

DEPARTMENT OF BIOLOGICAL, CHEMICAL, AND PHYSICAL SCIENCE  
ILLINOIS INSTITUTE OF TECHNOLOGY  
PHYSICS 123 (SAMPLE LAB)

MEASURING GRAVITATIONAL ACCELERATION  
Lab #1

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Date of Experiment: 18 Jan 99

Due Date: 21 Jan 99

Lab section 022

Lab Partner: Charlie Jones (use this only if submitting individual reports)

TA: Bob Smith

## STATEMENT OF OBJECTIVE

The objective of the lab was to determine the gravitational acceleration constant, "g", by measuring the change in velocity of known masses sliding down an inclined plane.

## THEORY

The force of gravity affects all massive bodies. The gravitational force of the Earth causes all objects to be accelerated towards the center of the Earth. Galileo demonstrated that all objects fall at the same rate, regardless of their mass. All bodies accelerate at the same rate,  $9.8 \text{ m/s}^2$ . This is known as the gravitational acceleration constant, or "g".

Galileo was able to measure the acceleration of falling bodies by using inclined planes. A glider sliding down a plane and a falling body feel the exact same force, but the glider must move along the horizontal axis at the same time that it is falling. If the amount of distance traveled along the plane as well as the time elapsed were measured, the kinematic equations could be used to calculate the acceleration. The relationship between the acceleration along the plane and the gravitational force can be easily derived, thus enabling the calculation of the gravitational acceleration constant.

## EQUIPMENT LIST

- an air track with air pump
- a block to incline the track
- a Pasco timer
- a digital photogate.

## PROCEDURE

Refer to Phys 123 Lab Manual Lab 2 Section C for the procedure.

## DATA

The photogate and timer were used to record times, as shown in Table 1. The side labels are the release distance from the photogate, and the top labels are height that the air track was inclined.

	H = 1 in	H = 2 in	H = 3 in
D = 10 cm	0.51 s	0.36 s	0.29 s
D = 15 cm	0.43 s	0.29 s	0.24 s
D = 20 cm	0.36 s	0.25 s	0.21 s

Table 1 - Photogate times varying by release distance, D, and incline height, H

## ANALYSIS OF DATA

First, the times were converted to velocities. The velocity of the glider was calculated by recognizing that velocity is change of distance over change of time. If the change of distance is the length of the glider (10 cm) then:

$$v = \frac{\Delta x}{\Delta t} = \frac{10\text{cm}}{T}$$

Equation 1

Where  $v$  = velocity  
 $\Delta x$  = change in distance  
 $\Delta t$  = elapsed time  
 $T$  = time measured by photogate

Velocities were calculated using Equation 1 as shown in Table 2.

	H = 1 in	H = 2 in	H = 3 in
D = 10 cm	.196 m/s	.278 m/s	.345 m/s
D = 15 cm	.233 m/s	.345 m/s	.417 m/s
D = 20 cm	.278 m/s	.400 m/s	.476 m/s

Table 2 - Glider velocities varying by release distance, D, and incline height, H

One kinematic relationship states that the velocity squared is equal to twice the acceleration times the distance traveled, therefore the velocities could be converted to accelerations (using the release distance to complete the equation):

$$a = \frac{v^2}{2d}$$

Equation 2

Where  $a$  = acceleration  
 $d$  = release distance

The velocities were then converted into accelerations via equation 2 and recorded in Table 3.

	H = 1 in	H = 2 in	H = 3 in
D = 10 cm	0.192 m/s <sup>2</sup>	0.383 m/s <sup>2</sup>	0.595 m/s <sup>2</sup>
D = 15 cm	0.18 m/s <sup>2</sup>	0.396 m/s <sup>2</sup>	0.579 m/s <sup>2</sup>
D = 20 cm	0.193 m/s <sup>2</sup>	0.400 m/s <sup>2</sup>	0.566 m/s <sup>2</sup>

Table 3 - Glider accelerations varying by release distance, D, and incline height, H

Finally, the acceleration of the glider along the plane is the gravitational acceleration times the sine of the angle of inclination. However, the sine of an angle is the opposite side divided by the hypotenuse of a right triangle. In this case the opposite side is the height of inclination, and the hypotenuse is the length of the air track. Substituting that into the acceleration equation gives the following:

$$\sin \theta = \frac{h}{L}$$

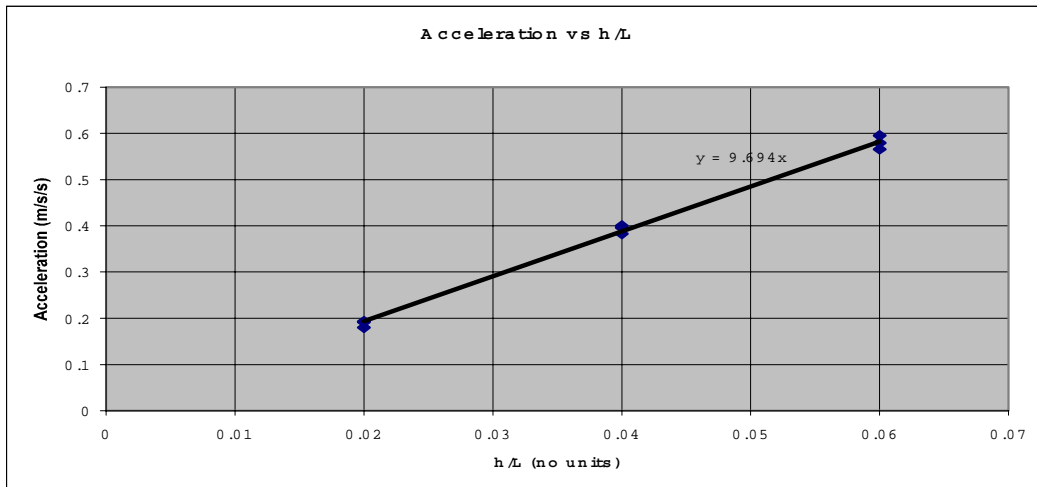
$$a = g \sin \theta$$

$$a = g \frac{h}{L}$$

Equation 3

Where  $g$  = gravitational acceleration  
 $h$  = incline height  
 $L$  = length of the air track

It is clear that a plot of acceleration vs.  $h/L$  should give a straight line with slope " $g$ ". The data from the experiment (Table 3) was plotted in order to compare the experimental values to equation 3 (Graph 1)



Graph 1 - Acceleration versus h/L with linear fit

The slope of the plot is 9.694, giving a value of  $9.694 \text{ m/s}^2$  for "g".

## DISCUSSION OF RESULTS

The final result of the analysis was very close to the accepted value of  $9.81 \text{ m/s}^2$ . There was a difference of 1.18 percent, a very accurate value. A further inspection of the plot showed that the linear fit was very good. The only possible source of error, friction, was apparently minimized.

## CONCLUSIONS

The accuracy of the results supports the hypothesis that gravitational acceleration is constant. For each height the acceleration was constant (Table 2), as the theory would predict (Equation 3). Moreover, when the height was taken into account, the gravitational acceleration was constant for all the masses (Graph 1).