Measuring “g” the acceleration caused by gravity

Introduction

With its automatic release mechanism and accurate digital timer, the **PASCO Model 9202C free fall timer** allows to measure the acceleration due to gravity with 1 percent accuracy. The **free fall timer** is shown in Figure 1. It includes a ball release mechanism, a receptor pad, and an electronic timer. Two steel balls, with diameters of 16 and 13 mm, and a 9/12 volt AC adapter are also included.

- In the basic free fall experiment, a steel ball is clamped into the spring loaded release mechanism. The ball is in series with the triggering circuit for the timer. When the thumbscrew is turned, the mechanism pops open, releasing the ball and starting the timer.
- When the ball strikes the receptor pad, the top plate of the pad is forced against the metal base, stopping the timer. The timer display shows the time it took for the ball to drop from the release mechanism to the pad. Timing is to the nearest millisecond with 1 percent accuracy.

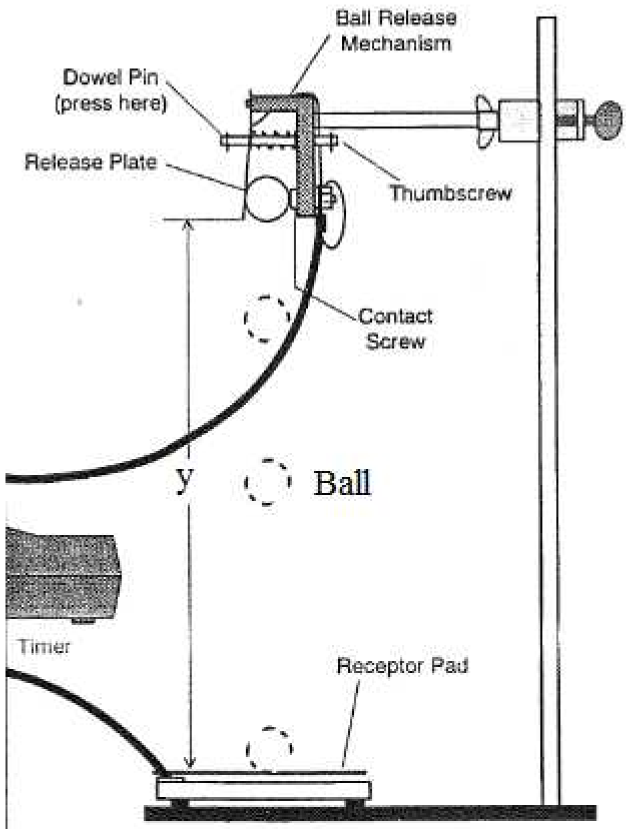

Figure 1. Experiment setup

Setup and operation

Set up the free fall timer as shown in figures 1.

(1) Clamp the ball release mechanism to a lab stand, and at the desired height over the floor. For best results, the drop height (y) should be the full 200 cm allowed by the cable. Shorter heights will work fine, but accuracy is reduced proportionally.
(2) Position the ball receptor plate directly under the ball. (You might want to place the receptor plate in a shallow box so the ball doesn't roll away after it falls).

(3) Insert one of the steel balls into the release mechanism, pressing in the dowel pin so the ball is clamped between the contact screw and the hole in the release plate. Lightly tighten the thumbscrew to lock the ball in place.

(4) Tum the timer on and press the **RESET** button.

(5) Loosen the thumbscrew to release the ball. It should hit in the center of the receptor pad. If not, reset the timer, reposition the pad, and try it again.

(6) Read the time on the digital display of the timer. This is the time it took for the ball to fall the distance y, as shown in figure 1.

Theory

We know equation of motion of a body

$$y = v_i t + \frac{1}{2} a t^2 \qquad (1)$$

The equation of motion for a body starting from rest and undergoing constant acceleration can be expressed as:

$$y = \frac{1}{2} g t^2 \qquad (2)$$

where y is the distance the object has traveled from its starting point, g is the acceleration, and t is the time elapsed since the motion began.

In order to measure the acceleration caused by gravity, several questions must be answered:

- Is the acceleration constant? If it is, then the distance an object falls will be proportional to the square of the elapsed time, as in the above equation.
- If the acceleration is constant, what is the value of the acceleration? Is it the same for all objects or does it vary with mass or size of the object, or with some other quality of the object? If it is not constant, how does it vary with time?

In this experiment you will answer these questions by carefully timing the fall of a steel ball from various heights.

Procedure

(1) Set up the free fall timer as described in the setup and operation section. Use the 13 mm diameter steel ball.

(2) Set y, the height from which the ball drops, to approximately $150\ \text{cm}$. Measure the distance as accurately as possible and record the distance in Table 1**. Press the reset** button on the timer, then loosen the thumbscrew so the ball drops. Record the measured time as t_1 in Table 1. Repeat the measurement at least four more times and record these values as $t_2 \cdots t_5$. Calculate the average of your five measured times and record this value as t_{avg}.

(3) Set y to 150, 140, 130, 120, 110, 100, $\cdots\cdots$50 *cm*, repeating step 2 for each value of y. (The actual value of y need not correspond exactly to the listed values, but be sure you measure it carefully)

(4) Repeat steps 2 and 3 using the different diameter steel ball.

Analysis

For each ball, plot a graph of y versus t_{avg}^2 with y as the dependent value (y-axis). Within the limits of your experimental accuracy, do your data points define a straight line for each ball? Was the acceleration constant for each ball?

If your graphs were linear, measure the slope of each graph. Using **your measured slopes and the equation 2, determine the acceleration caused by gravity**. Be sure to include the units. Was the acceleration the same for each ball?

Conclusion

Describe your laboratory experiment and discuss your results. Consider the following questions: (1) Is the acceleration caused by gravity constant? (2) Is the acceleration caused by gravity the same for all objects? Discuss the conditions under which you believe your results to be true. Include a discussion of the errors in your measurements and how they affect your conclusions. How linear was your graph? How might you alter your technique, or the experiment, in order to reduce experimental errors?

Table 1. Data and calculations

y (cm)	$t_1(s)$	$t_2(s)$	$t_3(s)$	$t_4(s)$	$t_5(s)$	$t_{avg}(s)$	$t_{avg}^2(s^2)$
150							
140							
130							
120							
110							
100							
90							
80							
70							
60							