^2 + \left(3.74\frac{\text{m}}{\text{s}^2}\hat{x}\right)t + 2.45\frac{\text{m}}{\text{s}}\hat{x}$$

Using this polynomial approximation, find the *instantaneous* velocity at t =0. 064 s. Please show your work carefully. Comment on how it compares to the average velocity you calculated at 0. 064 s. Are the two values close? Is that what you expect? *(Finding the % difference or % discrepancy, as described in the Contest Rules in Activity 2.3 in the Activity Guide, is a good way to compare the two values.)*

The most significant thing about this particular test is that both the bumper and the car survive the collision at 5 MPH. Later in the course you can use the same data to learn about the forces involved in the collision. This is important to know in bumper design.

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1 * The Ford Escort collision images were obtained from a videodisc entitled *Physics and Automobile Collisions* published by John Wiley & Sons.