M9a: Gravitational Free-Fall Acceleration and Projectile Motion

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. The object will be both dropped straight downward from rest and projected horizontally with an initial velocity.

In addition to this objective, this experiment will also examine if mass, distance, initial height and initial velocity influence the gravitational acceleration the object experiences. The experiment is divided into two parts. Initially in **PART 1** you will drop an object at rest from a variety of heights while timing the descent. Next, you will repeat this process with two other different masses. Then using the height and time of fall you will calculate the acceleration due to the force of gravity. In **PART 2** you will shoot an object through the air as a projectile. Measurements of its initial height, horizontal distance, time of flight, angle of projection and initial velocity will be used to calculate the acceleration and confirm several kinematic relationships.

Apparatus:

- long solid rod (1-meters in length) w/ table clamp
- ball release mechanism w/ mounting rod & clamp
- receptor pad w/ landing box
- 3 metal spheres
- mounted projectile launcher w/ table clamp
- photogate w/ mount for launcher
- plastic sphere
- time-of-flight landing pad w/ landing box & paper
- metal elevation platform
- laboratory balance
- 2-meter stick
- laser distance meter
- Plate marker
- computer timing system

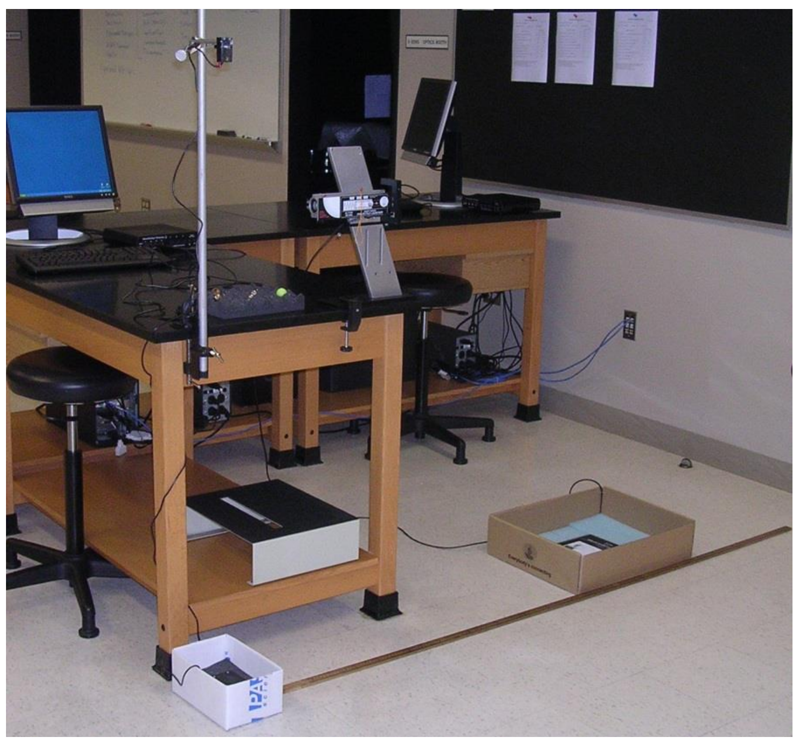

Figure 1

Discussion:

With physics, if one is given a concept (such as kinematics); then this concept in turn points towards a set of definitions or laws (such as the definitions of velocity and acceleration for the concept of kinematics). These definitions or laws 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. For this experiment utilize the kinematic definitions and derive the equations needed to solve for the following:

- Free Fall Acceleration
- Projectile's horizontal distance using the initial velocity, angle and time of flight
- Time of flight using both the height and horizontal distance

Procedures:

1. Log-On to the computer; locate and open the physics experiments folder; run the program labeled "M9a free-fall acceleration".
2. Measure and record the mass of the three spheres being used for the experiment with thousandth of a gram precision.

Part 1

3. Select the metal sphere with the largest mass and place it in the top ball release mechanism.
4. Move the rod holding the ball release mechanism up or down the vertical mounting rod to adjust for the appropriate free-fall height. The heights are given on the Data Sheet Part 1. Please be sure height is measured as the distance from bottom of the sphere to the top of receptor pad (millimeter precision).
5. Check the alignment between the ball release mechanism and the receptor pad to confirm that when the sphere is released, it will hit the center of the receptor pad.
6. Start the computer timing run, by clicking on Start in the program. The time displayed by the running clock at the top is not the actual time it takes the metal sphere to fall. Do not attempt to synchronize the release of the sphere with the activation of the computer timing program. Once you notice the clock at the top is running then release the sphere by loosening the set-screw holding it in place. Once the sphere has hit the receptor pad stop the computer timing run by clicking on stop. The relevant time for the free-fall will be displayed in the small window labeled "Time of Fall". This is the important time you need to record; it is from the moment you release the sphere to the moment it hits the pad; record all of the significant digits provided by the computer.
7. Calculate the free-fall acceleration the sphere experienced. Confirm it is reasonable.
8. Adjust the apparatus to the next height specified and repeat the process; steps 3 thru 7.
9. For the large mass, conduct one trial at each height: total of seven heights.

Cont. Part 1

10. Place the small metal mass in the top ball release mechanism.
11. Repeat the procedures as above, steps 4 thru 8, conduct one trial at each height: total of seven heights.

Part 2

12. Fasten the paper to the landing box, above the landing pad using the provided push pins.
13. Begin with the launcher on the table and the landing pad on the floor (trials 1 thru 4). Clamp the base of the launcher to the table.
14. Measure the height from the bottom of the ball (use the picture on the apparatus) to the top of the landing pad.
15. Adjust the launcher to the first specified launch angle; see **Table 1**.
16. Place the landing box's center line at the specified distance from the center of the ball's launch position, appropriate for the specific angle; see **Table 1**.
17. Place the plastic sphere (Mass 3) into the launcher and push it back until it latches at the short-range position. **Use only the short-range position during this experiment.**
18. Start the computer timing run to begin collecting data.
19. Fire the object by gently pulling the string on the launcher straight up. This fires the ball into the air with it landing on the landing pad, creating a small impact mark on the paper where it hit the pad.
20. Stop the compute timing run. Record the time interval, labeled "Time of Flight" and the initial velocity, labeled "Velocity Leaving Gate" displayed in small windows on the screen.
21. Place the plate marker on the impact mark. Ask a lab assistant to show you how to use the laser distance meter to determine the horizontal displacement. Record this measurement in the corresponding Data Table. Don't move the paper inside the box.
22. Adjust the launcher to the next specified launch angle and repeat the above procedures, steps 17 thru 22. Continue to repeat these steps for each angle.
23. Place the landing box on the metal elevation platform for the next series of trials (#5 thru #8). Repeat the sequence of procedures, steps 15 thru 22.
24. Place the landing box back on the floor and place the launcher on the metal elevation platform for the last series of trials (#9 thru #12). Clamp the launcher to the platform. Repeat the sequence of procedures, steps 15 thru 22.

Table 1

Angle	Distance to Center Line
0º	**1.400 m**
30º	**1.650 m**
45º	**1.600 m**
60º	**1.250 m**

Note: These distances are close approximations that usually work. Sometimes adjustments may be needed. Position your center line at the appropriate position necessary for the projectile to hit the landing pad. Document exactly the position that you use for each trial on your data page.

Analyses:

1. Calculate the free fall acceleration of the three metal spheres in **Part 1** (utilizing the initial height and the time).
2. Calculate the mean and standard deviation of the acceleration for **Part 1.**
3. Calculate the percent error for your acceleration (compare the mean acceleration for **Part 1** with the standard value for this specific location).
4. For the first mass in **Part 1**, the largest mass, construct a graph using Excel. Graph the time of fall as a function of initial height. Select the appropriate type of trendline to fit the data and include both the equation and R^2 value.
5. Calculate the free fall acceleration experienced by the projectile for each trial of **Part 2**. (Utilize the initial height, the time of flight, the initial velocity and the initial angle.)
6. Calculate the horizontal distance of the projectile for each trial in **Part 2**. (Utilize the time of flight, the initial velocity and the initial angle.)
7. Compare the calculated horizontal distance to the measured horizontal distance.
8. Calculate the time of flight for each trial in **Part 2**. (Utilize the initial height, the initial angle, the measured horizontal distance and the accepted value for the free fall acceleration.)
9. Compare the calculated time of flight to the measured time of flight.

Experiment M9a: Gravitational 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 Part 1: M9a: Gravitational Free-Fall Acceleration

NAME: ____________________________ **DATE:** _________________

Mass 1 (kg) =		
Height	**Time**	**Acceleration**
(meters)	(seconds)	(m/s^2)
0.150		
0.350		
0.550		
0.750		
0.950		
1.225		
1.605		

Mass 2 (kg) =		
Height	**Time**	**Acceleration**
(meters)	(seconds)	(m/s^2)
0.150		
0.350		
0.550		
0.750		
0.950		
1.225		
1.605		

Equation for acceleration:

g =

Mean of acceleration: __________

Standard Deviation: ___________

Percent Error: _______________

Data Sheet Part 2: M9a: Gravitational Free-Fall Acceleration: Projectile

NAME: ____________________________ **DATE: _________________**

Mass 3 = ________________ ((kg)

Trial #	Angle (degrees)	Height (meters)	Initial Velocity (m/s)	Time (seconds)	Horizontal Distance (meters)
1	0				
2	30				
3	45				
4	60				
5	0				
6	30				
7	45				
8	60				
9	0				
10	30				
11	45				
12	60				

Analyses Sheet Part 2: M9a: Gravitational Free-Fall Acceleration: Projectile

NAME: ____________________________ **DATE: _________________**

Trial #	**Calculated**		
	Acceleration	**Horizontal Distance**	**Time**
	g =	**Δ x =**	**t =**
	(m/s^2)	(meters)	(seconds)
1			
2			
3			
4			
5			
6			
7			
8			
9			
10			
11			
12			

Questions:

Please answer the following. Include your results in supporting your explanation.

1. Discuss if the variation of the initial height influenced the acceleration.

2. Discuss if the variation of the mass of the falling object influenced the acceleration.

3. Discuss if the initial velocity of the object influenced the acceleration.

4. Discuss if the initial angle of the projectile influenced the acceleration.

Accepted Value for Gravitational Acceleration

The accepted value for the acceleration due to the force of gravity varies by geographical location. The accepted value provided for the west campus physics laboratory takes into account the latitude and elevation of the laboratory location. With the significant increase of the number of GPS devices available you can easily confirm the calculation. There are three slightly different approximations that can be utilized to make the calculation:

1. From the CRC Handbook of Chemistry and Physics: the reference is to:
   Handbook of "Geophysics and the Space Environment"
   4th edition, Air Force Geophysics Laboratory, 1985, p. 14-17.

2. Geodetic Reference Formula of 1967, including the first order free-air correction

3. World Geodetic System 1984 (WGS84), including the first order free-air correction

The specific latitude and elevation used for the west campus physics laboratory are:

Latitude: + north	28	degrees	31	minutes	15	seconds

Elevation:	40.84	meters (or 134 feet)

This results in a value of: 9.79197 m/s^2 ± (2 e-5) m/s^2

latitude deviation ± 1.0 minute
elevation deviation ± 3.0 meter

For all of your physics laboratory experiments use $g = 9.792\ m/s^2$ as your standard value for the gravitational acceleration.