FREE FALL

Objective

To measure the acceleration of a freely falling object.

Equipment

Free fall apparatus and mounting hardware, Smart timer, steel balls, tape measure or meter stick.

Introduction

There is an old story that Galileo dropped similar spheres off the leaning tower of Pisa to prove that objects do not, as reported by Aristotle, fall with accelerations proportional to their masses. There is strong evidence that Galileo never did the experiment as described in the story, but gathered his data in an equivalent but much slower manner using inclined planes. We will do the experiment as described in the traditional story but using modern electronic timing equipment.

Galileo showed that an object falling freely in a uniform gravitational field is constantly accelerated. The force that causes the acceleration is the result of the mutual attraction between the falling mass and the earth. Of course, if there are other forces present, such as friction or air resistance, the motion of the falling object would not be one of constant acceleration. However, if the distance of fall is not too great and the object is sufficiently dense, the effects of air resistance are very small and may be ignored. If we use Newton's second law to find the acceleration a of a mass m subjected to a force F, we get

$$a = \frac{F}{m} \tag{1}$$

If the force is the gravitational force, we call the acceleration g, the acceleration due to gravity. This experiment is to study the motion of a falling object in order to measure the acceleration g. An object falling from rest with constant acceleration g for a time t will fall a distance d given by

$$d = \frac{1}{2}gt^2 \tag{2}$$

In this experiment you will measure the height of fall d and the time t for different heights and use the data to determine the value of g.

Activity 1.

1) Assemble the timer with the free fall apparatus so the steel ball has an unobstructed path to the stop pad. The distance the ball falls is measured from the bottom of the ball when held in the ball dropping mechanism to the top of the stop pad. Push in the spring-held rod slightly and tighten the thumbscrew. Place the ball between the two metal contacts on the drop mechanism so that it is held in place. You can then release the ball by loosening the thumb screw.

2) Adjust the height of the ball to about 1.25m. Measure the height and record your measurement on the data sheet.

3) On the Smart Timer, set the measurement to "Time" and the mode to "Stopwatch". Press the "Start/Stop" button. The timer will beep and "*" will appear on the second line of the display. Dropping the ball will start the timer. When to ball hits the stop pad, the timer will stop and display the elapsed time.

Activity 2.

4) Drop the ball 5 times. Record the time from the Smart Timer for each instance, and compute the average of the 5 fall times. Make sure this information is recorded on your data sheet.

Activity 3.

5) Repeat Activity 2 for four more drop heights. For example, you could use 0.25m, 0.5m, 0.75m and 1m. It is important that you measure the actual height used for each run. Record the data from Activity 2 and this Activity in the provided table on the data sheet. Make sure to compute the average fall times.

Activity 4.

6) From your data table generated in Activity 3, calculate the average fall time squared and multiply the height values by 2. Record these values on the data sheet in Table 2.

Activity 5.

7) Using a spreadsheet, preferably Microsoft Excel, or other graphing software, prepare a graph of $2 * d$ versus t^2. Make sure to label the axes and give your plot a title.

8) Using the trendline function, add a linear trendline to your plot. Make sure you turn on the trendline values to see the equation of the line.

9) The slope of the trendline is the experimental value for g, the acceleration due to gravity. Make sure to record your experimental value for g on your data sheet.

Activity 6.

10) Compare your experimental value of g to the standard value of $9.81 m/s^2$ by computing the percent error. The percent error is given by the absolute value of the difference between your result and the standard value divided by the standard value and converted to a percent.

$$\text{percent error} = \left| \frac{\text{experimental value} - \text{standard value}}{\text{standard value}} \right| * 100 \tag{3}$$

Summary.

Answer the following questions on your data sheet:

How well does your measurement compare with the "standard value" for the gravitational acceleration? What factors could contribute to any differences between what you have found and what you expected?

FREE FALL
DATA SHEET

Activity 1.

Height of ball above pad (m): ____________________

Activity 2.

Units for fall time are? ____________________

Table 1: Data table for Activity 2.

Length (m)	Trial 1 (s)	Trial 2 (s)	Trial 3 (s)	Trial 4 (s)	Trial 5 (s)

Average value of time of fall (s): ____________________

Activity 3.

Table 2: Data table for Activity 3.

Height (m)					
Trial 1 (s)					
Trial 2 (s)					
Trial 3 (s)					
Trial 4 (s)					
Trial 5 (s)					
Average (s)					

Activity 4.

Table 3: Data table for Activity 4.

2*fall distance (meters)	(average t)^2 (seconds^2)

Activity 5.

Include a copy of your plot with this assignment. Make sure your plot is in the proper format. For example, are your axes labeled and show the proper units?

Experimental value for g: ______________________________

Activity 6.

Compare your experimental value for g to the standard value of 9.81 m/s^2 by computing a percent error.

Percent Error: ______________________________

Summary

Answer the questions from the summary and include with this assignment.