Experiment 5

Determining g, the Acceleration of Gravity

INTRODUCTION

A glider sliding down an inclined air track or a steel ball rolling down a V-grooved 2 in × 6 in wooden plank has the force of gravity pulling vertically downward on it. The force acting is equal to the weight of the object. A second force is also acting on the object. The second force is exerted by the supporting air track or the wood plank, which acts perpendicular to the surface of the supporting air track or wood plank and is called the normal force. Fig. 5.1 shows the two forces and the resultant of the two forces that act parallel to the incline to produce an acceleration of the object down the incline. An analysis of the two forces shows that the resultant force F down the incline is equal to $mg \sin \theta$. (See Fig. 5.2.) The sine of the angle θ is equal by definition to the side opposite the angle divided by the hypotenuse. Thus, the height of the incline divided by the length of the incline equals $\sin \theta$, or $\sin \theta = h/L$. This force of $mg \sin \theta$ or mgh/L is the unbalanced force acting to accelerate the mass down the incline. Newton's second law of motion states the relationship between the unbalanced force, mass, and acceleration of the object. This can be written as

$$a = F/m$$

Since $F = mgh/L$,

$$a = \frac{mgh/L}{m} = gh/L$$

or

$$g = \frac{aL}{h} \tag{5.1}$$

To determine the value of g we need to measure the values of h and L and determine the value of a. The acceleration a can be determined by the following relationship:

$$a = \frac{v_f - v_o}{t} \text{ by definition}$$

If $v_o = 0$, then $a = \frac{v_f}{t}$. Since $v = \frac{(v_f + v_o)}{2}$, if $v_o = 0$, then $v = \frac{v_f}{2}$ or $v_f = 2\bar{v}$.

But $\bar{v} = \frac{d}{t}$ by definition. Therefore

$$a = \frac{2v}{t} = \frac{2d/t}{t} \tag{5.2}$$

where d is the distance traveled and t is the time for the object to travel the distance d.

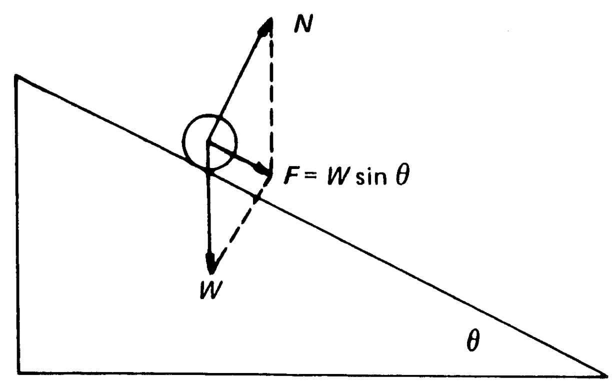

Figure 5.1 *Diagram illustrating the two forces acting on an object traveling down a frictionless inclined plane. Air resistance is neglected. W represents the weight of the object, N represents the normal or perpendicular force on the object, and F is the resultant of W and N.*

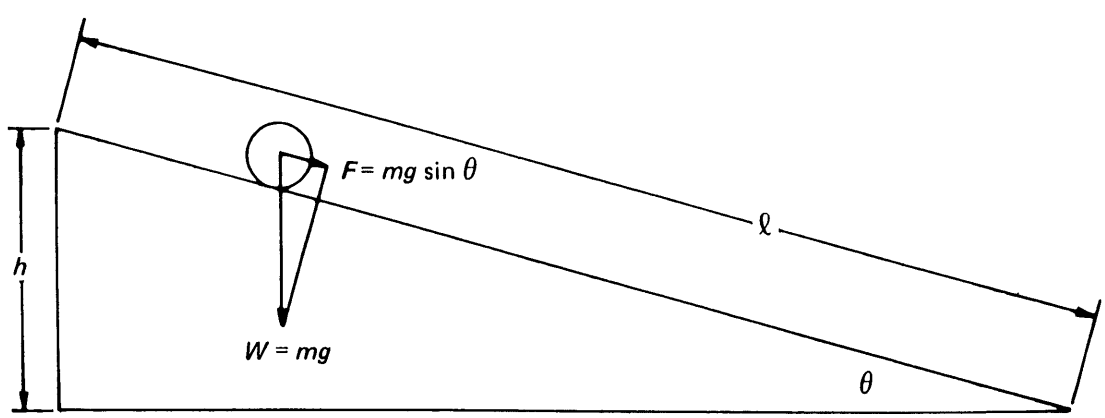

Figure 5.2 *Steel ball rolling down an incline due to the pull of gravity, or the weight of the ball.*

LEARNING OBJECTIVES

After completing this experiment, you should be able to do the following:

1. Determine experimentally the acceleration (g) of gravity at the surface of the Earth.
2. Calculate the percent error of your measurement with the accepted value of g at your surface location.

APPARATUS

Linear air track, glider, meter stick, five timing devices (stop watches or electric timers), and masking tape. If the air track is not available, then a 2 in × 6 in wood plank 10 ft long plus a 3/4-in-diameter steel ball can be used. The wood plank must have a trough milled into one edge of the plank. A V-grooved trough is preferred.

EXPERIMENT 5 NAME (print) ______________________________ DATE __________
LAST FIRST
LABORATORY SECTION ________ PARTNER(S) ______________________________

PROCEDURE

1. If the air track is to be used, ask the instructor to adjust the air track at an angle with the table top. This can be done by placing a small block (about 2 cm high) under one end of the air track. If the 2 in × 6 in plank is used, ask the instructor to elevate the plank at an angle of about 5°. Use small pointed pieces of masking tape and mark off five equal distances (50 cm) along the incline. Place the glider or the steel ball on the incline at the piece of tape farthest up the incline. This is the starting point. Release the object and start all timers simultaneously. Determine the time for the moving object to travel the distance from rest at the starting point to each marker. Make three trials and record the values obtained for each distance in Data Table 5.1.
2. Measure the height h and the length L of the incline and record in the data table.

CALCULATIONS

1. Plot a graph with distance on the vertical axis and time squared on the horizontal axis. Make sure the graph contains all the information concerning graphs as given in Experiment 1.
2. Calculate the acceleration of the object down the incline. Use Eq. 5.2. Show your work. The final answer will be the average acceleration for the three distances.

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Data Table 5.1

Distance traveled (d)	50 cm	100 cm	150 cm	200 cm	250 cm
Time to travel distance (d), in seconds					
Average time (t), in seconds					
Height of the incline ________ cm Length of the incline ________ cm					

3. Calculate the experimental value for the acceleration of gravity. Use the value of (a) from 2 above.

$$g = \frac{aL}{h}$$

4. Calculate the percent error using 980 cm/s^2 as the correct value of g. Show your work.

QUESTIONS

1. What was your greatest source of error in this experiment? Justify your answer.

2. What kinematic concept of the moving object does the slope of the graph give?

3. If the initial velocity was not zero, how would the value of g compare with the value you obtained? For instance, suppose you accidentally gave the object a slight shove down the incline at the starting point.

4. What will be the value of the acceleration when θ (theta) in Fig. 5.2 is increased to 90°?

5. Is the acceleration due to gravity always pointing vertically downward even for an object whose velocity is vertically upward? Explain your answer.