I. Objectives

1. Investigate the behavior of falling objects.
2. Calculate the value of g, the acceleration of gravity.

II. Introduction

We will determine if bodies dropped from rest fall with constant velocity or constant acceleration, and at the same time, will calculate the value of g, using the free fall apparatus.

Practice using the apparatus before taking data to be sure that you understand how it works. You will adjust the displacement y by changing the height of the ball holder and the timer will indicate how long it takes the ball to fall that displacement.

III. Calculations

From the laws of kinematics along a straight line we know that:

$$y = y_0 + v_0 t + \frac{1}{2} at^2$$

In this experiment $y_0 = 0.0$ m/s, and $v_0 = 0.0$ m/s so the equation above simplifies to:

$$y = \frac{1}{2} at^2$$

We can replace a with the acceleration of gravity g:

$$y = \frac{1}{2} gt^2$$

$$2y = gt^2$$

$$g = \frac{2y}{t^2}$$

Graphing $2y$ versus t^2 should result in a straight line with a slope of g. **Remember that the value of y is negative since it is measured in the downward direction.**

IV. Equipment and Materials

Free fall apparatus, ring stand, clamp, metal ball, PASCO Smart Timer, calculator

V. Procedure

1. **The free fall apparatus clamp is delicate. Treat it gently!**

2. Set up the ring stand, clamp, and free fall apparatus as shown in the diagram. (Source: Instruction Manual and Experiment Guide for the PASCO scientific Model ME-9207B)

3. Plug free fall apparatus phone jack into port 1 of the PASCO Smart Timer.

4. Clamp the metal ball into the release mechanism of the free fall timer using the small metal plate and the screw.

5. Measure the displacement y from the bottom of the metal ball to the surface of the ball receptor pad.

6. Record the displacement in Table 1, column B for trial 1.

7. Position the ball receptor pad directly under the ball.

8. Press the PASCO Smart Timer Select Measurement button repeatedly until **Time** appears on the PASCO Smart Timer display screen.

9. Press the PASCO Smart Timer Select Mode button repeatedly until **Time: Stopwatch** appears on the PASCO Smart Timer display screen.

10. Press the PASCO Smart Timer Start/Stop button once. An * will appear on the PASCO Smart Timer display screen directly below the word Time. The * indicates that the Smart Timer is ready to collect fall time data.

11. Loosen the free fall apparatus thumbscrew to release the ball, which should land near the center of the free fall receptor pad. If it doesn't, reset the timer by pressing the PASCO Smart Timer Start/Stop button, reposition the pad, reclamp the metal ball, and repeat the trial.
12. Record the time on the display screen of the PASCO Smart Timer in Table 1.

13. **Press the PASCO Smart Timer Start/Stop button after every time trial to reset the timer**.

14. Record at least 3 successful time trials for the first displacement, then repeat the process again, recording three successful time trials for each of the four additional y displacements. Be sure that you record the displacements in Table 1. There will be a total of 15 trial times, 5 displacements x 3 time trials per displacement.

15. Complete Table 1.
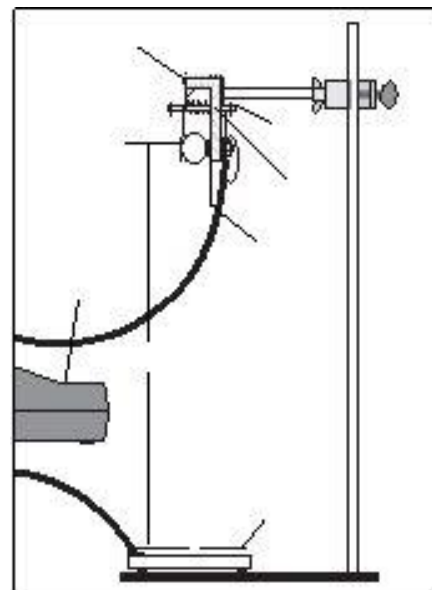
16. Graph $2y$ versus t^2, using t^2 as the x-coordinate and $2y$ as the y-coordinate. You must include the **linear** best fit line generated by the spreadsheet program, **not** a hand drawn line, to connect the points on the graph. If you don't know how to do this, ask! Staple the graph to the lab.

17. On a **separate graph**, graph y versus t, using t as the x-coordinate and y as the y-coordinate. You must include the **polynomial order 2** best fit line generated by the spreadsheet program, **not** a hand drawn line, to connect the points on the graph. Be sure to check the Set Intercept box if you are using Excel and leave the intercept value at zero. If you are using a different spreadsheet program you will need to figure out how to do the equivalent. Staple the graph to the lab.

VI. Data

Table 1 Free Fall Apparatus

A	B	C	D	E	F	G	H	$I = \dfrac{H}{G}$
Displacement	Displacement y in m	Time trial 1 time t in s	Time trial 2 time t in s	Time trial 3 time t in s	Average time t in s	Average time squared t^2 in s^2	Displacement $2y$ in m	$g = \dfrac{2y}{t^2}$ in m/s^2
1								
2								
3								
4								
5								
							Average g:	

VII.   Discussion Questions

1. What was your average value for the acceleration of gravity, g? Does it agree with the accepted value? Explain what factors in the experiment might account for any difference.

2. Calculate the percent error:

$$\% \ error = \frac{experimental \ value - accepted \ value}{accepted \ value} x \ 100\%$$

What is the percent error?

3. Would changing the mass of the ball change the results? Explain why or why not.

4. What shape should the line on the y versus t graph have? Explain why it should not be linear. "Curved" is not the correct answer. You must be more specific.

5. Why should the coefficient of the squared term of the best fit line on the y versus t graph be approximately equal to -4.9? Be sure that your explanation includes the equation used to calculate y if t is known.