

## ACTIVITY ONE

### CONSTANT VELOCITY ALONG A HORIZONTAL PLANE

#### Purpose

To capture and display the motion of an object moving with constant velocity along a horizontal plane.

#### Materials

- Pasco **red** constant speed buggy [alternate: a bright colored ball rolled down a slight incline.]
- Computer with Motion Visualizer software
- Digital video camera with tripod
- Masking tape and marker
- Angle measuring device
- Tape measure

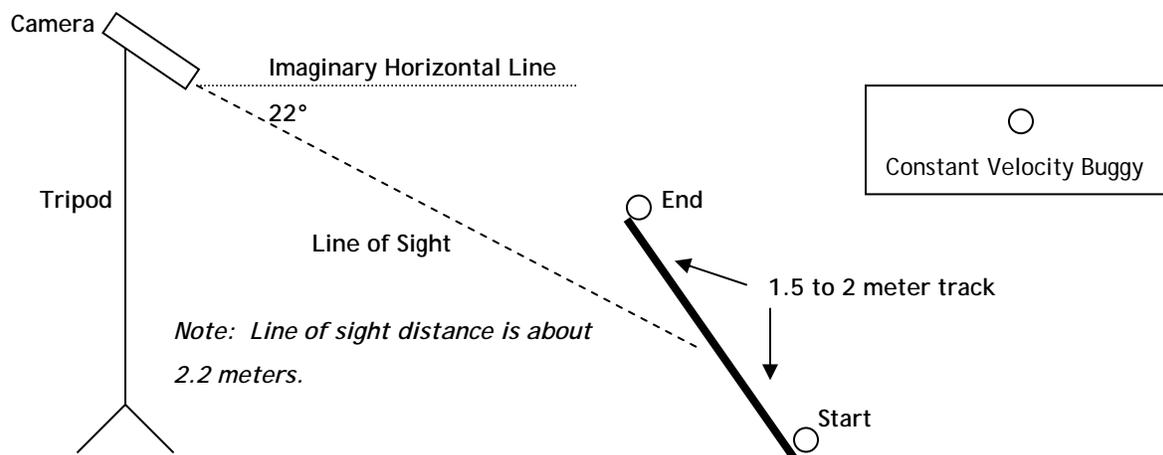


#### Set-up Guidelines

1. Mark out a 1.5 to 2 meter track on a smooth and level surface.
2. Put pieces of tape on the surface to mark the start and end of track.
3. Place front end of buggy at start.
4. While one person is holding the buggy, turn it on.
5. Another person should start the video camera [in record mode - no tape needed.]
6. Let buggy roll.
7. Capture the motion of the buggy with digital video camera.

#### Diagram

[Refer to the Motion Visualizer setup manual for a general description of equipment setup.]



## Data Presentation Guidelines

There are many ways to show the motion of an object with the Motion Visualizer software; however, it is important to keep in mind the objective of the activity. This will help prevent the user of the program from displaying redundant or unnecessary information.

In this case, we were interested in studying the motion of an object moving with a constant velocity, in the x plane. Knowing this, we consciously did not display data that seemed irrelevant [i.e., Y Position v. Time, Z Position v. Time, Y Velocity v. Time, Z Velocity v. Time, etc.] Rather, we deliberately decided to display data that would highlight constant velocity motion.

After you have captured the motion of the object via the video camera, you should follow the list of steps below to present the data to your students. It is helpful if your computer is connected to a video projector. This will provide the opportunity for all the students to see the data at the same time. As the instructor, you can use this as a chance to have an interactive analysis of the data.

The following is a list of steps to execute after capturing the data.

1. View the motion via the Motion Visualizer (MV) software on the **Room Coordinate Graph**. [Figure 1] The trial can be viewed over and over again by hitting the play button found in the MV's **Tool Bar Menu**. [Figure 2] The speed at which the trial is replayed can be varied by clicking and dragging the toggle bar to the right of the play button. At times, it may be helpful to "eliminate" any data that is captured before the object starts moving. This is done by using the anchor button in the MV's Tool Bar Menu. As the motion is played, click the anchor button when the object starts to move. Now when the play button is hit, it will start at this point.

Figure 1

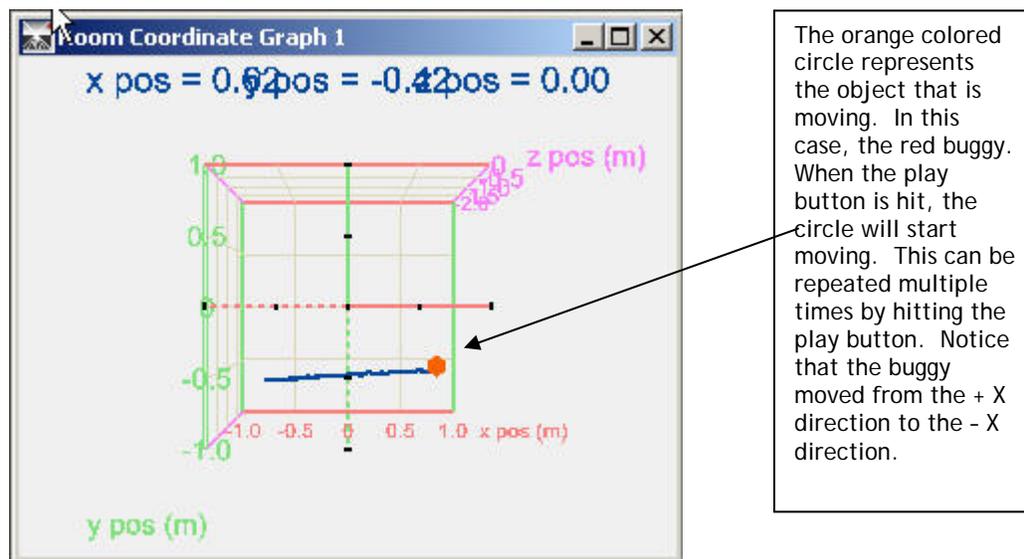
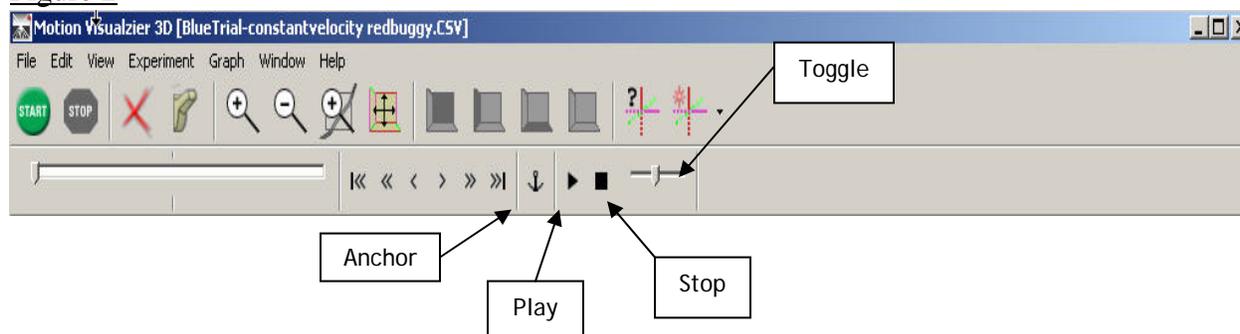


Figure 2



2. Since the motion happened along one axis, it is best if the **Room Coordinate Graph** is seen from the **Orthographic View**. This can be done by choosing *projection* under the *graph* menu. [Figure 3] The orthographic view will show you the motion of the object along two of the three available axes (x and y, y and z, or x and z.) [Figure 4]

Figure 3

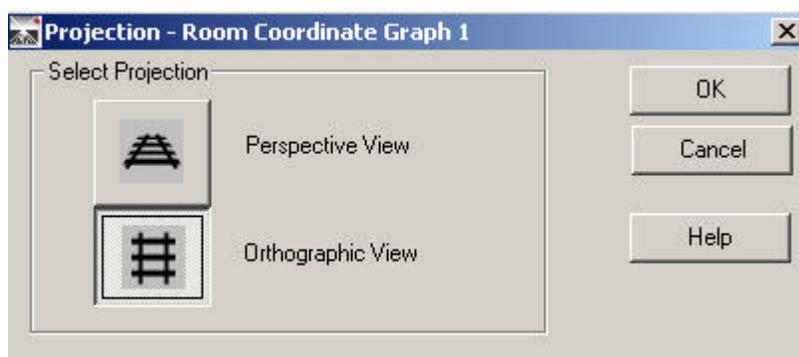
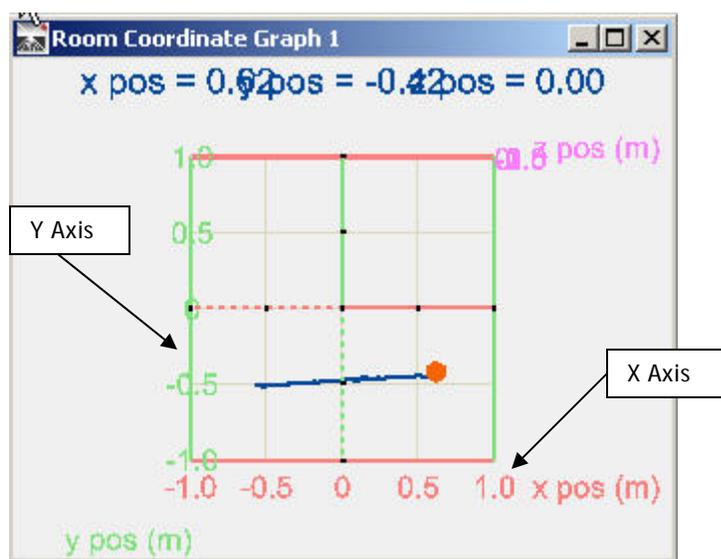
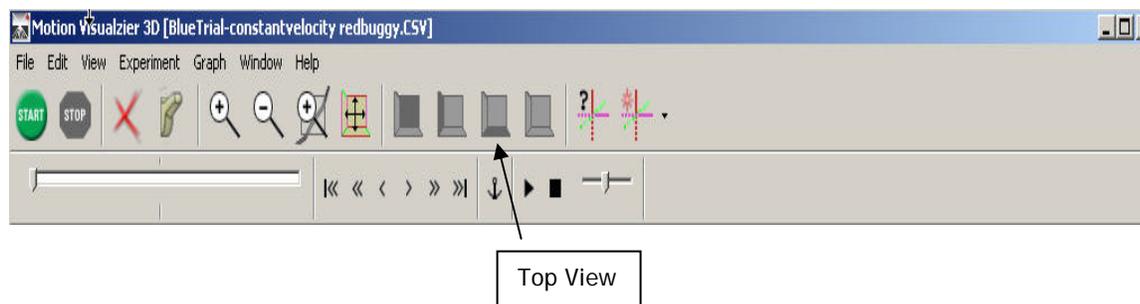


Figure 4



This room coordinate graph displays only the X and Y axes. The Z axis extends outward of the page.

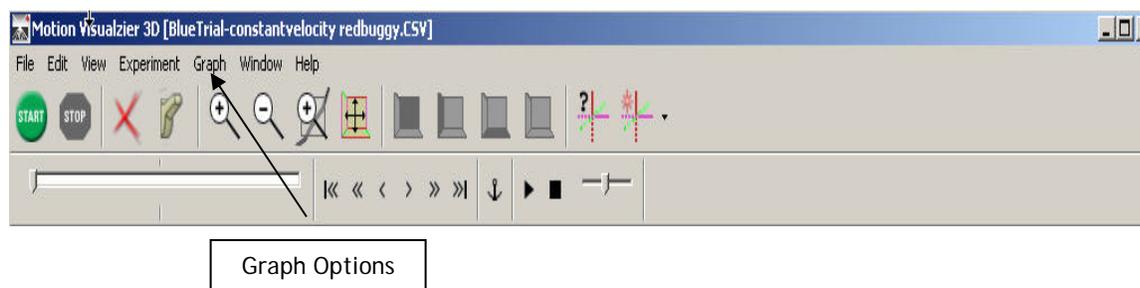
*Note: The  $x$  and  $y$  axes shown in Figure 4. This was a deliberate decision which can be chosen by clicking on the icon for top view in the MV toolbar.*



3. In addition to showing the MV's representation of the motion, it is possible to view the data in graphical format by choosing *add graph* under the *graph* menu item of the MV toolbar. [Figure 5] A unique feature of the MV program is that multiple graphs can be shown **at one time**. This option allows the user to compare and contrast the motion on one screen.

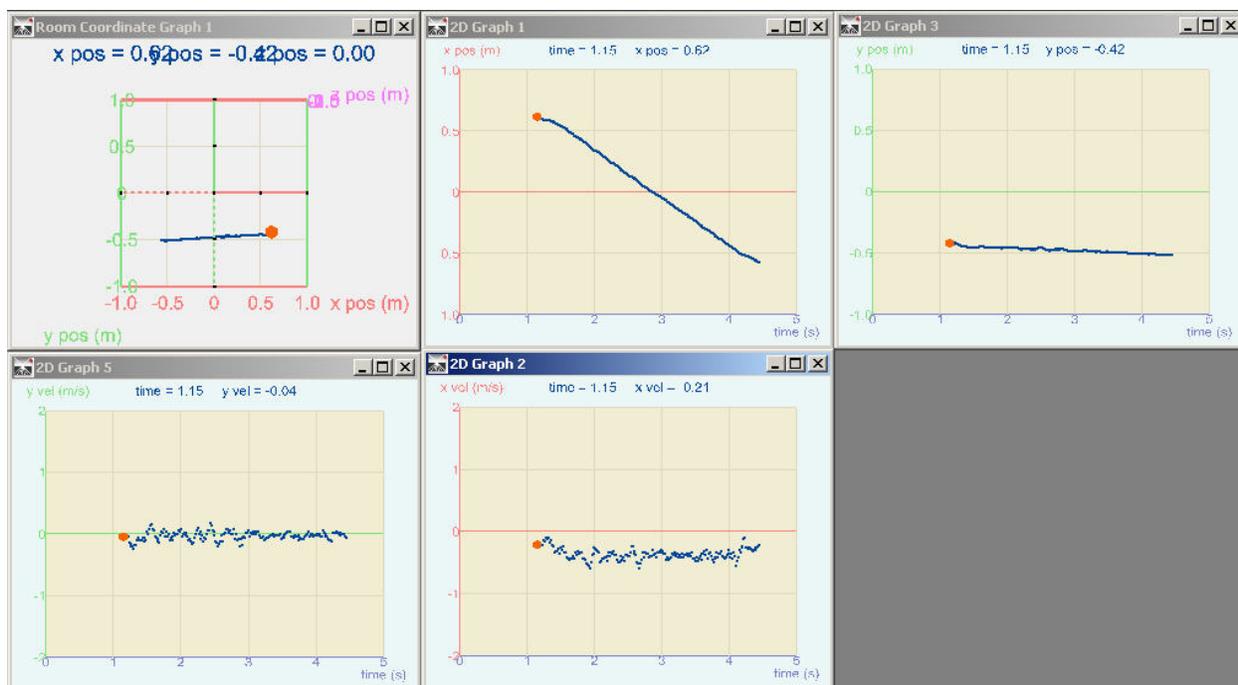
*(Note: There are many different graphs that can be displayed. For this activity, we made a conscious decision to show only those that illustrated constant velocity in the  $x$  direction.)*

**Figure 5**



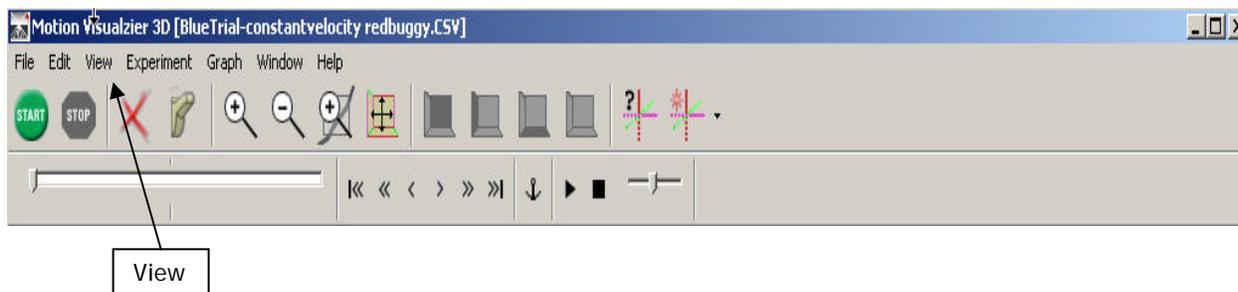
4. Below is a picture of a screen that has the **Room Coordinate Graph** and four (4) different graphs. The images below are as follows [from left to right]: Room Coordinate Graph, X Position v. Time, Y Position v. Time, Y Velocity v. Time and X Velocity v. Time.

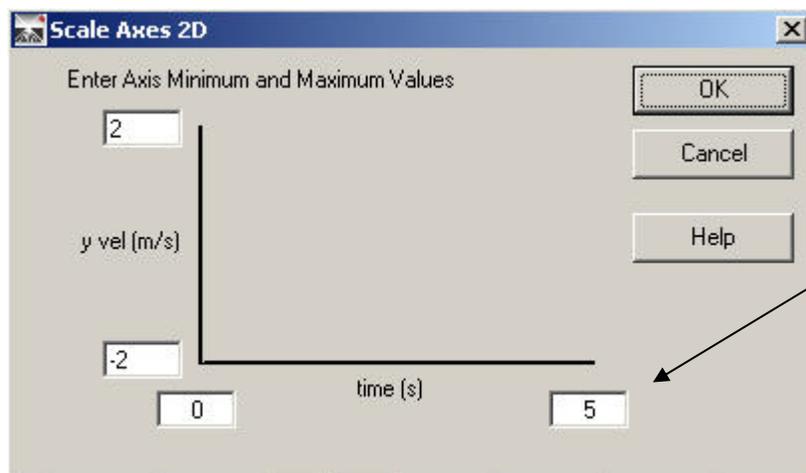
*(Note: Images can be arranged and resized many different ways. Some options include vertical stacking or maximizing one image to occupy the entire screen.)*



Once you know the parameters of your experiment, [i.e., total distance traveled, elapsed time, etc.] you can adjust the minimum and maximum values on the X and Y axes to focus on the motion of the object. This scaling feature allows you to remove any “bad” data that precedes or follows the actual motion of the object. This can be done by selecting **scale axes** under the **view** menu item in the MV toolbar. [Figure 6] (Note: The software is also capable of “auto scaling” the data; this is accomplished by hitting the F4 button on the computer keyboard.)

Figure 6





The X axis, which represented time, in this case, was changed to 5 sec. [Maximum and Minimum positions and velocities can also be adjusted based on the experimental set-up.]

## Discussion of Data

The results of these images are what we would expect. Since the car moved at a constant velocity in a leftward direction, the X Position v. Time graph has a non-curved line with a negative slope, indicating “backwards” or toward the origin.

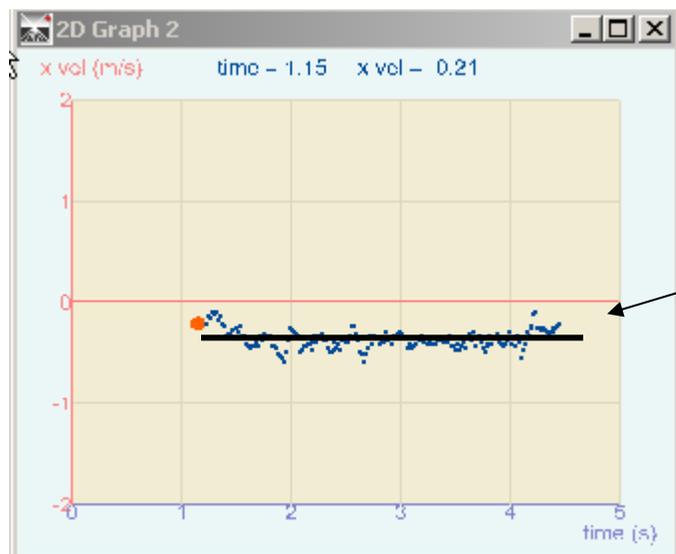


The average velocity can be determined quantitatively by calculating the slope of this line.

$$V_{\text{avg}} = (X_f - X_i) / (T_f - T_i)$$

$$(-0.6 - 0.6) \text{ m} / (4.5 - 1) = -0.34 \text{ m/sec}$$

The X Velocity v. Time graph also shows that the object moved with a constant negative velocity (approximately -0.40 m/sec) since there is no slope and all the data points are found in the negative portion of the velocity graph.



All the data points lie in the negative portion of this graph. Drawing a best-fit line to smooth out the data points, yields an average velocity of about -0.4 m/sec.

Since there was no motion in the Y direction, it is expected that the Y Position v. Time graph would be a horizontal line, indicating a constant position.



This is verified by the Y Velocity v. Time graph which shows a constant velocity of 0 m/sec.



Other graphs (Z Position v. Time and/or X Acceleration v. Time) can be shown at any time to underscore the fact that the buggy only moved in the X direction and there was no acceleration.

(Note: If the instructor has access to a projector, it is recommended that the computer be connected to it so that the images can be displayed to the entire class at one time. This will provide the instructor with an opportunity to engage all the students in a discussion about motion and may make the presentation more interactive.)

## Extension

The raw data that is collected by the MV is saved in a .csv file that can be imported into Microsoft Excel. This provides a unique opportunity for the instructor and student to work with the data and to make decisions on how it should be displayed and analyzed.

(Note: The .csv file contains a lot of information that can be deleted. It is recommended that the instructor view the data file before the students. Figure 7 shows a selection of data copied from the .csv file for this activity.)

Figure 7

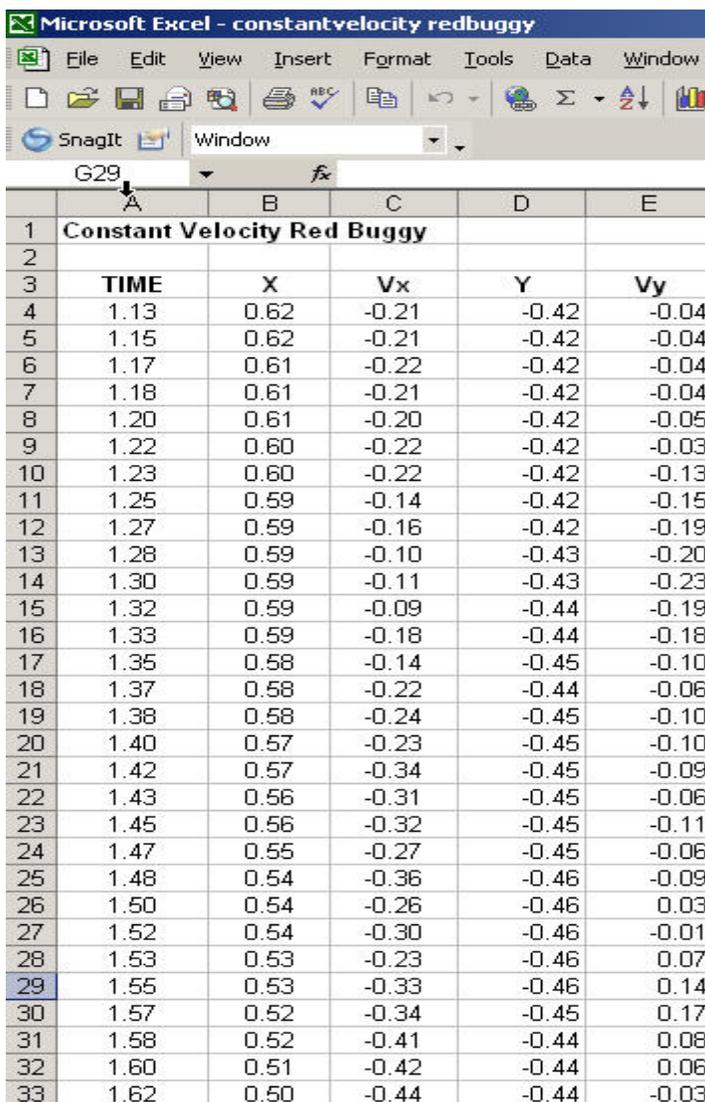
Alberti's W 1Obj Point Count: 200 Version: 1.2.2

t	X	Y	Z	Vx	Vy	Vz	Ax	Ay	Az	Speed	Xraw	Yraw	Zraw	Lct
1.133333	0.621006	-0.41527	0	-0.20837	-3.90E-02	0	-0.75626	-2.73522	0	0.211995	0.618699	-0.41781	0	1
1.15	0.61696	-0.41809	0	-0.21156	-0.04207	0	0.200413	1.036369	0	0.215699	0.617555	-0.4148	0	1
1.166667	0.613482	-0.41778	0	-0.21544	-4.20E-02	0	5.95E-02	-0.75038	0	0.219491	0.613625	-0.42081	0	1
1.183333	0.609926	-0.41946	0	-0.20839	-3.60E-02	0	0.101817	1.074084	0	0.211483	0.611624	-0.4148	0	1
1.2	0.606624	-0.41922	0	-0.20048	-5.10E-02	0	-8.24E-02	-0.63298	0	0.206869	0.604321	-0.4268	0	1
1.216667	0.603311	-0.42104	0	-0.22308	-3.31E-02	0	-0.46348	1.331995	0	0.225512	0.604161	-0.4148	0	1
1.233333	0.599434	-0.41825	0	-0.21959	-0.13057	0	-0.13342	-5.95403	0	0.255473	0.598672	-0.42381	0	1
1.25	0.593866	-0.42224	0	-0.1413	-0.15179	0	4.364168	-3.07612	0	0.207382	0.596736	-0.41781	0	1
1.266667	0.593736	-0.42383	0	-0.16374	-0.19	0	0.127437	-5.28429	0	0.250819	0.593534	-0.4268	0	1
1.283333	0.589464	-0.43114	0	-0.10373	-0.1965	0	3.715738	1.894211	0	0.222193	0.585709	-0.41781	0	1
1.3	0.589632	-0.43304	0	-0.11091	-0.23109	0	0.279275	-1.03992	0	0.256323	0.585414	-0.45044	0	1
1.316667	0.587846	-0.43997	0	-0.08926	-0.18706	0	0.487004	5.021928	0	0.207266	0.600988	-0.43276	0	1
1.333333	0.589357	-0.44116	0	-0.17747	-0.18332	0	-6.06967	1.68985	0	0.255152	0.575153	-0.44751	0	1
1.35	0.58465	-0.44579	0	-0.13626	-0.10386	0	-2.39558	5.622132	0	0.171334	0.595774	-0.43276	0	1

For the purposes of this activity, we deliberately edited the data file and kept the information that pertained to the objective of this activity. After careful deletion we were left with five (5) columns of data as seen in Figure 8.

Figure 8

At each indicated time, the following data is displayed:  
 X = X distance  
 Y = Y distance  
 Vx = X velocity  
 Vy = Y velocity

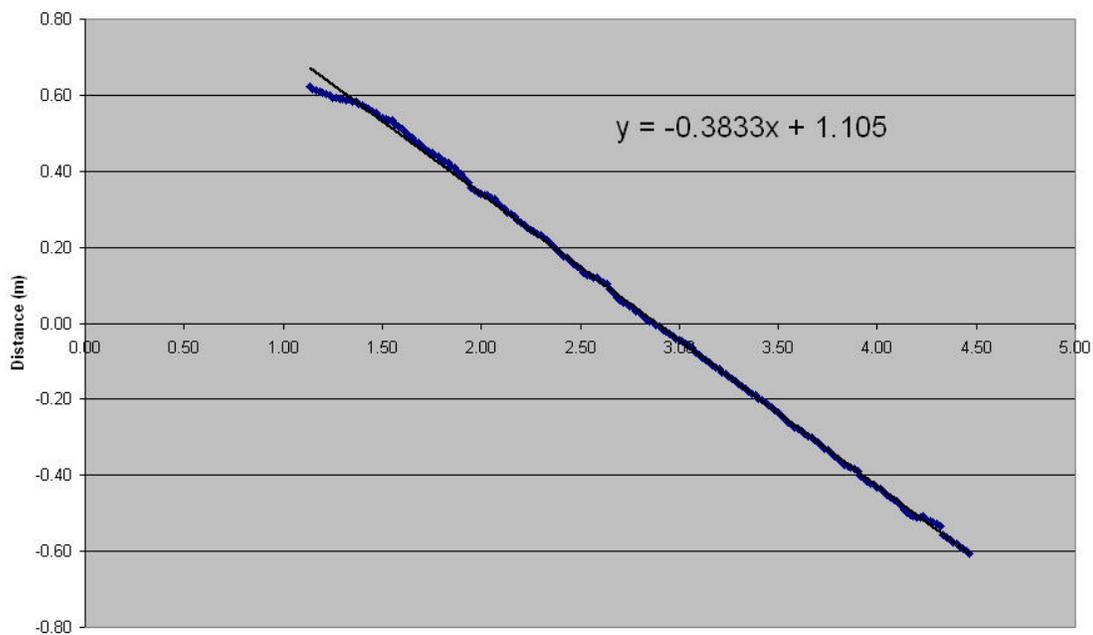


	A	B	C	D	E
1	<b>Constant Velocity Red Buggy</b>				
2					
3	<b>TIME</b>	<b>X</b>	<b>Vx</b>	<b>Y</b>	<b>Vy</b>
4	1.13	0.62	-0.21	-0.42	-0.04
5	1.15	0.62	-0.21	-0.42	-0.04
6	1.17	0.61	-0.22	-0.42	-0.04
7	1.18	0.61	-0.21	-0.42	-0.04
8	1.20	0.61	-0.20	-0.42	-0.05
9	1.22	0.60	-0.22	-0.42	-0.03
10	1.23	0.60	-0.22	-0.42	-0.13
11	1.25	0.59	-0.14	-0.42	-0.15
12	1.27	0.59	-0.16	-0.42	-0.19
13	1.28	0.59	-0.10	-0.43	-0.20
14	1.30	0.59	-0.11	-0.43	-0.23
15	1.32	0.59	-0.09	-0.44	-0.19
16	1.33	0.59	-0.18	-0.44	-0.18
17	1.35	0.58	-0.14	-0.45	-0.10
18	1.37	0.58	-0.22	-0.44	-0.06
19	1.38	0.58	-0.24	-0.45	-0.10
20	1.40	0.57	-0.23	-0.45	-0.10
21	1.42	0.57	-0.34	-0.45	-0.09
22	1.43	0.56	-0.31	-0.45	-0.06
23	1.45	0.56	-0.32	-0.45	-0.11
24	1.47	0.55	-0.27	-0.45	-0.06
25	1.48	0.54	-0.36	-0.46	-0.09
26	1.50	0.54	-0.26	-0.46	0.03
27	1.52	0.54	-0.30	-0.46	-0.01
28	1.53	0.53	-0.23	-0.46	0.07
29	1.55	0.53	-0.33	-0.46	0.14
30	1.57	0.52	-0.34	-0.45	0.17
31	1.58	0.52	-0.41	-0.44	0.08
32	1.60	0.51	-0.42	-0.44	0.06
33	1.62	0.50	-0.44	-0.44	-0.03

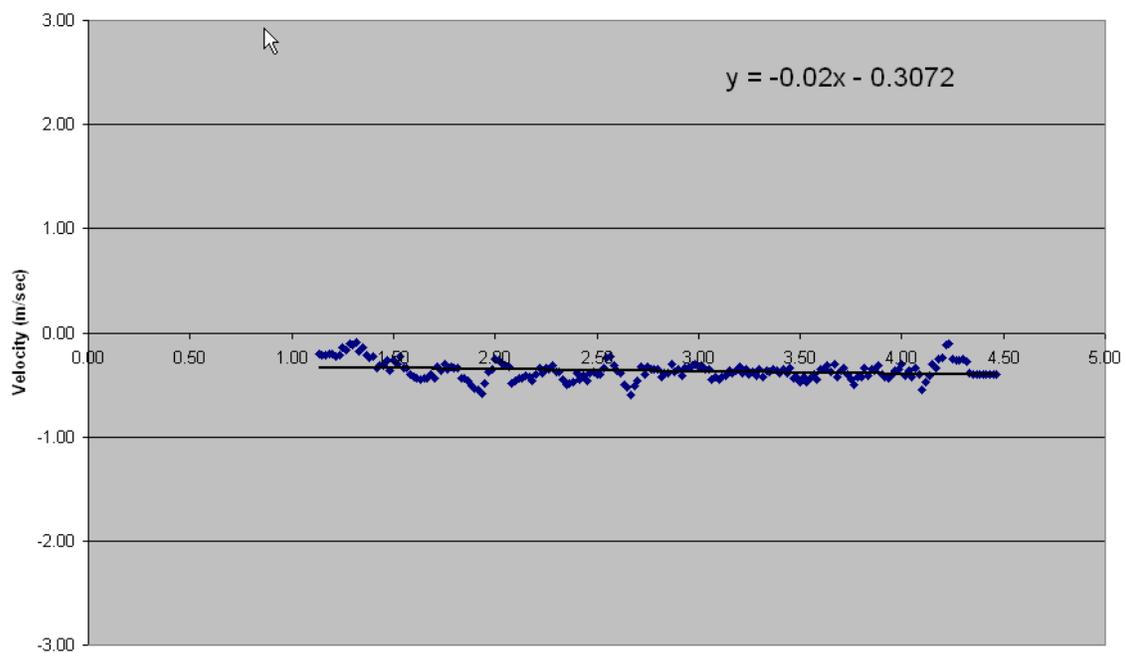
Microsoft Excel is capable of graphing the data and including useful quantitative data such as a trendline and an equation to fit the data. Below are two graphs that were created in Excel using the data in the .csv file from this activity. The first is the X Position v. Time graph and the second is the X Velocity v. Time graph.



Distance (X) v. Time for Red Buggy



Velocity (X) v. Time for Red Buggy



## Questions for Discussion

1. Describe in words the motion of the object. Use words like constant and changing to describe the speed. Use words like leftward, rightward, negative and positive to describe the direction in relation to the starting point.
2. What is slope? Describe the slope of the data on the X Position v. Time graph. Describe the slope of the data on X Velocity v. Time graph. How do they relate?
3. What is average velocity? Is there a way to find it by analyzing the graphs? Describe how you would do it. What is the average velocity of the object?
4. If you were to do a second trial of this activity by having the object start on the left side of the screen and moving to the right, compare and contrast how this motion would be represented by the graphs.
5. Would the slope on the X Position v. Time graph be the same in trial 2 as it was in trial1? Explain.
6. How do average velocity and instantaneous velocity compare? What do they tell you about the motion?
7. Sometimes people use the word speed rather than velocity. How are these words similar? Different?
8. Quantities such as mass, time, age and color are different from quantities such as velocity, displacement, acceleration and force. What is different about these quantities?
9. How would the graphs of Distance v. Time and Position v. Time be different? How would the graphs of Speed v. Time and Velocity v. Time be different?
10. Sketch a Position v. Time and Velocity v. Time graph to describe the motion of the object if it were rolled down a ramp?