PHYS 103 LAB 3 FREE FALL

INTRODUCTION

In this laboratory you will study examples of motion with *constant acceleration*, ***g*** (i.e. under the influence of gravity). You will investigate the motion of a bouncing ball, using **Data Studio** to record its *position*, *velocity*, and *acceleration*. You will tabulate and average your results using a **Microsoft Excel** spread sheet.

THEORY

An object doesn't always move at constant *velocity*. If the *velocity* of the object is changing (e.g. the object is speeding up or slowing down), then the object is *accelerating*. We sometimes say that an object is *decelerating* when it is slowing down but that just means it is *accelerating* in the negative direction with respect to the direction of its *velocity*. If the rate of the change of the *velocity* is constant we say that an object is moving with a constant *acceleration*.

Consider an object that was originally placed at a *distance* d_0 from the reference point and originally moving with *velocity* v_0. If the object is then *accelerating* with *acceleration, a,* then its motion is described by the following set of equations:

$$d = d_0 + v_0 t + \frac{at^2}{2}, \tag{1}$$

$$v = v_0 + at, \tag{2}$$

$$a = \text{constant}. \tag{3}$$

Equation (1) is an example of a quadratic equation i.e. the *distance* travelled depends on the *time* squared. In general a quadratic relation can be defined by the equation

$$y = C + Bx + Ax^2, \tag{4}$$

where A, B, and C are constant coefficients.

Equation (2) is an example of a linear equation (i.e. the *velocity* with which the object travels depends on *time*). In general, a linear relation can be defined by the equation

$$y = b + mx, \tag{5}$$

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

Equation (3) is an example of a constant relation (i.e. the *acceleration* of an object does not change with *time*). In general a constant relation can be defined by the equation

$$y = \text{constant} \tag{6}$$

If you drop a ball which is originally at rest (i.e. $v_0 = 0$ m/s) from a *height*, h_0, it will fall under the action of the *gravitational acceleration*, ***g***, which points downwards and has the accepted value of 9.8 m/s^2. Then equations (1), (2), and (3) reduce to:

$$\Delta h = \frac{g\,t^2}{2}, \tag{7}$$

with $\Delta h = h_0 - h$, and

$$v_{\mathrm{f}} = gt, \tag{8}$$

$$a = g = \text{constant}, \tag{9}$$

where Δh is the difference between the final and the original *height* of the ball and v_{f} is the final velocity of the ball.

PROCEDURE:

In this part of the experiment you will use the **Data Studio Motion Sensor** mounted from above to record several bounces of a ball after it is dropped from some *height*. Figure 1 is a sample graph of the *position* and *velocity* of the ball plotted as functions of *time.* The *position* graph looks somewhat strange because the *position* of the ball is recorded from above and, thus, it is greatest when the ball bounces off the floor. In between bounces, the ball is moving with constant *acceleration*, ***g***.

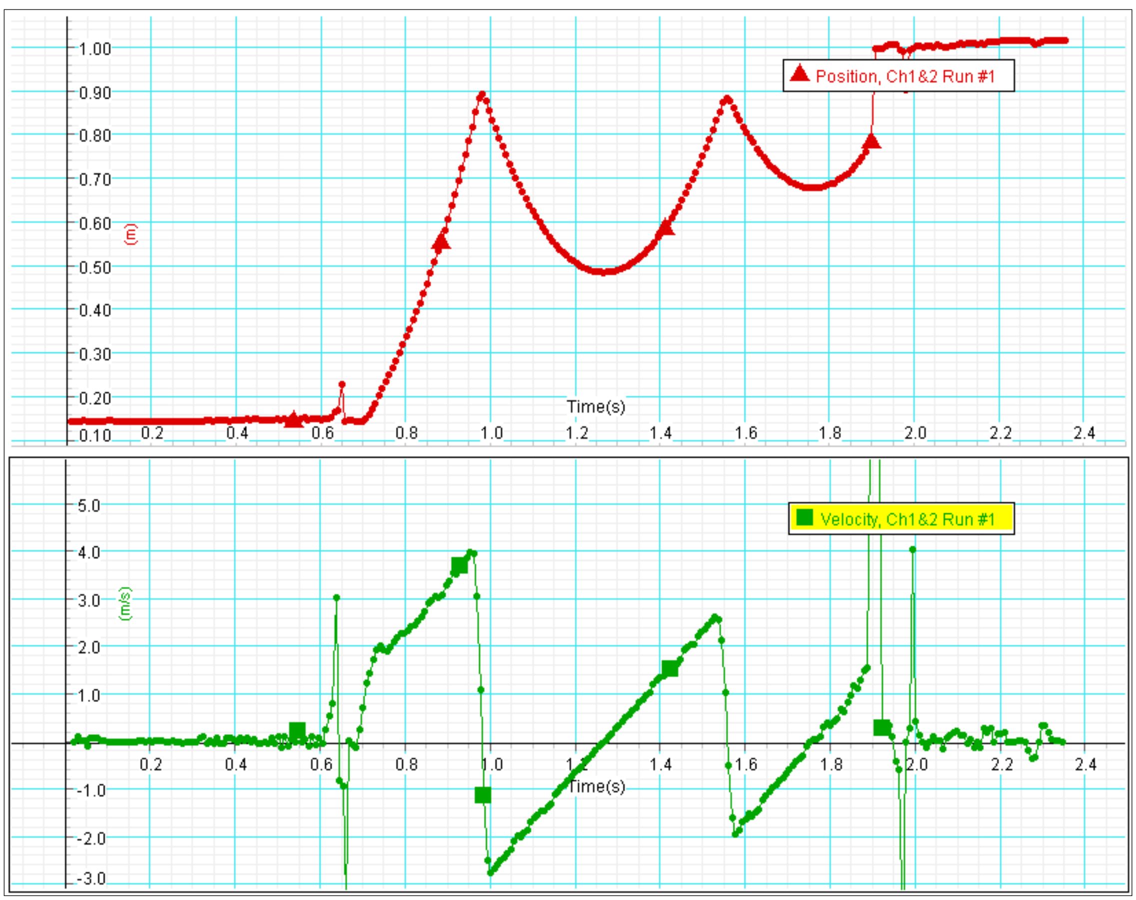

Figure 1. Sample graph of position vs. time and velocity vs. time for a bouncing ball.

The graph of *velocity* vs. *time* shows a sudden change of direction during each bounce. The direction of the *velocity* is indicated by plus or minus sign. The sign of *velocity* is negative as the ball is moving toward the motion sensor i.e. right after it bounces of the floor. After each bounce the ball's *velocity* changes sign abruptly and then it increases linearly with slope equal to ***g*** until the next bounce.

1. Check to make sure that the **Motion Sensor** is set to the correct distance measurement for today's lab. Try a few bounces and if you get a lot of spikes change it from short to long range designation.

2. Now you are ready to begin your experiment, double click on the **Data Studio** icon. Choose **'Create Experiment'**. (Note: If the software cannot find the interface box, make sure the box is on and then reboot the machine; this will allow the box to be seen by the computer). **Do not turn off the Interface Box at any time, even at the end of the experiment!**

3. 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 **'Science Workshop 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 ~~120~~ 100 Hz. Then under the **'Measurements'** tab select position, velocity, and acceleration.

4. Physically plug the yellow and black wires into the (1) and (2) digital channels on the 750 Interface Box as shown on the screen.

5. In the **'Data'** section to the left of **'Experiment Setup'** you will see **'Position'**, **'Velocity'**, and **'Acceleration'**. These are the values that **Data Studio** will calculate for you as the ball falls.

6. In **Data Studio** generate a *position* vs. *time* graph. To do this drag the **'Position'** symbol in the **'Data'** section to the **'Graph'** image in the **'Displays'** section below the **'Data'** section or the opposite: drag the **'Graph'** symbol in the **'Displays'** section to the **'Position'** symbol in the **'Data'** section. Also, in a similar fashion, create the *velocity* vs. *time* graph.

7. Hold the ball about 10 -15 cm below the **Motion Sensor**. Hit the **'START'** button on the top of the **Data Studio** screen and release the ball. Do not push it, just let it go gently – we want *initial velocity* to be zero. After the ball has bounced several times, press the **'STOP'** button.

8. Examine the *position* vs. *time* graph. You should have at least 2-3 complete bounces in it. Note the shape of the *position* vs. *time* graph. Does the *position* of the ball vary quadratically with *time* while the ball is in the air?

9. Now check your *velocity* vs. *time* graph. Does the *velocity* of the ball vary linearly with *time* while the ball is in the air?

10. Real good bounces will be characterized by smooth linear data on the *velocity* vs. *time* graph and smooth parabolic data on the *position* vs. *time* graph with sharp distinct end points when the ball hits the floor. Continue collecting data until you have at least 5 really good bounces on one or two Runs of data. Select the best 5 bounces and **save your data.**

11. In Excel generate a table similar to table 1 below.

12. Use your mouse to select the data on your *velocity* graph corresponding to the first full good bounce. Select **'Linear Fit'** from the **'Fit'** menu in your graph window to display the slope of the selected region of your *velocity* vs. *time* plot. Record the value in the **Excel** table.

Table 1.

bounce #	***r* parameter value for the fit**	**measured values of *g* (m/s²)**
1		
2		
3		
4		
5		
the average value of *g* (m/s²)		
% difference with accepted value		

13. Repeat step 12 for the remaining 4 good bounces. Don't forget to discuss the quality of your fits (look at values of the parameter *r*).

14. Average your measured values for ***g***. Do this using **Excel** by selecting the **'Paste Function'** ($\boldsymbol{f x}$) from the top toolbar. In the **'Function Name'** section of the window select **'AVERAGE'**, then select the cells you wish to average.

15. Compare your averaged value of *g* with the accepted value by calculating the percent difference (in **Excel**). Discuss your results.

16. In **Data Studio** generate a graph of *acceleration* vs. *time.* Does your *acceleration* graph show constant *acceleration* of 9.8 m/s^2 while the ball is in the air? Based on your best bounce find the mean value of *g* using 'Σ' tool in **Data Studio**. Is it close to the expected value?

17. Put all three graphs: the *position* vs. *time* graph, *velocity* vs. *time* graph and *acceleration* vs. *time* graph on one page. Get rid of any highlights, fit boxes, smart, dumb, or delta tools, adjust the scale to best show the data (i.e. do the needed cosmetic work) and then print this page and attach it to your report.

18. Look at the *acceleration* vs. *time* graph and see what happens to *acceleration* when the ball hits the ground. How does the collision with the ground affect the *acceleration*? For one of the collisions, read the peak *acceleration* from the *acceleration* vs. *time* graph and record this value. For the same collision, estimate the initial and final *velocities* from the *velocity* vs. *time* graph and the duration of the collision. Then use the definition of average acceleration:

$$\vec{a}_{ave} = \frac{\Delta\vec{v}}{\Delta t} \qquad (10)$$

to estimate the average *acceleration* during the collision based on the data from the *velocity* vs. *time* graph. Do the two estimates for *acceleration* during the collision with the floor agree? Why is the *acceleration*'s magnitude so huge during the collision? Does the *velocity* change a lot? Discuss.

Print all your data, graphs, and tables, and attach them to your report.
Whenever possible SAVE PAPER.
Delete your files from the computer.
Disconnect all equipment, close all applications, but DO NOT TURN THE COMPUTER OFF.
Make sure you leave the classroom as you found it. PICK UP YOUR TRASH.

LAB 3 REPORT

Group name: ....

Partners names: ....

....

....

INTRODUCTION:

DATA PRESENTATION:

8.

9.

13.

15.

16.

18.

REMINDERS: Include units.

Make sure to attach all your data and graphs. No data = No credit
Please do not hand in the manual, just the report.

CONCLUSION: