

M9b: 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 also 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
- computer timing system

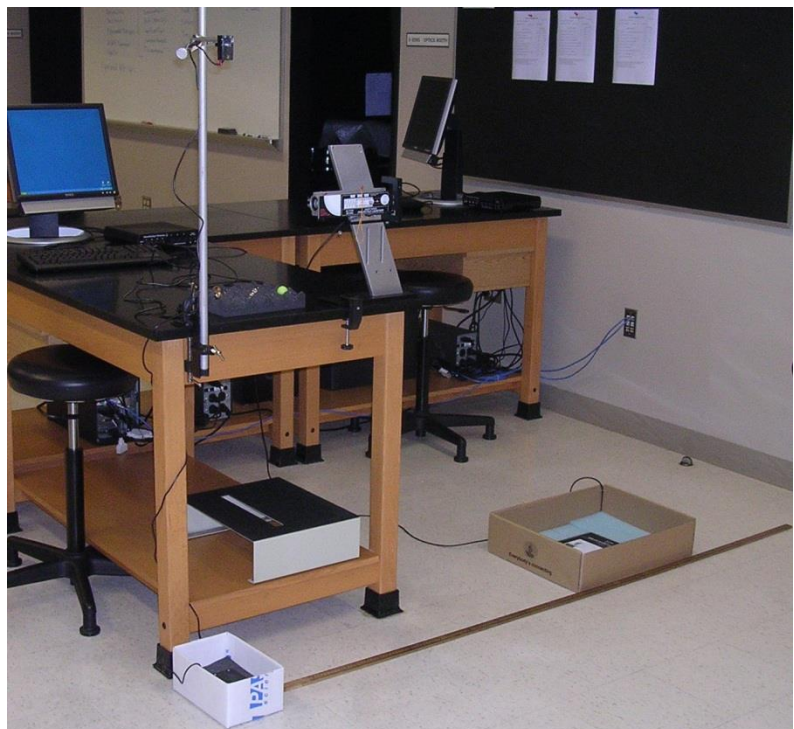


Figure 1

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 the height and horizontal distance

Procedures:

1. Log-On to the computer; locate and open the physics experiments folder; run the program labeled "M9b free-fall acceleration".
2. Measure and record the mass of the four spheres being used for the experiment; 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 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. For the large mass conduct one trial at each height; total of seven heights.
9. Adjust the apparatus to the next height specified and repeat the process; steps 3 thru 7.

Cont. Part 1

10. Select the medium mass from the other two metal spheres and place it in the top ball release mechanism.
11. Repeat the procedures as above, steps 4 thru 9, except conduct three trials at each height with a total of 5 different heights.
12. Select the smallest of the metal spheres and again repeat the procedure sequence as above, conducting only one trial at each height, with a total of 5 different heights.

Part 2

13. Draw a center horizontal line across the top sheet of the provided landing paper. Align the center line on the paper with the center line on the landing box. Fasten the paper to the landing box, above the landing pad using the provided push pins.
14. 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.
15. Measure the height from the bottom of the ball (use the picture on the apparatus) to the top of the landing pad.
16. Adjust the launcher to the first specified launch angle; see **Table 1**.
17. 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**.
18. Place the plastic sphere into the launcher and push it back until it latches at the short range position. **Use only the short range position during this experiment.**
19. Start the computer timing run to begin collecting data.
20. 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 where it hit the pad.
21. Carefully mark the landing pad paper with the trial # close to the small impact mark. Don't move the paper inside the box.
22. Record the time interval, labeled "Time of Flight" and the initial velocity, labeled "Velocity Leaving Gate" displayed in small windows on the screen. Stop the compute timing run.
23. 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.
24. 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 23.
25. 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 23.

Table 1

Angle	Distance to Center Line
0°	1.400 m
30°	1.650 m
45°	1.600 m
60°	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. 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.
2. Calculate the free fall acceleration of the three metal spheres in **Part 1** (utilizing the initial height and the time).
3. Calculate the free fall acceleration experienced by the projectiles for each trial of **Part 2**. (Utilize the initial height, the time of flight, the initial velocity and the initial angle.)
4. Measure the horizontal distance for each trial of **Part 2** by combining the specific distance to the center line on landing paper (for the angle) with the measured distance from that center line to each impact point.
5. 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.)
6. Compare the calculated horizontal distance to the measured horizontal distance.
7. 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.)
8. Compare the calculated time of flight to the measured time of flight.
9. Calculate the mean and standard deviation of the acceleration for **Part 1**.
10. Calculate the percent error for your acceleration compared to the standard value for this specific location.

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.

Experiment M9b: Gravitational Free-Fall Acceleration

Student Name _____

Lab Partner Name _____

Lab Partner Name _____

Physics Course _____

Physics Professor _____

Experiment Start Date _____

<i>Lab Assistant Name</i>	<i>Date</i>	<i>Time In</i>	<i>Time Out</i>

Experiment Stamped Completed

Data Sheet Part 1: M9b: 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)
1.095	-----	

1.225	-----	

1.355	-----	

1.475	-----	

1.605	-----	

Mass ₃ (kg) =		
Height	Time	Acceleration
(meters)	(seconds)	(m/s ²)
1.095		
1.225		
1.355		
1.475		
1.605		

Data Sheet Part 2: M9b: Gravitational Free-Fall Acceleration: Projectile

NAME: _____

DATE: _____

Mass₄ = _____ (kg)

Trial #	Angle	Height	Position of Landing Pad	Initial Velocity	Time	+/- dist. impact point to center line	Horizontal Distance
	(degrees)	(meters)	(meters)	(m/s)	(seconds)	(meters)	(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: M9b: Gravitational Free-Fall Acceleration: Projectile

NAME: _____

DATE: _____

Trial #	Calculated		
	Acceleration	Horizontal Distance	Time
	(m/s ²)	(meters)	(seconds)
1			
2			
3			
4			
5			
6			
7			
8			
9			
10			
11			
12			

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
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Elevation:	40.84	meters (or 134 feet)
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This results in a value of: $9.79197 \text{ m/s}^2 \pm (2 \text{ e-}5) \text{ m/s}^2$ latitude deviation ± 1.0 minute
elevation deviation ± 3.0 meter

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