Formal Lab
Measuring g

Physics 4A

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Contents

Chapter 1

Purpose

1.1 What is the purpose of this lab?

The purpose of this lab is to measure gavitational acceleration and compare it to the theoretical value of the gravitational value of Earth g found to be about $9.80\frac{m}{s^2}$

1.2 What are you trying to measure?

In the lab the goal is to attempt to measure the value g

Chapter 2

Theory

2.1 Give a description of the theory involved for this particular lab.

Objects that fall freely near Earth will accelerate at approximately $9.81\frac{m}{s^2}$ if they:

- are near the surface of the Earth
- are at a geographic location where the Earth's radius is approximately its average value
- When air friction is ignore, the acceleration of an object falling is independent of the mass, volume, and shape
- For short distances and small objects it is not unreasonable to neglect air resistance, but for
- For long distances and large objects, air resistance is significant Acceleration of gravity g can be calculated using kinematics
- Δy is the displacement
- t is the time
- v_0 is the initial velocity
- v_f is the final veolcity
- $a = g_{exp}$ a is the experimental acceleration due to gravity

Chapter 3

Procedure

3.1 Equipment

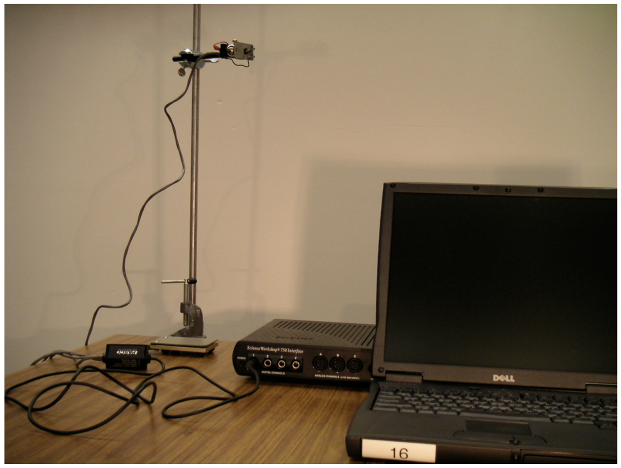
The necessary equipment for this lab is as follows:

- 2 meter aluminum rod
- Table clamp
- Swivel clamp or 90° Offset Clamp
- Meter Stick
- $\frac{1}{2}$" and $\frac{3}{8}$" steel ball
- Freefall Adapter - PASCO #ME
- PASCO 750 Interface box
- PASCO Interface box power cord and SCSI Interface Card
- Laptop Computer w/ Data Studio

3.2 Procedure

3.3 A. Apparatus Setup

Setup the apparatus as shown in the picture below. Make sure that the clamps are tight, but not over tight. The clamp holding the apparatus should be tight enough to not allow the apparatus to move around. Makre sure that the small thumb screw on the ball clamp is on top.



The apparatus consists of a small clamp that holds the metal ball and a steel rod; it is designed to complete a circuit when the ball is installed. There is a plunger that goes through the thin steel plate that has a retaining ring on both ends. This plunger places pressure on the steel plate and holds the ball in place.

Place the ball in the clamp, positioning it between the hole and the brass screw, pull on plunger so that the retaining ring is exerting pressure on the steel plate. When there is enough pressure on the plate to retain the ball, tighten the thumbscrew. The ball and apparatus are now ready to be used.

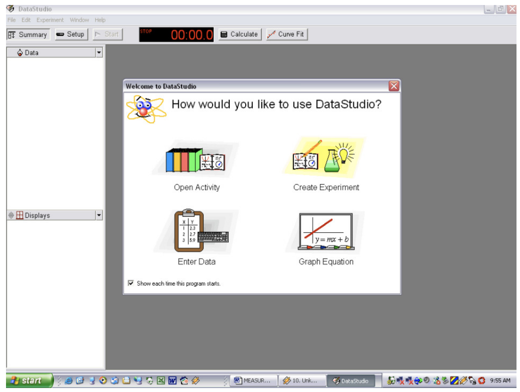
Position the floor plate directly beneath the ball clamp. Do a few test drops to make sure that the ball solidly strikes the plate.

Possible Pitfalls:
Due to the age of the apparatus, the circuit may be easily broken. It is possible, however, to maneuver the ball so that the circuit remains closed. The thumbscrew must be tightly set; otherwise it will not hold the plunger. This means that the slightest turn on the thumbscrew will release the plunger.

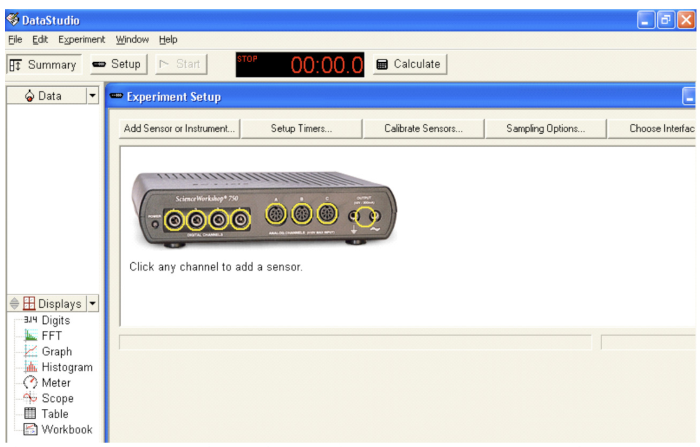
3.4 B. Computer Setup

Provide power to the PASCO 750 Interface box, connect the box to the computer with the SCSI cord and turn on the box, making sure the word "Honda" on the cord is facing upward when it gets plugged into the computer. Only after you have turned on the PASCO 750 Interface box 750 and plugged it into the computer, can you turn on the computer. (If you do not perform these tasks in the above listed order, your computer will not recognize the PASCO 750 Interface box.) When the computer is first turned on, it may have a Found New Hardware window open. If so, just ignore the window and proceed with the steps below. Double-Click on the *Data Studio* icon on the desktop. The following screen should appear:

Click *Create Experiment*, if it cannot find the Interface box right away, click *Scan*. If it doesn't find it after you have clicked *Scan*, make sure that it is



connected properly. If it is connected properly and everything seems to be in order, restart the computer and the Interface box should load proper. Once the Interface box is found, the following screen will appear:



This is your main window. This window contains a picture of the interface box you currently have attached, access to a list of sensors that can be attached to the Interface box, a toolbar to *adjust* sensor options and other items.

Under *Experiment Set-Up*, click *Add Sensor or Instrument* and a window will open. Then click on the small black arrow near the top of the window to open a drop-down menu and select *Scientific Workshop Digital Sensors*. Finally select *Free-Fall Adapter* and click *Ok*. See picture below.

In the *Experiment Set-Up* window, on the bottom left corner of the window, click the *Measurements* tab and de-select *Acceleration, Ch 1 box*. As seen below.

3.5 C. Data Collection Setup

On the left-hand side of the Data Studio program, there are two windows: *Data* and *Displays*.

Data shows you what you are going to collect. Here, you can see that the only data being collected is the *Time of Fall*, in seconds.

Displays gives you several choices and formats in which to display your captured data. In this lab, we are only going to be concerned with the *Table* display. We will explore other displays in subsequent labs.

Double-Click *Table* in Displays and select *Time of Fall, Ch 1 (s)*. Click *OK*. The following table will appear on your screen:

3.6 D. Data Collection

The goal of this experiment is to capture the time it takes the ball to fall a certain distance. We have set up the computer and apparatus to assist us in capturing the data required.

You will be dropping each ball over a minimum of 5 distances (0.2 m, 0.4 m, 0.6 m,0.8 m, 1.0 m, etc.). Drop the ball 5 times per height to get an average time.

Load the apparatus with the large ball, and set the apparatus at the correct height. Click the Start button; this will start the timer. Leave it on for the remainder of the experiment. When you drop the ball, the data will appear on the table. If it appears to be good data, click the *Keep* button

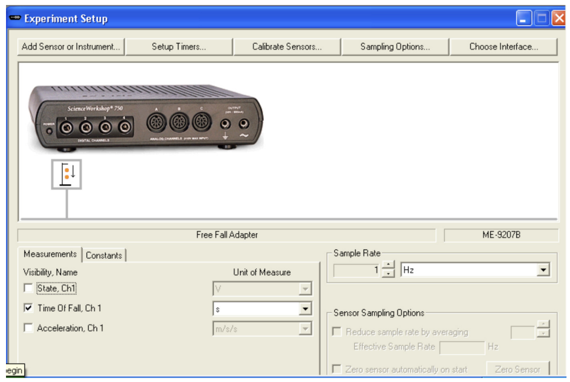


Figure 3.1: Plug the *Free Fall Adapter* into the channel indicated (here it is in Channel 1). Click the *Sampling Options* button (located on the top of the *Experiment Setup* window). Make the selections as below:

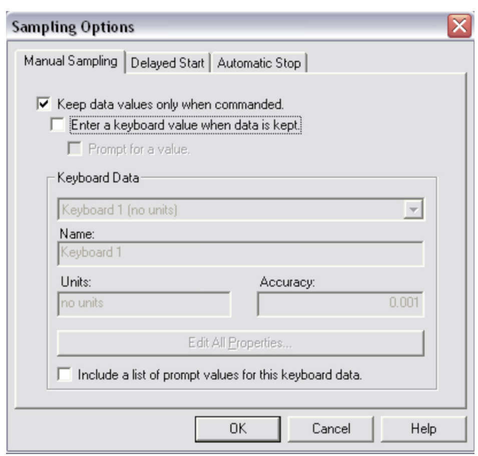


Figure 3.2: When you click on *"Keep data values only when commanded,"* you will have to uncheck *"Enter a keyboard value when data is kept."* Click *Ok*. The computer is now ready to collect data.

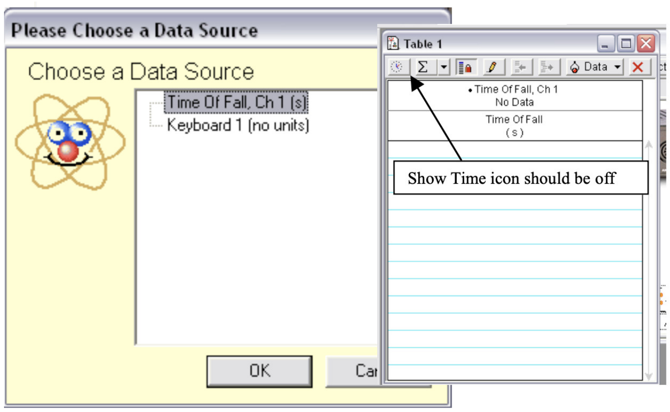


Figure 3.3: Make sure that the *Show Time* icon, on the top of your table, is **off**. You are now ready to begin the experiment.

Chapter 4

Data

4.1 Raw Data

Raw Untouched Data

Time Of Fall, 0.2m, 1/2" large	Time Of Fall, 0.2m, 3/8" small
Time Of Fall (s)	Time Of Fall (s)
0.2021	0.2028
0.2032	0.2021
0.2009	0.2028
0.2004	0.2029
0.2005	0.2017

Time Of Fall, 0.4m, 1/2" large	Time Of Fall, 0.4m 3/8" small
Time Of Fall (s)	Time Of Fall (s)
0.2849	0.2862
0.2843	0.2866
0.284	0.2866
0.2851	0.2872
0.2845	0.2874

Time Of Fall, 0.6m, 1/2" large	Time Of Fall, 0.6m, 3/8" small
Time Of Fall (s)	Time Of Fall (s)
0.3476	0.3487
0.3476	0.3494
0.3494	0.3498
0.3491	0.3489
0.3487	0.3491

Time Of Fall, 0.8m, 1/2" large	Time Of Fall, 0.8m, 3/8" small
Time Of Fall (s)	Time Of Fall (s)
0.402	0.4049
0.4036	0.4034
0.4025	0.4036
0.4048	0.4037
0.4034	0.4043

Time Of Fall, 1.0m, 1/2" large	Time Of Fall, 1.0m, 3/8" small
Time Of Fall (s)	Time Of Fall (s)
0.4508	0.4531
0.4498	0.4512
0.4501	0.452
0.4517	0.452
0.4519	0.451

4.2 Formatted Raw Data

Raw Data Fromatted in a Data

Small Ball (3/8" steel ball)

Height (cm)	Uncertainty (+- cm) based on meter stick	Height (m)	Uncertainty (m)	Time of Fall (s)	Uncertainty (+- s) based on photogate timer
20.0	0.05	0.200	0.005	0.2028	0.00005
				0.2021	
				0.2028	
				0.2029	
				0.2017	
40.0	0.05	0.400	0.005	0.2862	0.00005
				0.2866	
				0.2866	
				0.2874	
				0.2872	
60.0	0.05	0.600	0.005	0.3487	0.00005
				0.3494	
				0.3498	
				0.3489	
				0.3491	
80.0	0.05	0.800	0.005	0.4049	0.00005
				0.4034	
				0.4036	
				0.4037	
				0.4043	
100.0	0.05	1.000	0.005	0.4531	0.00005
				0.4512	
				0.4520	
				0.4520	
				0.4510	

Large ball (1/2" steel ball)

Height (cm)	Uncertainty (+- cm) based on meter stick	Height (m)	Uncertainty (m)	Time of Fall (s)	Uncertainty (+- s) based on photogate timer
20.0	0.05	0.200	0.005	0.2021	0.00005
				0.2032	
				0.2009	
				0.2004	
				0.2005	
40.0	0.05	0.400	0.005	0.2849	0.00005
				0.2843	
				0.284	
				0.2851	
				0.2845	
60.0	0.05	0.600	0.005	0.3476	0.00005
				0.3476	
				0.3494	
				0.3491	
				0.3487	
80.0	0.05	0.800	0.005	0.402	0.00005
				0.4036	
				0.4025	
				0.4048	
				0.4034	
100.0	0.05	1.000	0.005	0.4508	0.00005
				0.4498	
				0.4501	
				0.4517	
				0.4519	

Chapter 5

Analysis

5.1 Include Values

calculated fron data, graphs, answers to Qs

5.2 Average Time Calculated

In the following data tables, the average time of the fall for each ball at each height is calculated

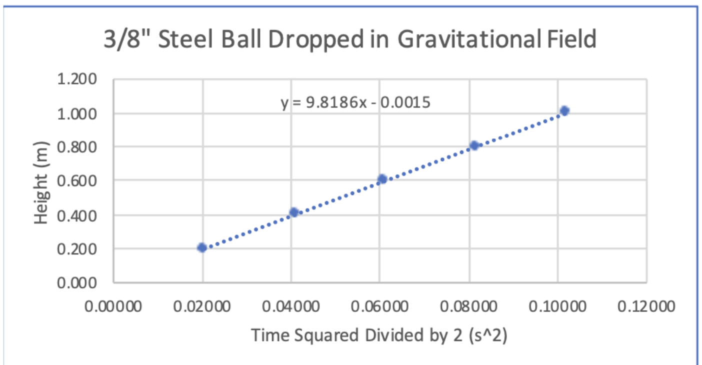
Height (m)	3/8" Small Ball	Time of Fall (s)
		0.2028
		0.2021
0.200		0.2028
		0.2029
		0.2017
	Average	0.2025
		0.2862
		0.2866
0.400		0.2866
		0.2874
		0.2872
	Average	0.2868
		0.3487
		0.3494
0.600		0.3498
		0.3489
		0.3491
	Average	0.3492
		0.4049
		0.4034
0.800		0.4036
		0.4037
		0.4043
	Average	0.4040
		0.4531
		0.4512
1.000		0.4520
		0.4520
		0.4510
	Average	0.4519

Height (m)	1/2" Large Ball	Time of Fall (s)
		0.2021
		0.2032
0.200		0.2009
		0.2004
		0.2005
	Average	0.2014
		0.2849
		0.2843
0.400		0.284
		0.2851
		0.2845
	Average	0.2846
		0.3476
		0.3476
0.600		0.3494
		0.3491
		0.3487
	Average	0.3485
		0.402
		0.4036
0.800		0.4025
		0.4048
		0.4034
	Average	0.4033
		0.4508
		0.4498
1.000		0.4501
		0.4517
		0.4519
	Average	0.4509

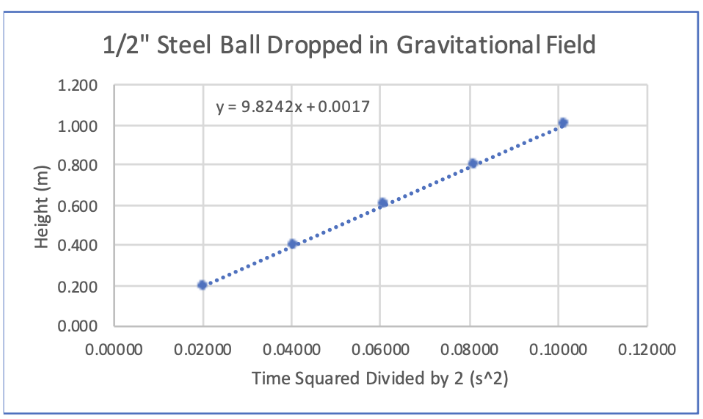
5.3 Graphed Data

The following graphs for the small and large ball and their avaerge fall times at each height squared then divided by 2, are plotted on a scatter plot and given a linear line with a calculated slope.

Height (m)	Average Time of Fall (s)	Time Squared Divided by 2 (s^2)
0.200	0.2025	0.02050
0.400	0.2868	0.04113
0.600	0.3492	0.06097
0.800	0.4040	0.08161
1.000	0.4519	0.10211



Height (m)	Average Time of Fall (s)	Time Squared Divided by 2 (s^2)
0.200	0.2014	0.02028
0.400	0.2846	0.04050
0.600	0.3485	0.06073
0.800	0.4033	0.08133
1.000	0.4509	0.10166



Chapter 6

Error Analysis and Procedural Errors

6.1 Front-End Error - RSS

3/8" Steel Ball $RSS =$

$$\sqrt{\left(\frac{0.005m}{0.200m}\right)^2+\left(\frac{0.005m}{0.400m}\right)^2+\left(\frac{0.005m}{0.600m}\right)^2+\left(\frac{0.005m}{0.800m}\right)^2+\left(\frac{0.005m}{1.000m}\right)^2+\left(\frac{0.00005s}{0.2025s}\right)^2} \text{---}$$

$$\text{----} \overline{+\left(\frac{0.00005s}{0.2868s}\right)^2+\left(\frac{0.00005s}{0.3492s}\right)^2+\left(\frac{0.00005s}{0.4040s}\right)^2+\left(\frac{0.00005s}{0.4519s}\right)^2} \cdot 100\% = 3.0\%$$

$$\text{3/8" Steel Ball } RSS = \sqrt{\left(\frac{0.005m}{0.200m}\right)^2+\left(\frac{0.00005s}{0.2025s}\right)^2} \cdot 100\% = 2.5\%$$

1/2" Steel Ball $RSS =$

$$\sqrt{\left(\frac{0.005m}{0.200m}\right)^2+\left(\frac{0.005m}{0.400m}\right)^2+\left(\frac{0.005m}{0.600m}\right)^2+\left(\frac{0.005m}{0.800m}\right)^2+\left(\frac{0.005m}{1.000m}\right)^2+\left(\frac{0.00005s}{0.2014}\right)^2} \text{---}$$

$$\text{----} \overline{+\left(\frac{0.00005s}{0.2846s}\right)^2+\left(\frac{0.00005s}{0.3485}\right)^2+\left(\frac{0.00005s}{0.4033}\right)^2+\left(\frac{0.00005s}{0.4509s}\right)^2} \cdot 100\% = 3.0\%$$

$$\text{1/2" Steel Ball } RSS = \sqrt{\left(\frac{0.005m}{0.200m}\right)^2+\left(\frac{0.00005s}{0.2014s}\right)^2} \cdot 100\% = 2.5\%$$

6.2 Back-End Error

In this case, percent error should be used because this is an experimental result being compared to the accepted known value of $g = 9.8\frac{m}{s^2}$ With the following percent error calculated, none of the data points were over the Front-End Error percentage. In general the calulated gravitational acceleration was very close to the theoretical value of Earth's $g = 9.8\frac{m}{s^2}$

$$3/8\text{" } ball: \qquad \%error = \frac{|E-K|}{K} \cdot 100\%$$

$$= \%\text{error for } 0.200m = \frac{|9.819\frac{m}{s^2} - 9.755\frac{m}{s^2}|}{9.755\frac{m}{s^2}} \cdot 100\% = 0.71\% \ (0.707\%)$$

$$= \%\text{error for } 0.400m = \frac{|9.819\frac{m}{s^2} - 9.726\frac{m}{s^2}|}{9.726\frac{m}{s^2}} \cdot 100\% = 0.96\% \ (0.956\%)$$

$$= \%\text{error for } 0.600m = \frac{|9.819\frac{m}{s^2} - 9.841\frac{m}{s^2}|}{9.841\frac{m}{s^2}} \cdot 100\% = 0.22\% \ (0.223\%)$$

$$= \%\text{error for } 0.800m = \frac{|9.819\frac{m}{s^2} - 9.803\frac{m}{s^2}|}{9.803\frac{m}{s^2}} \cdot 100\% = 0.16\% \ (0.163\%)$$

$$= \%\text{error for } 1.000m = \frac{|9.819\frac{m}{s^2} - 9.794\frac{m}{s^2}|}{9.794\frac{m}{s^2}} \cdot 100\% = 0.26\% \ (0.255\%)$$

$$1/2\text{" } ball: \qquad \%error = \frac{|E-K|}{K} \cdot 100\%$$

$$= \%\text{error for } 0.200m = \frac{|9.824\frac{m}{s^2} - 9.824\frac{m}{s^2}|}{9.824\frac{m}{s^2}} \cdot 100\% = 0.38\% \ (0.375\%)$$

$$= \%\text{error for } 0.400m = \frac{|9.824\frac{m}{s^2} - 9.877\frac{m}{s^2}|}{9.877\frac{m}{s^2}} \cdot 100\% = 0.54\% \ (0.537\%)$$

$$= \%\text{error for } 0.600m = \frac{|9.824\frac{m}{s^2} - 9.880\frac{m}{s^2}|}{9.880\frac{m}{s^2}} \cdot 100\% = 0.57\% \ (0.567\%)$$

$$= \%\text{error for } 0.800m = \frac{|9.824\frac{m}{s^2} - 9.837\frac{m}{s^2}|}{9.837\frac{m}{s^2}} \cdot 100\% = 0.13\% \ (0.132\%)$$

$$= \%\text{error for } 1.000m = \frac{|9.824\frac{m}{s^2} - 9.837\frac{m}{s^2}|}{9.837\frac{m}{s^2}} \cdot 100\% = 0.13\% \ (0.132\%)$$

6.3 Potential Cause of Error

There are a number of potential causes to the error presented in this lab experiment. The two most notable causes of error are as follows:

- Miscalculated height - although we were aiming for 0.005m within each labeled drop height. There is possibilty that, that was not achieved for every drop

- Timing limitations - the timing mechanism is only accyrate a few decimal places
- a third cause to error is the disregarded air resistance. Although is stated that air resistance only has significant impact on large objects falling far distances, air resistance could be a factor for some error

Chapter 7

Conclusion

Chapter 8

Suggestions for Improvement