M9c: Free Fall Acceleration

Introduction:

Gravity represents one of the central concepts of physics. In fact, two of the most well known names in physics found their fame in dealing with gravity. If one were to ask people the first name that pops into their mind when they hear the word “physics”, most likely it will be Sir Isaac Newton (and his allegorical apple falling from the tree), or Albert Einstein (whose theory of relativity modifies and extends Newton). The main objective for this experiment is to calculate the acceleration “g” of a free falling object manifested due to the force of gravity.

In addition to this objective, this experiment will also determine if mass or the distance that an object falls influence the gravitational acceleration that object experiences. The question of whether or not heavier objects fall faster will be answered yet again, determining if Galileo’s experiments at the Leaning Tower of Pisa were right. This all will be accomplished first by dropping a silver colored metallic sphere from several pre-established heights. Measuring how long it takes the sphere to fall, it is then possible to calculate gravitational acceleration. The effects (if any) of mass on gravitational acceleration are tested by dropping a second sphere, different from the first, and measuring how long it takes to fall.

One final component of this lab, found within the Discussion section, will be the demonstration of how the application of key concepts within physics can lead to the derivability of any number of equations, which is a very useful aspect of the study of physics.

Apparatus:

- 1 long solid rod (1 to 3 meters in length) w/ table clamp
- 1 right angle clamps
- 1 holder arm/ gate one
- 1 impact sensor / gate two
- 2 metal spheres
- laboratory balance
- 2 meter measuring stick
- computer timing system

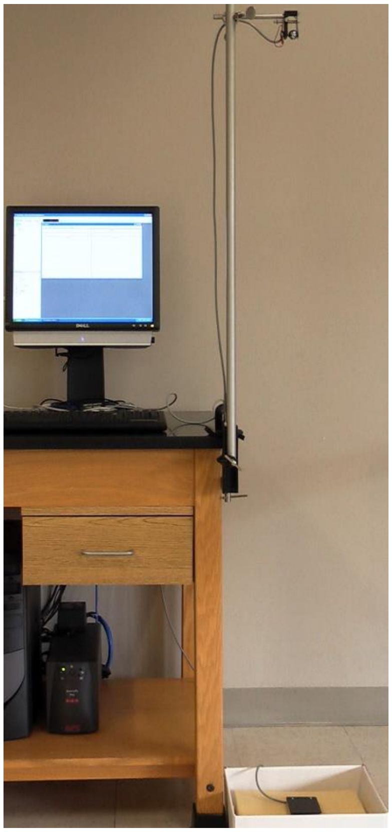


Figure 1

Discussion:

With physics, if one is given a concept (such as kinematics); then this concept in turn points towards a set of definitions (such as the definitions of velocity and acceleration). These definitions finally will yield up a base set of equations that approximate a physical relationship, and with these equations, it is then possible to derive new sets of relationships that can correlate to your experiment. This derivability of equations gives the equation needed to calculate the acceleration due to gravity.

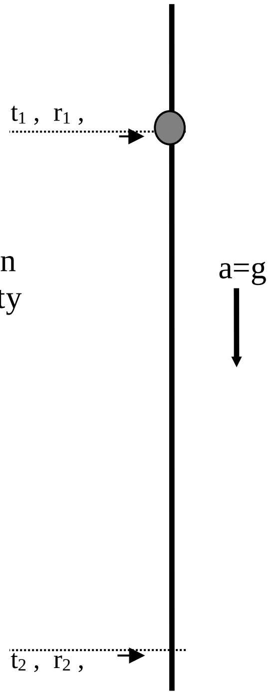
Kinematic Definitions

Acceleration $a=\frac{\Delta v}{\Delta t} \longrightarrow a=\frac{v_f - v_i}{t_f - t_i}$

velocity $v_{avg}=\frac{\Delta r}{\Delta t} \longrightarrow \frac{v_i + v_f}{2}=\frac{r_f - r_i}{t_f - t_i}$

Figure 2

In order to derive the equation necessary to calculate the acceleration due to gravity, it is first necessary to consider the two most basic and fundamental concepts of Kinematics (the study of motion): **acceleration** and **velocity**. Now, in order to simplify calculations, and because it correlates with this experiment's setup, acceleration and velocity can be considered as representing **Motion in only One Dimension**. In light of this fact , the definitions for acceleration and for velocity are defined within Figure 2 as being dependent on the initial and final velocities (v_i, v_f), the initial and final times (t_i, t_f), and the initial and final positions (r_i, r_f). Now, consider the diagram provided in Figure 3, representing this experiment's setup. The different t's, r's, and v's with their different subscripts (of 1 and 2) represent the different points of observation: the holder at the top of the apparatus, and the impact sensor at the bottom.



t = time
r = position
v = velocity

$t_2 - t_1 = t$
$r_2 - r_1 = d$

Figure 3

Collected Data

t = computer time interval
d = distance between timing gates

For the experiment, the following equation may be surmised, working under the original definitions provided in Figure 2, where a has been replaced by g, and $t_f - t_i$ and $r_f - r_i$ have been changed according to Figure 3's equations and relationships:

$$g=\frac{v_2 - v_1}{t} \quad \text{and} \quad \frac{v_1 + v_2}{2}=\frac{d}{t}$$

Now, by assuming that v_1 is equal to 0 (since the sphere is being dropped from a resting position, this is a valid assumption), it is possible to see that $g=\frac{v_2}{t}$ and $v_2=\frac{2d}{t}$, which, in turn gives the final equation for acceleration due to gravity for this experiment: $g=\frac{2d}{t^2}$

Procedures:

1. Activate the computer program and follow the instructions for using the appropriate timing program; the file named **M9c**.
2. Measure the mass of each object.
3. Using the first object, position it at the top gate using the holding arm.
4. Set the timing gates to the specified distance apart according to the first trial of the experiment on the Data Sheet. Please be sure to measure the distance from bottom of the sphere to the impact sensor.
5. Activate the computer timing program to begin collecting time. The time displayed in the running clock is not at all connected to the time it actually takes the metal sphere to fall, and thus the object must not be released exactly concurrently with the start of the timing program.
6. Release the object allowing it to fall to bottom gate / impact sensor.
7. Record the time interval displayed on the computer screen.
8. Conduct the specified number of trials at this distance for each object.
9. Adjust the timing gates to the next separation distance specified and repeat the process for the new distance.

Analysis:

The main calculation necessary to determine the acceleration due to gravity was derived earlier, within the Discussion section. Using the data collected (distance between the gates and the times between gates); calculate the value for the gravitational acceleration "*g*" for each trial using the formula provided below. After calculating the individual acceleration values "g" for each trial, calculate the mean "g" value for each distance. Then calculate the overall mean "*g*" value for the first object and the overall mean "*g*" value for the second object. Next calculate the standard deviation of "*g*" for object 1 and object 2. Now using the mean gravitational acceleration calculated for each object, calculate the weight of each object in Newtons.

Finally, calculate the percent error for each overall mean "*g*" compared to the accepted value of the gravitational acceleration for this location of **9.792 m/s^2**.

As the final calculations are being performed, think back to the introduction of this lab and its stated purpose. Has the existence of gravity been confirmed, thus thankfully saving humanity from flying off the face of the earth? Has the acceleration due to gravity been shown to be a constant according to the experimental value obtained within this experiment? Obviously, there was probably some slight discrepancy amongst the calculated values. What could have caused these discrepancies; can they be explained away? As the trials for object 1 and object 2 are examined, did mass influence the gravitational acceleration? As one looks at the trials having different heights, did the distance of fall influence the acceleration?

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

Use this equation to solve for the acceleration due to the force of gravity.

Experiment M9c: Free Fall Acceleration

Student Name____

*Lab Partner Name*____

*Lab Partner Name*____

Physics Course____

Physics Professor______________________________________

Experiment Start Date__________________________________

Lab Assistant Name	*Date*	*Time In*	*Time Out*

Experiment Stamped Completed

Data Sheet: M9c: Free Fall Acceleration

NAME: ______________________________ DATE: __________________

Object 1: mass= (kg) weight= (Newtons)

Trial	*distances*									
	1.545 (m)		1.485 (m)		1.375 (m)		1.215 (m)		1.005 (m)	
	t (s)	*g* (m/s^2)	*t* (s)	*g* (m/s^2)	*t* (s)	*g* (m/s^2)	*t* (s)	*g* (m/s^2)	*t* (s)	*g* (m/s^2)
1										
2										
3										
Mean *g* (m/s^2)										
Overall Mean *g* (m/s^2):________________ Standard Deviation (m/s^2):_____________ %Error:_______________										

Object 2: mass= (kg) weight= (Newtons)

Trial	*distances*									
	1.545 (m)		1.485 (m)		1.375 (m)		1.215 (m)		1.005 (m)	
	t (s)	*g* (m/s^2)	*t* (s)	*g* (m/s^2)	*t* (s)	*g* (m/s^2)	*t* (s)	*g* (m/s^2)	*t* (s)	*g* (m/s^2)
1										
2										
3										
Mean ***g*** **(m/s^2)**										
Overall Mean *g* (m/s^2):_______________ Standard Deviation (m/s^2):_____________ %Error:________________										