 Name:_____

Date:_____

Velocity Change

Analyzing Position vs. Time Graphs: The most fundamental measurements of motion involve the determination of an object's location at a series of times. A very effective way to represent these measurements is to plot graphs of an object's position and velocity as a function of time. Learning to relate an x vs. t graph or a v_x vs. t graph to what a motion looks like and being able to extract both qualitative and quantitative information from the graphs are vital tools for studying motion.

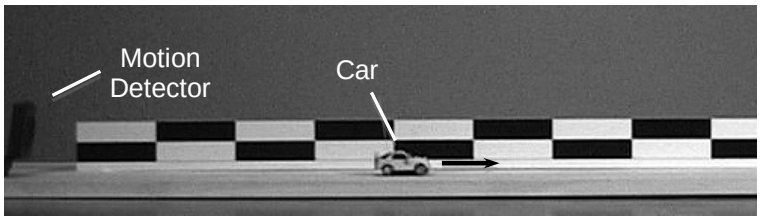


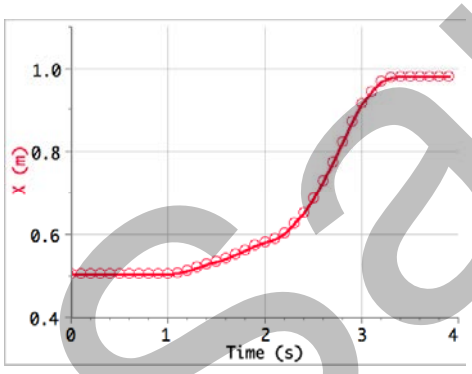
Figure 1: A robotic car moves under remote control

Your task in this assignment is to (1) examine a video clip of a remotely controlled toy car that changes its velocity as it moves away from an ultrasonic motion detector; (2) study motion graphed by Logger *Pro* from motion detector data to describe the car's motion qualitatively; and (3) learn to use the data, the graphs and Logger *Pro* Analysis tools to extract quantitative information about the motion.

1. Preliminary Questions

Note: You will receive **full credit for each prediction** made in this preliminary section whether or not it matches conclusions you reach in the next section. As part of the learning process it is important to compare your predictions with your results. **Do not change your predictions!**

(a) A graph of the location in meters of the car along a horizontal x-axis as a function of time, as recorded by the motion detector, is shown below. Describe the car's motion.



(b) At approximately what time or during what time interval is the car moving most rapidly? Explain your reasoning.

(c) You just examined the x vs. t graph. If instead, you were only allowed to look at the v_x vs. t graph, how could you estimate the time or time interval for which the magnitude of the velocity is greatest?

2. Activity Based Questions

Before answering the questions in this section, open the <VelocityChange.mov> in *QuickTime Player*. Play the movie or advance it frame-by-frame using the right arrow key (→) on your keyboard.

(a) Based on what you see in the movie, describe the car's motion again.

(b) Open the Logger *Pro* experiment file <VelocityChange.cmbl>. This file has both the motion detector data and the toy car movie contained in it. The movie has been synchronized with the motion detector data. There is also a graph of x vs. t and one of v_x vs. t (where v_x represents the x-component of velocity). If you like, click on the start button in the *Replay* dialog box and watch the movie progress as data and the graphs build up over time.

1. Use the ***Tangent*** tool in the ***Analyze*** menu with the x vs. t graph, to determine both the magnitude of the velocity and the time or time interval over which it is greatest.

2. Use the ***Examine*** tool in the ***Analyze*** menu with the v_x vs. t graph, to determine both the magnitude of the velocity and the time or time interval over which it is greatest.

3. Look at the velocity column in the data table to determine both the magnitude of the velocity and the time or time interval over which it is greatest.

(c) If you were only allowed to examine the movie of the toy car (either as a whole or frame by frame) but not take data from it, how could you determine the frame in which the velocity is greatest? No need to write down a frame number or time, just describe your procedure.

3. Reflections on Your Findings

(a) How did your description of the motion based on the *x* vs. *t* graph in Preliminary Question 1(a) compare with the description you would give now that you have looked at the movie and the motion detector data?

(b) What was most useful representation in shaping your present understanding of how to describe the motion? Circle your answer. If two or more representations were equally useful circle them. Put an X through the least useful representation.

a. 1. The movie 2. The *x* vs. *t* graph 3. The v_x vs. *t* graph 4. The data in the table

(c) What was most useful representation in shaping your present understanding of when the toy car had the greatest velocity? Circle your answer. If two or more representations were equally useful, circle them. Put an X through the least useful representation.

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Velocity Change

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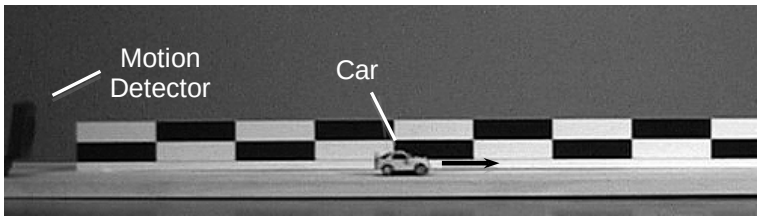

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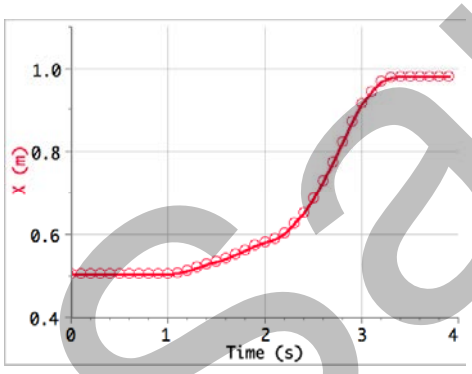
1. Preliminary Questions

Note: You will receive **full credit for each prediction** made in this preliminary section whether or not it matches conclusions you reach in the next section. As part of the learning process it is important to compare your predictions with your results. **Do not change your predictions!**

(a) A graph of the location in meters of the car along a horizontal x-axis as a function of time, as recorded by the motion detector, is shown below. Describe the car's motion.



ANSWER: The car is stationary (or stopped) for the first second or so. Then it speeds up quickly and moves at a almost constant speed between 1.1 s and 2.2 s. It then speeds up again and moves at a higher constant velocity between about 2.3 s and 3.3 s. and then almost immediately stops. Grader–Any serious attempt should be given full credit.

(b) At approximately what time or during what time interval is the car moving most rapidly? Explain your reasoning.

ANSWER: Between 2.3 and 3.3 s, maybe the fastest is about 2.8 s. This is because slope looks greatest during that time interval. Grader–Any serious attempt should be given full credit.

(c) You just examined the *x* vs. *t* graph. If instead, you were only allowed to look at the v_x vs. *t* graph, how could you estimate the time or time interval for which the magnitude of the velocity is greatest?

ANSWER: Look for the point on the graph or the range of points on the graph that are farthest away from the horizontal axis. In other words, the maximum or minimum that has the greatest magnitude. Grader – Any serious attempt should be given full credit.

2. Activity Based Questions

Before answering the questions in this section, open the <VelocityChange.mov> in *QuickTime Player*. Play the movie or advance it frame-by-frame using the right arrow key (→) on your keyboard.

(a) Based on what you see in the movie, describe the car's motion again.

ANSWER: The car is still and then starts moving at a constant velocity and then it speeds up to a greater constant velocity for awhile. Finally it comes to a rapid stop in the last few frames.

(b) Open the Logger *Pro* experiment file <VelocityChange.cmbl>. This file has both the motion detector data and the toy car movie contained in it. The movie has been synchronized with the motion detector data. There is also a graph of x vs. t and one of v_x vs. t (where v_x represents the x-component of velocity). If you like, click on the start button in the *Replay* dialog box and watch the movie progress as data and the graphs build up over time.

1. Use the ***Tangent*** tool in the ***Analyze*** menu with the x vs. t graph, to determine both the magnitude of the velocity and the time or time interval over which it is greatest.

   ANSWER: This analysis gives 0.462 m/s at a time of 2.80 s. Grader – Something very close is ok.

2. Use the ***Examine*** tool in the ***Analyze*** menu with the v_x vs. t graph, to determine both the magnitude of the velocity and the time or time interval over which it is greatest.

   ANSWER: This analysis gives 0.462 m/s at a time of 2.80 s. Grader – Something very close is ok.

3. Look at the velocity column in the data table to determine both the magnitude of the velocity and the time or time interval over which it is greatest.

   ANSWER: This analysis gives 0.462 m/s at a time of 2.80 s. Grader – Something very close is ok.

(c) If you were only allowed to examine the movie of the toy car (either as a whole or frame by frame) but not take data from it, how could you determine the frame in which the velocity is greatest? No need to write down a frame number or time, just describe your procedure.

ANSWER: Look for frame where the car has changed its position the most with respect to the previous frame. Grader – Something very close is ok.

3. Reflections on Your Findings

(a) How did your description of the motion based on the *x* vs. *t* graph in Preliminary Question 1(a) compare with the description you would give now that you have looked at the movie and the motion detector data?

ANSWER: Quantitative data is more precise when the data are examined. The movie helps to visualize the motion.

(b) What was most useful representation in shaping your present understanding of how to describe the motion? Circle your answer. If two or more representations were equally useful circle them. Put an X through the least useful representation.

ANSWER: When grading – look for 1, 2, or 3 circles & one "X"

a. 1. The movie 2. The *x* vs. *t* graph 3. The v_x vs. *t* graph 4. The data in the table

(c) What was most useful representation in shaping your present understanding of when the toy car had the greatest velocity? Circle your answer. If two or more representations were equally useful, circle them. Put an X through the least useful representation.

ANSWER: When grading – look for 1, 2, or 3 circles & one "X"

a. 1. The movie 2. The *x* vs. *t* graph 3. The v_x vs. *t* graph 4. The data in the table

Velocity Change

This activity is designed to give students experience with how use different ways to represent and describe an irregular motion. In particular, how various representations and tools can be used to determine when the car's velocity is a maximum.

A remotely controlled toy car starts at rest, then speeds up and slows down and comes to rest again. The car's motion is tracked with an ultrasonic motion detector while a digital video recording is made. Before using the Logger *Pro* tools, students are asked to:

1. Describe the irregular motion of the car in words by examining an *x* vs. *t* graph created from motion detector data.
2. Use the graph to identify the time at which the car is moving most rapidly and describe how this might look on a *v* vs. *t* graph.

Then students are asked to use Logger *Pro* analysis features to:

1. View the video clip of the motion and once again describe the motion in words.
2. Use the Tangent feature in the Examine menu to find when the maximum velocity occurs.
3. Look at the data table where calculated values of v_x are listed for the car to determine when the maximum velocity occurs.
4. Describe how a careful frame-by-frame analysis of the video can yield information about when the velocity will be maximum.

Time to complete as a homework assignment: 10 to 30 minutes (less if done as a collaborative in-class activity)