3

FREE FALL

OBJECTIVE

To measure the acceleration of a freely falling object.

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

$$d = \tfrac{1}{2} g t^2. \tag{2}$$

It 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   METHOD ONE – USING THE ELECTRONIC TIMER

1. Assemble the timer with the free fall adapter so the steel ball has an unobstructed path to the gray 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 gray pad. Push in the spring-held rod slightly and tighten the thumb screw. 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 screw.

2. Adjust the height of the ball to about 1.25 m. **Measure the height and record your measurement.**

3. Set the timer modes to "no memory", "1 ms", and "gate". Reset the timer by pushing the red button and with a quick movement release your fingers outward.

4. Practice dropping the ball several times to ensure that the ball hits the pad near the center before you begin the experiment.

ACTIVITY 2

5. Drop the ball 5 times. **Record the times and compute the average.**

ACTIVITY 3

6. **Repeat Activity 2** recording the fall times for heights of 0.25, 0.50, 0.75, and 1.00 meters. It is not important that the heights be exactly at the specified values, but you should measure these heights as accurately as you can.

ACTIVITY 4

7. Open DataStudio. In the Displays menu, click on the Table icon.

8. A data table should appear. Click on the pencil icon to edit the data. Under the Data button on the Table's toolbar, select Data.

9. Enter the times and heights determined in Activities 2 and 3.

10. A Data icon will appear in the Data menu. Create a graph of this data.

11. **Describe the position vs. time graph of your data. What type of curve is it? Is it linear, quadratic, power, or something else?**

ACTIVITY 5

12. Click on the graph so that it becomes the active window. Pull down the fit menu and select linear. **Do you have a good fit? What are the quantities in the box that describe the fit?**

13. Pull down the fit menu and select linear again. Doing so will remove the fit. Then pull down the menu again and select quadratic.

14. **Do you get a better fit now? What are the quantities that describe the fit?**

15. **Compare the fit parameters to the quantities in Equation (2) and use them to calculate the acceleration of gravity**

16. Close DataStudio.

DISCUSSION   METHOD TWO – USING THE PHOTOGATE

We can find *g* another way by dropping a sheet of clear plastic with evenly-spaced black band printed on it through a photogate. The photogate detects the presence or absence of light passing from one side to the other. When the plastic "picket fence" is dropped through the gate it chops the light beam off each time an opaque black band passes through. The DataStudio software will detect the time the light path is broken as successive bands interrupt the beam. The software will then compute the average velocity of the picket fence during that time interval.

ACTIVITY 6

17. Connect the Photogate port to the USB link. Connect the USB link to your computer. Plug the photogate into the #1 location on the photogate port.

18. Open DataStudio. It will open a window asking you to "Choose a timing or counting mode to add to the activity." Choose the Photogate and Picket Fence option and click OK.

19. Use a meter stick to measure the leading edge to leading edge distance between opaque strips on the "picket fence." You will have the option to edit the variable values. Make sure that the band spacing is 0.050 meters.

ACTIVITY 7

20. Connect the photogate to a stand. Notice that the photogate is in the shape of a "C." Arrange the gate so that the C is parallel to the floor.

21. Place a cushion on the floor underneath the gate.

22. Press Start to begin timing and drop the picket fence (the strip of clear plastic with the evenly spaced black bands) through the photogate. Press Stop after the photogate hits the cushion.

23. **Determine the slope of the resulting velocity plot**.

24. **What does the slope represent? What are the units?**

ACTIVITY 8

25. Repeat the steps 22 and 23 to collect a total of 7 data runs.

26. **Compute the average value of *g* from your data.**

27. **Compare your average value of *g* to the standard value of 9.81 m/s² by computing the percent error.** The percent error is given by the difference between your result and the standard value divided by the standard value and converted to a percent.

$$\text{percent error} = \left| \frac{\text{experimental value - standard value}}{\text{standard value}} \right| \times 100\%.$$

SUMMARY

Answer the following questions on your data sheet.
How well do your measurement compare with the "standard value" for the gravitational acceleration?
What factors contribute to any differences between what you have found and what you expected?
How do the two methods for measurement of *g* compare?

Tear out and hand in.   Name ————————————

FREE FALL
DATA SHEETS

ACTIVITY 1   **METHOD ONE**

1. Height of ball above pad: ——————————————

ACTIVITY 2

Measurements of time of fall. Units = ————

Average value of time of fall ——————.

ACTIVITY 3

Repeat Activity 2

Height				
1st time				
2nd time				
3rd time				
4th time				
5th time				
average				

ACTIVITY 4

Describe the position vs. time graph of your data. What type of curve is it?

ACTIVITY 5

Do you have a good fit?
What are the quantities in the box that describe the fit?

Do you get a better fit now?
What are the quantities in the box that describe the fit?

Calculate the acceleration of gravity from the fit parameters.

METHOD TWO

ACTIVITY 7

What is the slope of the velocity plot?

What does the slope represent?

What are the units of the slope?

ACTIVITY 8

Determine the slope of each velocity plot in SI units.

Using the slopes determined in the previous step, **determine the acceleration of gravity (for each data run).**

Compute the average value of *g*.

Compare your average value to the standard value of 9.81 by computing a **percent error**.

Answer summary questions here.