NAME ______________________________ LAB PARTNERS ______________________________

Station Number ______________________________ ______________________________

Motion: Uniform Velocity and Acceleration

Experiment 9

INTRODUCTION

According to Newton's first law of motion, an object with no net force acting on it remains at rest if it is initially at rest, and moves with a constant velocity if it is initially in motion. If there is a net force acting on the object, the object accelerates. The direction of the acceleration is in the direction of the force, and its magnitude is directly proportional to the magnitude of the force and inversely proportional to the mass of the object. If the force and mass are both constant, then the object moves with constant (or uniform) acceleration. The object of this experiment is to study constant velocity motion and constant acceleration motion, and to understand their graphical representations.

THEORY

Recall that the average velocity $<v>$ of an object is given by $<v> = \Delta x \,/\, \Delta t$, where Δx is the displacement and Δt the corresponding time interval. A change in the velocity (either direction or magnitude) results in an average acceleration $<a>$ given by $<a> = \Delta v \,/\, \Delta t$. In words, an object that moves in a straight line making equal velocity changes in equal time intervals is moving with a constant acceleration. If the acceleration is constant, then the average velocity can also be written as $<v> = (v_0 + v_f) \,/\, 2$. Furthermore, if the acceleration is constant, then the instantaneous acceleration a is equal to the average acceleration $<a>$. As your textbook shows, these definitions lead to the following equations for constant acceleration. All quantities are defined as in your text:

$$v = v_0 + at, \qquad x = x_0 + v_0\,t + (1/2)\,a\,t^2, \qquad v^2 = v_0^2 + 2a\,\Delta x.$$

EXPERIMENT NO. 9

The primary purposes of this experiment are (1) to learn experimental procedures for measuring position versus time, (2) to learn to use a scientific analysis and graphing program to analyze the data, and (3) to learn graphical representations of the equations that describe constant velocity and constant acceleration. You will use the dynamics cart to study constant velocity motion and constant acceleration motion. Recall that constant velocity is a result of the motion when the sum of all forces acting on an object is zero. When the sum of all forces acting is not zero, acceleration occurs, and that acceleration is constant if all the forces are constant. You will learn to use some of the features of a scientific data analysis and plotting program that will be used in other experiments during the semester.

1. Level the track by adjusting the screws on the feet of the track.

2. In the first part of the experiment, the object is to study constant velocity motion. Add enough mass (2 or 3 small paper clips) to the string, without the mass hanger, just to overcome friction.

   Give the cart a small push to see if it appears to move with constant velocity. Then remove or add mass if necessary. This is a bit difficult to judge, but with some practice, you can get very close to having constant velocity.

3. The pulley used in this experiment is call a "smart" pulley because it can, along with the proper computer interface, allow you to obtain a record of position versus time for the cart. The pulley works in the following way. The yolk, in which the pulley is mounted, contains a light emitting diode (LED) on one side and a photodetector on the other side. When the spokes of the pulley alternately block and unblock the light, a series of pulses is generated. The distance between the spokes is known, and the time interval between them can be found using the computer's internal clock as a timer. Since the cart is connected to masses that pass over the pulley, a record of distance versus time can be obtained.

   Log into the Student account and open the **exp9** file from the Start Menu.

4. Before each time data is acquired, place the front of the cart at 40 cm, give it a small push and click **Start** to record data. Click again to stop recording data before the cart reaches the end of the track.

5. Your data set contains the position as a function time of the cart as it moved along the track. It is stored as **Run #1** and listed under the **Data** window. To view a graph of your data, drag the data set **Run #1** onto the **Graph** header in the **Display** window below. You should now see a graph of position vs. time.

6. Since these data are supposed to represent motion with constant velocity, the graph should be a straight line. If your graph does not look like a straight line adjust the amount of mass added to the weight hanger and repeat the process until your graph looks straight.

7. The equation $x = x_0 + vt$ describes position as a function of time when an object moves with constant velocity. If this equation is plotted with x on the vertical axis and t on the horizontal axis, the slope of the graph is represented by ________ and the x-intercept is represented by ________.

8. Click on **Display** on the menu at the top of your screen and select **Settings**. Uncheck the box that says "Connect Data Points" and click **OK.** Print graph and then close the graph window.

9. Draw the best fit line through the graph and calculate the slope. Record both the slope and the x-intercept. Show all your calculations on the graph print out.

   Slope = ___________ x-intercept = ___________

Constant Acceleration

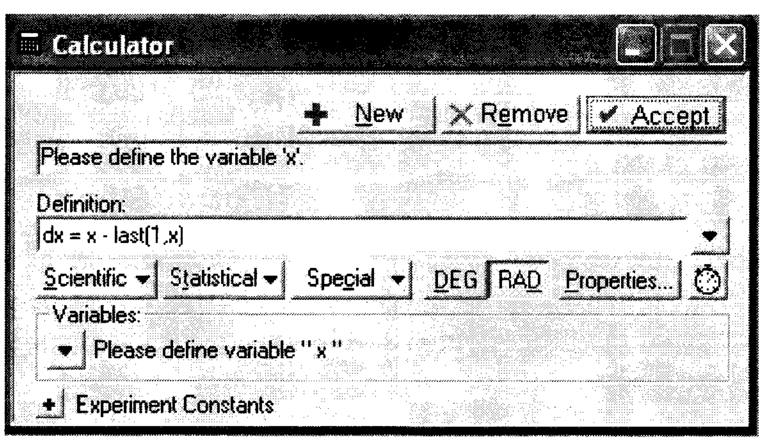
10. Place the weight hanger at the end of the string and add five grams to it. Record another data set. This time there is a net force to accelerate the cart up the track so the equation that describes the position of the cart as a function of time is given by $x = x_0 + v_0 t + \frac{1}{2}at^2$.

11. Plot and print the graph of position vs. time for the new data set. This graph should not be a straight line. What is the name of the curve that describes this graph? Answer the question in the space provided below and then close the graph window.

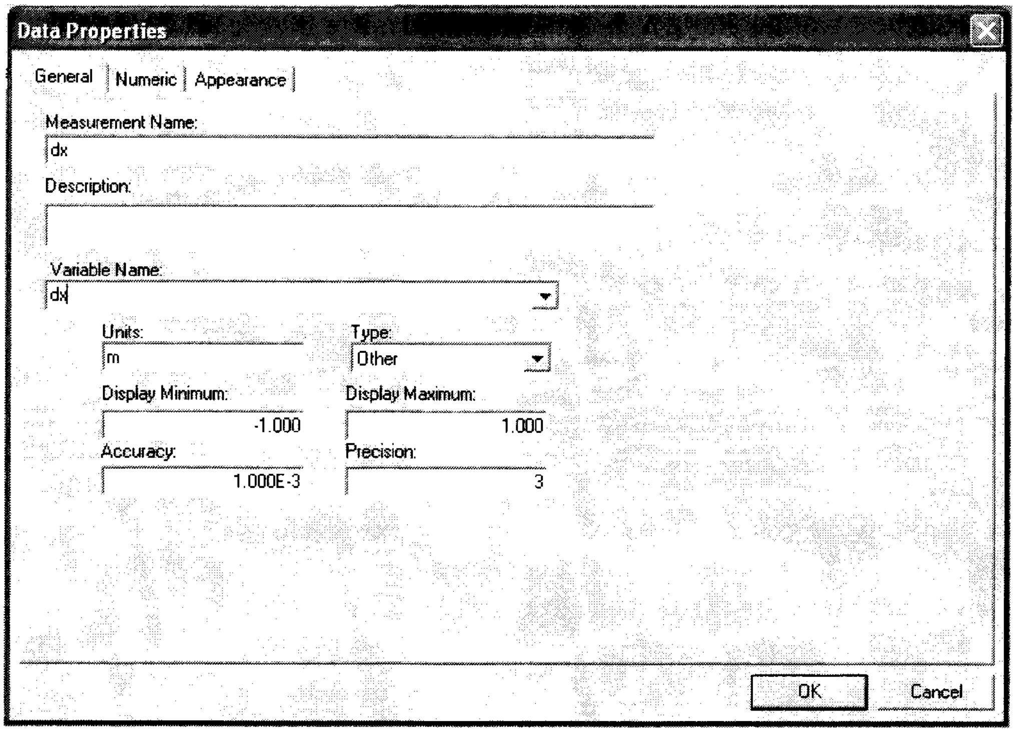
    ____

12. We now want to look at the graph of velocity as a function of time. Remember that velocity is defined as **v = dx/dt**. Before we create the graph of v vs. t

    Click on the **Calculate** button at the top of the screen and select **New**. Under **Definition** type "dx = x-last(1,x)", as shown in the figure below, and click **Accept**. This definition uses the special function "last" to calculate the difference between two adjacent values of the variable x, ($x_2 - x_1$). If you are asked to define the variable x, simply drag **x (m)** to where it says "Please import the variable x" under **Variables**



13. Now set the variable name and the units of dx, click **Properties** in the **Calculator** window then type "m" under **Units.** Under **Variable Name** type "dx". Click **OK.**



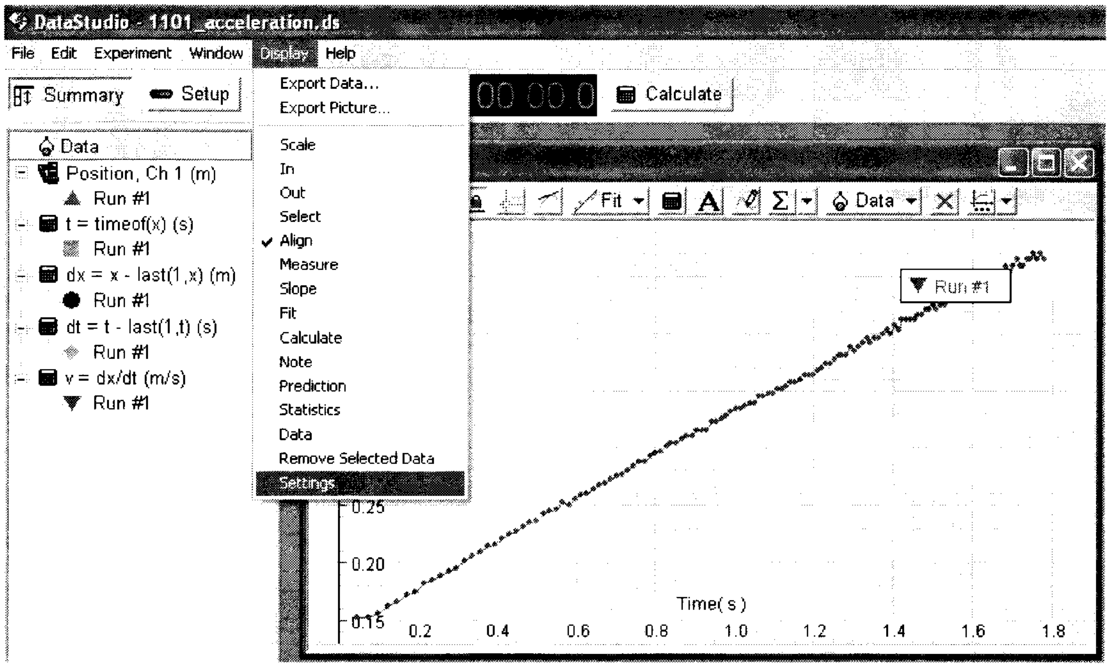
14. Similarly, we are going to create the variable dt. Click on **New** in the **Calculator** window. Type "dt = t-last(1,t)" under definition and click **Accept**. If asked to define the t, click on "t = timeof(x)" in the **Data** window and drag it to define the variable.

15. Click **Properties** in the **Calculator** window and type "s" under **Units.** Click on the drop down button besides **Variable Name** and select Y, erase it and type "dt". Click **OK.**

16. Create the variable v by clicking **New** in the **Calculate** window and typing "v =dx/dt" under **Definition**. To set the units of v click **Properties** in the **Calculator** window and type "m/s" under **Units.** Click the button besides **Variable Name** and select Y, erase it and type "v".

    Then click the button again, this time select X, erase it type "time". Then type "s" under **Units.** Click **OK.**

17. To plot the graph of v vs. t drag "v = dx/dt" on the **Data** window and drop it on **Graph** in the **Display** window. Eliminate the line connecting the data points as we did on step 8. The graph should be a straight line since it is described by the equation $v = v_0 + at$.



18. Print the graph, draw the best fit line through it and calculate the slope. Record both the slope and the v-intercept. Show all your calculations on the graph print out.

Slope = ____________ v-intercept = ____________

19. Explain the physical significance of both the slope and the v-intercept.

20. Add another five grams to the weight hanger and record another set of data. The velocity should be calculated automatically for this data set. Obtain the slope and intercept and record the values

Slope = ____________ v-intercept = ____________

21. Compare the values for the two slopes and comment on why they are related as they are.

22. When you are done go to, close the program and do not save your changes.

23. **Logout of the computer.**

QUESTIONS

1. Suppose you plot a graph of $(x-x_0)/t$ versus t. Explain why the graph is a straight line. What do the slope and intercept represent? Refer to the equations in the theory section.

2. If you were to give the cart a harder push up the track, how would the graph of position versus time compare to the one that you obtained with a weaker push? Assume for this question that the net force on the cart is zero after you make the push; the push is simply to provide an initial velocity.

3. Assume a cart has the same acceleration as the cart you used in Part 11. How long a time would it take the cart to travel 34.0 cm over a level surface, starting from rest?