PHYS 103 LAB 2: MOTION AT CONSTANT VELOCITY.

INTRODUCTION

The purpose of this lab is to study the motion of an object. Specifically, this lab focuses on the motion at constant velocity, but you'll also look at other types of motion. You will investigate the relationship between the motion of an object and graphs of the position of the object versus time and the velocity of this object versus time. You'll use the Motion Sensor and Data Studio to view the motion of the object in real time.

When describing the motion of an object, knowing where it is relative to a reference point, how fast and in what direction it is moving is essential. A sonar ranging device such as the Motion Sensor uses pulses of ultrasound that reflect from an object to determine the position of the object. As the object moves, its position is measured many times each second. The position of an object at a particular time can be plotted on a graph. You can also graph the velocity of the object versus time. A graph is a mathematical picture of the motion of an object. For this reason, it is important to understand how to interpret a graph of position or velocity versus time. In this activity you will plot a graph in real-time, that is, as the motion is happening.

Objects can remain stationary, move at constant velocity, or move with a varying velocity. If an object is stationary, and placed at a distance d_0 from some reference point, then its position, d, is described by equation:

$$d = d_0 \tag{1}$$

and its velocity, v, by the equation:

$$v = 0\,. \tag{2}$$

If an object that was originally placed at a distance d_0 from the reference point moves with a constant velocity, v_0, then its motion is described by the following set of equations:

$$d = vt + d_0\,, \tag{3}$$

$$v = v_0\,, \tag{4}$$

where t denotes time.

A detailed description of motion with a varying velocity is more complex, as you will find out later in this semester. However, a quantity called average speed can be defined for such motion in the following way: if an object moved from a distance d_0 to a distance, d_f, (i.e. it moved by a distance $\Delta d = d_f - d_0$) in the time interval $\Delta t = t_f - t_0$, then the average speed v_{ave} is defined as

$$v_{ave} = \frac{\Delta d}{\Delta t}\,. \tag{5}$$

The actual or instantaneous speed can vary from moment to moment e.g. your car can stop and go as you pass through the intersections, but if you travelled 50 miles in 1 hour you know your average speed was 50 miles per hour, no matter how fast or slow you were going at any particular time.

If an object moves with a constant velocity, v_0, then its instantaneous velocity at any moment and its average velocity will also be equal to v_0.

Equation (3) is an example of a linear equation i.e. the distance travelled is proportional to time. In general, a linear relation is be defined by equation

$$y = m x + b, \tag{6}$$

where m is the slope and b is the y-intercept.

Equation (4) is an example of a constant equation, i.e. the velocity doesn't change with time. In general, a constant relation is be defined by the equation

$$y = \text{constant}. \tag{7}$$

Below are some questions which should help you recall what you should know about linear relations.

PROCEDURE

NEW EQUIPMENT - DATA STUDIO

This is a very important part of the lab designed to acquaint you with some equipment which you will use throughout this course, so pay attention. In this part you will not be taking any data.

To begin, let's open up **Data Studio** and look at its main components. Double click on the **Data Studio** icon on the desktop. In the newly opened **'Welcome to Data Studio'** window double click on the **'Create Experiment'** icon and you should see the image shown in figure 1.

Notice the three areas: **'Experiment Setup'**, **'Data'**, and **'Displays'**. The **'Experiment Setup'** is where you will choose the sensors used in a particular experiment and do any customizing of the sensor before the experiment begins. Then, by pressing **'START'**, the button above the **'Experiment Setup'** area, data will begin to be taken and icons will show up in the **'Data'** section for the selected sensor's measured values. Each time the **'START'** button is pressed a new **'Run'** will appear in the **'Data'** window.

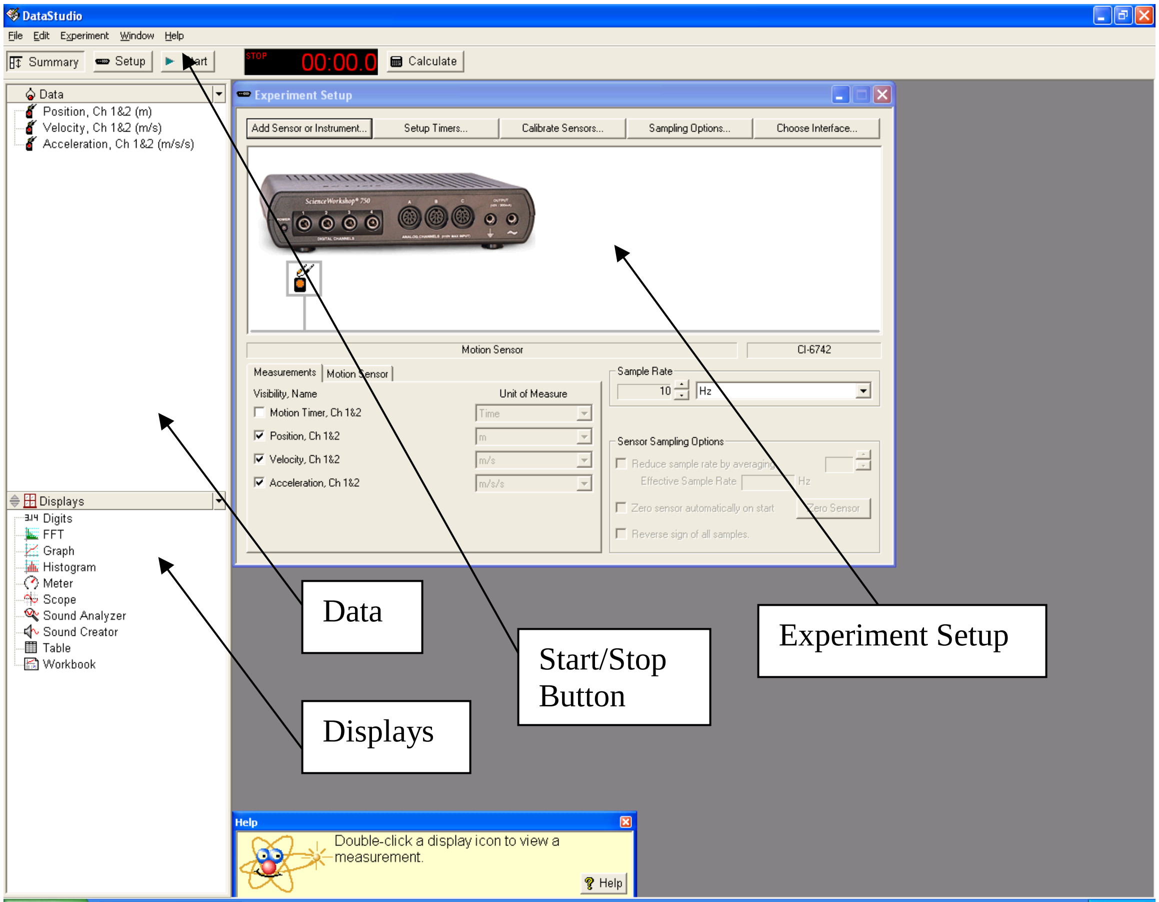

Figure 1. Data Studio interface.

When **'STOP'** is pushed, data collection stops. At any time during the data acquisition, a graph can be opened up to view real time data. To do this simply drag the data icon of a particular **Run** to the **'Graph'** icon in **'Displays'** and a graph will be created (or drag the **'Graph'** icon in **'Displays'** over the icon of the **Run** in **'Data'** window). You may also view the numerical values at any time during the acquisition by dragging the **Run** icon from the **'Data'** section to the **'Table'** icon in the **'Displays'** section (or drag **'Table'** icon in **'Displays'** over the icon of the data in the **'Data'** window).

More than one run can be displayed in one graph. **Data Studio** does it automatically, so sometimes you need to remove some data from the graph. Select the data you wish to remove by clicking on it in the legend window. Then right click your mouse and from the pull-down menu select remove.

Sometimes we want to view two or more different plots on one graph (e.g. position versus time and velocity versus time). This can be accomplished by first creating one plot (e.g. of position versus time), then pulling the second icon (e.g. velocity icon) from the **'Data'** window to the bottom half of the first plot.

In order to accurately read the coordinates of a point from the graph you can use the **'Smart Tool'**, which is located on the toolbar of the **'Graph'** window. It will give you much more precise coordinates of a given point on your plot than you can get by eye.

To analyse the data we will frequently need to fit it with a particular function. First, you need to select the range of data which you wish to fit (not all of collected data will always be good or interesting). To do this use the mouse to click-and-draw a rectangle around the section of your plot that contains the data to be fitted. The selected data should now be highlighted in yellow. Next, in the **'Graph'** window, select the **'Fit'** button. Then from a pull down menu select the type of relation you want to fit your data with. A window will appear with the results of the fit: the type of function, the values of the fitted parameters, and the statistics which tell us how good or bad our fit was. If it all seems confusing do not worry too much, we will practice it all.

PART 1 MOTION AT CONSTANT SPEED

1. In the **'Experiment Setup'** window double-click on the **'Add Sensor or Instrument'** button located in the upper left hand corner. The **'Choose Sensor or Instrument'** window should open. In the **'Choose Sensor or Instrument'** window, double-click on the down arrow in the upper right hand corner and select **'ScienceWorkshop Digital Workshop'**. From the list of sensors displayed below, select **'Motion Sensor'** and double click it. In the **'Experiment Setup'** window, adjust the sample rate to 25 Hz. Then under the **'Measurements'** tab, select position and velocity.

2. Create plots (for details see **NEW EQUIPMENT- DATA STUDIO**) of position vs. time and velocity vs. time on one graph.

3. Physically connect the motion sensor's stereo phone plugs to Digital Channels 1 and 2 of the interface. Connect the yellow-taped plug to Digital Channel 1 and the other plug to Digital Channel 2, as shown in your **'Experiment Setup'** window.

4. Position the **Motion Sensor** so that it is aimed at your midsection when you are standing in front it. Make sure that you are more than 15 cm away from the sensor and that you can move at least 2 meters away from the motion sensor without running into any obstacles.

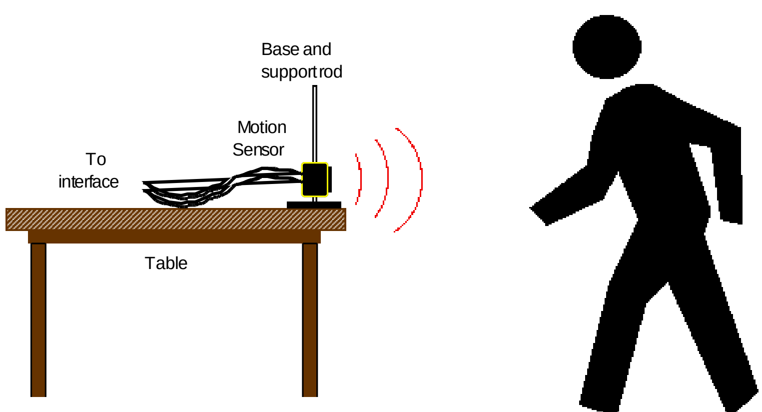

Figure 2.

5. Click the **'START'** button to begin recording data. (Data recording will begin almost immediately. The motion sensor will make a faint clicking noise.)

6. Walk away from the motion sensor until you cannot walk any further. Practice walking at an even pace so that that the plot of your motion on the computer screen shows a smooth straight line.

7. Click on **'STOP'** to end data taking.

8. Repeat the data recording process a second and a third time. Select the data run that gives the most smooth (i.e. least bumpy) graph as you move away from the motion sensor. Delete the other runs and analyse the best run as described below. **Save your data – computers crash frequently.**

9. From the **Fit** menu (for details see **NEW EQUIPMENT- DATA STUDIO**) select **Linear Fit** to display the slope of the selected region of your position vs. time plot. The **"m"** term of the equation in the **Linear Fit** window is the slope fitted for the selected range of motion. The slope of this part of the position vs. time plot is the velocity during the selected region of motion, so what was your average speed based on this fit?

Record the value of parameter "***r***" from the **Linear Fit** window. Parameter *r* is a statistical quantity which tells us how well the fitted line describes the actual data points. The closer its value is to 1 (or -1 for negative slope) the better a match exists between the fitted line and the experimental data (i.e. the data points lay closer to the fitted line). Is your fit good?

10. Use the mouse to click-and-draw a rectangle around the section of your plot where you are moving away from the detector at constant speed. This is the part of the data you'll be analysing. Study this portion of the position versus time plot and using the **Smart Tool** (located in the top toolbar of your graph window), determine the following:

What are the coordinates of the first highlighted data point i.e. what was your distance d_0 from the motion sensor at that time? Record t_0 and d_0 in step 10 of the report.

What are the coordinates of the last highlighted data point i.e. what was your distance d_1 from the motion sensor at that time? Record t_1 and d_1 in step 10 of the report.

Find the differences $\Delta t = t_1 - t_0$ and $\Delta d = d_1 - d_0$ and record them in the report.

11. Now use the **"Delta tool"** to find these differences from the graph. Are these values for Δt and Δd the same as those obtained in step 10? If not, what may be the source of the discrepancy?

12. For the part of your data corresponding to the period through which you moved at constant speed, calculate you average speed, v_{ave}, using equation (5). Compare this value with the value of v_{ave} you have calculated above by calculating the percent difference. Are the two values in agreement? What does it mean?

13. Look at the corresponding velocity vs. time plot. Was your speed indeed constant? Was your instantaneous speed always the same as your average speed?

14. Use the highlighter to select the data for our time period of interest and then use the **"Statistics"** button to find the mean value of the velocity during this time period. Is this value roughly in agreement with the other methods you've used to find the average velocity?

15. Repeat the above procedure **PART** 1.5-1.9 but walk considerably faster or considerably slower than you did before. Make sure both data sets are plotted on the same graph.

Discuss how the slope in the position vs. time plot changes depending on how fast you walked and why.

16. Now position yourself as far from the detector as you can. Repeat the above procedure: **PART 1**.5-1.9, while walking towards the detector with constant speed. Create new graphs of position vs. time and velocity vs. time with only this last data set in them. How has the slope changed? Why?

17. Print the graphs.

PART 2 INVESTIGATING MOTION

In **PART 1** you were told to move in a certain way and observe the resulting graphs of your motion produced by the **Data Studio** on the computer. In this part we will reverse the process: in figures 3 and 4 you will find two plots of position versus time. Your task is now to move in such way in front of the **Motion Sensor** so as to reproduce these graphs. The graphs in figure 2 deliberately lack the scale since you are only required to reproduce the general shape and not specific values. For each graph:

- Print your plots which resemble the graphs in figures 3 and 4 most closely.

a)

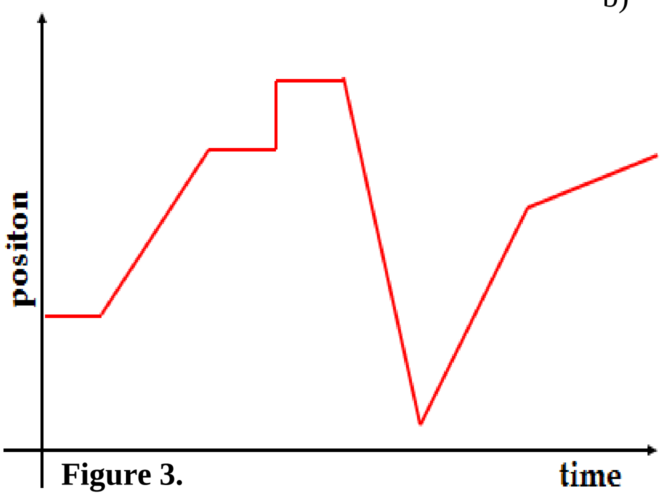

Figure 3.

b)

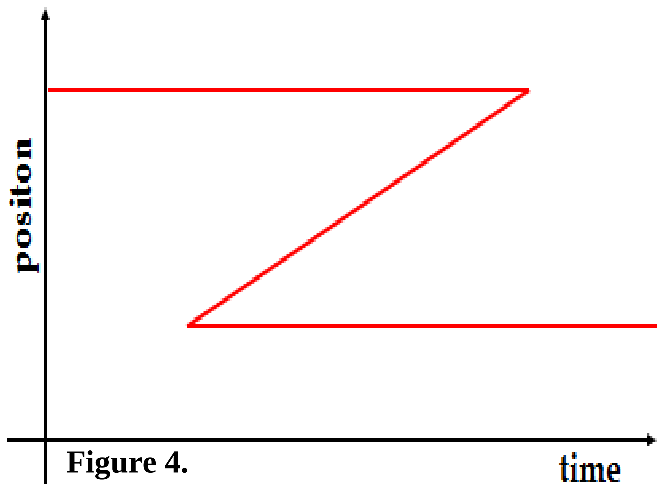

Figure 4.

REMEMBER TO:

- **Print all your data, graphs, and tables, and attach them to your report. You can also copy and insert it into your report file and then print the whole thing together.**
- **Whenever possible, SAVE PAPER.**
- **Delete your files from the computer.**
- **Disconnect all equipment, close all applications, and log off your PC. DO NOT TURN THE COMPUTER OFF.**
- **Clean up your workstation. Make sure you leave the classroom as you found it.**

<u>LAB 2 REPORT</u>

Group name: ……………………………………

Partners names: ……………………………………

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<u>INTRODUCTION:</u>

<u>DATA PRESENTATION:</u>

<u>PART 1</u>

9. The fitted slope = ………..……….

Was your fit good? ……………. my r = ………..……….

What was your average speed based on this fit?......................................

10.	t_0 = …………………...	t_f = …………………….	Δt = …………………
	d_0 = …………………..	d_f = …………………….	Δd = …………………
11.	Δt = ………………… `		Δd = …………………

Are these values for Δt and Δd the same as those obtained in step 10? ……………………………………………

If not, what may be the source of the discrepancy?……………………………..………………………………

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12. v_{ave} = ………..………………………………………………………………………………………..

Reminder: show calculations; include units

Compare the value for fitted slope with the calculated value for v_{ave} by calculating the percent difference:

Are the two values in agreement? …………………………………………………………………………............

What does it mean? ……………………………………………………………………..................................

13. Was your speed indeed constant? …………………………………………………………………............

Was your instantaneous speed always exactly the same as your average speed?

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14. Is the mean value roughly in agreement with the other methods you've used to find the average velocity?

v_{mean} =……

15. v_{ave} = the fitted slope = ………..……….

Was your fit good? ……………. my r = ………..……….

Discuss how the slope in the position vs. time plot changed depending on how fast you walked and why.

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16. v_{ave} = the fitted slope = ………..……….

Was your fit good? ……………. my r = ………..………

How has the slope changed? Why?

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PART 2

Attach or paste in your graphs from **Data Studio**.

CONCLUSION:

Note: Make sure to attach all your data and graphs for both parts of the lab.
REMEMBER: No data = No credit.
Also, please do not hand in the manual (pages 1-6), just the report (pages 7-9).