

6. Measuring g , the Free Fall Acceleration

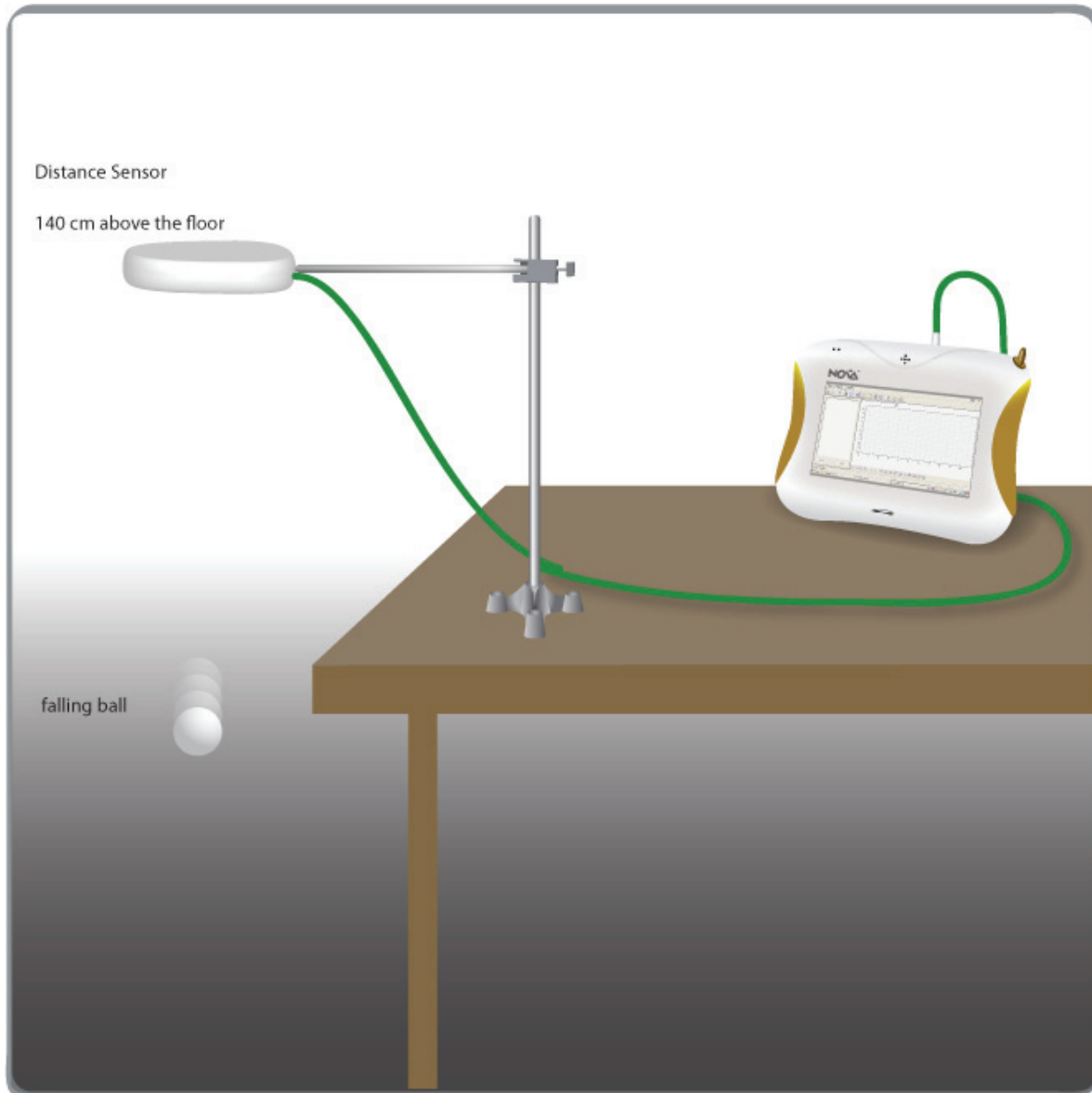


Figure 1

Introduction

In this experiment we use a Distance sensor to examine the position, velocity and acceleration of a free-falling table tennis ball during its downward and upward motion




(after it has bounced on the floor). We assume that the only force acting on the ball is the gravitational force. This experiment also measures the acceleration of the ball during its motion.

Equipment


- Nova5000
- Distance sensor
- Table tennis ball
- Stand with a clamp to hold the Distance sensor
- C-clamp to hold the stand on the tabletop

Equipment Setup Procedure

Note: *Ensure that the AC/DC adapter is connected as the Distance sensor consumes relatively high current.*

1. Launch MultiLab.
2. Connect the Distance sensor to Input 1 (I/O-1) of the Nova5000.
3. Assemble the equipment as shown in Figure 1 above.
4. Place the Distance sensor on a stand, which is attached to the edge of the table with a C-clamp. The Distance sensor should be 1.4m above ground, facing down.
5. Set the positive direction of the position axis in the upward direction:
 - a. Click **Logger** on the menu bar, and then click **Preferences**.
 - b. Select Distance (incoming) from the Distance positive direction drop down menu, then click **OK**.
6. Click **Setup**  on the upper toolbar and program the data logger according to the setup specified below.


To set the coordinate system's origin at the desired point (which is the table), you

have to click **Sensor properties**  next to **Input 1: Distance**, in the **Setup** dialog and follow the instructions below.

Data Logger Setup

Sensors:

Input 1: Distance

Go to **Properties**  > **Set zero**, and select **Set the current reading to zero**

Rate:

25 samples per second


Samples:

200 samples


Experimental Procedure

1. Hold the ball directly beneath the sensor and drop the ball.

Preliminary Questions

- a. Observe the motion. Sketch a graph of Position v_s Time for the ball. Set the origin at the floor (or the table) and upward as the positive direction.
 - b. Describe in words the shape of the Distance v_s Time graph for one jump of the ball.
 - c. Sketch a graph of the Velocity v_s Time for the ball below the graph of the Distance v_s Time, using the same length Time scale. Set the origin at the floor (or the table) and upward as the positive direction.
 - d. Describe in words the shape of the Velocity v_s Time graph. How is this related to the shape of the Distance v_s graph?
2. Click **Run**  on the upper toolbar to begin recording data.



- Drop the ball again. A graph of the results will appear automatically. The ball will jump several times before the end of the measurement (Figure 2).
- Save your data by clicking **Save**  on the upper toolbar.

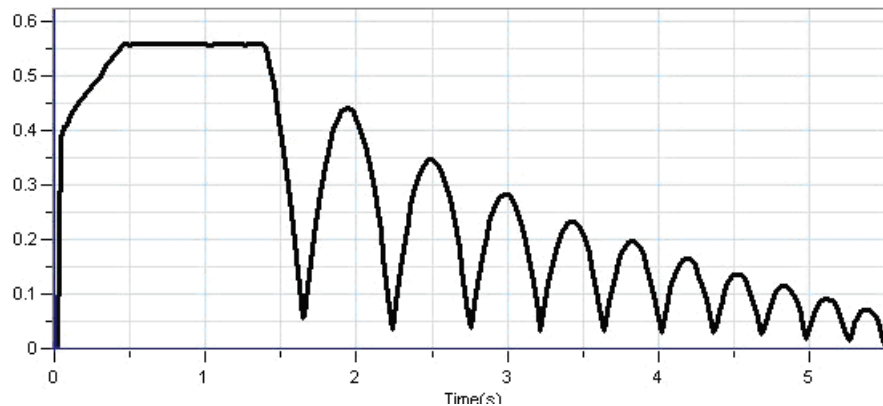





Figure 2

Data Analysis




A. Finding the acceleration due to gravity from the Distance graph

- Compare the **Distance graph** to your sketched prediction in the **Preliminary Questions**. Are the graphs similar?
- Use the cursors to select only one *jump* on the **Distance graph**.
- Click **Tools** on the menu bar, and then click **Crop**. Now the graph Distance *vs.* Time for one cycle is displayed.
- Click **Add to Project**  on the graph toolbar, then click **Save** .
- Use the cursors to select the region on the **Distance graph** where the ball was in free fall and moving upward.
- Use the cursors to select the region on the **Distance graph** where the ball was in free fall and moving downward.
- The Distance *vs.* Time graph while the ball was in free fall should be parabolic, as predicted by the theory. Fit a parabola to the **Distance vs. Time** graph. Click **Tools**

on the menu bar; click **Analysis**, and then click **Quadratic curve fit**. The graph of the parabolic fit will appear on the **Distance vs. Time** graph and the fit equation will be displayed in the information bar at the bottom of the graph window.

8. Save your data by clicking **Save**  on the upper toolbar.
9. Record the equation in your notebook. Does the equation fit the mathematical model (the formula)? Use this equation to define the acceleration g .
10. What is the percent difference between the measured value for the acceleration due to gravity and the expected value (9.8 m/s^2)?

B. Finding the acceleration due to gravity from the Velocity graph

1. Choose the Distance vs. Time graph from the Data Map, for one jump. Click **Derivative**  on the upper toolbar to display a graph of the **Velocity** of the cart.
2. Use the cursors to select two well separated points on the graph and then click **Linear fit**  on the upper toolbar. The graph of the linear fit will appear on the **Velocity** graph and the fit equation will be displayed in the information bar at the bottom of the graph window. Record the equation in your notebook. Does the equation fit the mathematical model (the formula)? Use this equation to define the acceleration g .
3. What is the percent difference between the measured value for the acceleration due to gravity and the expected value (9.8 m/s^2)?
4. Click on the **Distance vs. Time** graph from the Data Map and then click **Show** on the lower bar.
5. Click **Derivative**  on the upper toolbar to display a graph of the **Velocity** of the ball (for a few jumps, see Figure 3).
6. Compare the **Velocity graph** to your sketched prediction in the Preliminary Questions. Are the graphs similar?
7. Repeat the same procedure for two points during one of the *jumps* of the ball to verify that the acceleration is the same for the upward and downward motion.



8. Save your data by clicking **Save**  on the upper toolbar.

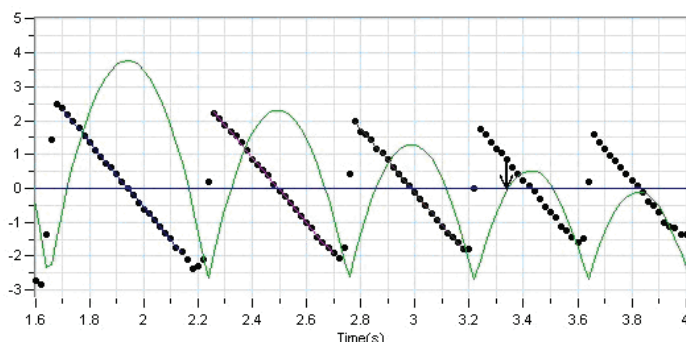





Figure 3

9. Use the cursors to select two well separated points in the first fall of the ball and then click **Linear fit**  on the upper toolbar. The graph of the linear fit will appear on the velocity graph and the fit equation will be displayed in the information bar at the bottom of the graph window. The value of the slope of this graph is the acceleration.
10. Repeat the same procedure for two points during one of the *jumps* of the ball to verify that the acceleration is the same for the upward and downward motion.

Further Suggestions

1. Use the cursor to select the velocity graph, and then click **Derivative**  on the upper toolbar to display a graph of the acceleration. You can investigate this graph to see that the acceleration during free flight is constant. (Since this graph is a second derivative of the experimental results it is expected that it may be *noisy* – try to use the **Smoothing**  tool).

The fact that a fit is possible indicates that the parabola is the correct shape of the graph and the values of the parameters are half the acceleration, the initial velocity and the initial position of the ball.

2. You may want to repeat the experiment several times dropping the ball from different heights. You may then compare the acceleration and the times of the falls (the time of the fall should be proportional to the square root of the height).