

Determining g on an Incline

During the early part of the seventeenth century, Galileo experimentally examined the concept of acceleration. One of his goals was to learn more about freely falling objects. Unfortunately, his timing devices were not precise enough to allow him to study free fall directly. Therefore, he decided to limit the acceleration by using fluids, inclined planes, and pendulums. In this lab exercise, you will see how the acceleration of a cart depends on the ramp angle. Then, you will use your data to extrapolate to the acceleration on a vertical “ramp;” that is, the acceleration of a cart in free fall.

If the angle of an incline with the horizontal is small, a cart rolling down the incline moves slowly and can be easily timed. Using time and distance data, it is possible to calculate the acceleration of the cart. When the angle of the incline is increased, the acceleration also increases. The acceleration is directly proportional to the sine of the incline angle, (θ). When $\sin\theta$ is 1, the angle of the incline is 90° . This is equivalent to free fall. The acceleration during free fall can then be determined from the slope of the acceleration vs $\sin\theta$ graph.

Galileo was able to measure acceleration only for small angles. You will collect similar data. These data be used in extrapolation to determine a useful value of g , the acceleration of free fall. You will make quantitative measurements of the motion of a cart rolling down inclines of various small angles.

Figure 1



objectives

- Use a Motion Detector to measure the acceleration of cart rolling down an incline.
- Determine the mathematical relationship between the angle of an incline and the acceleration of cart rolling down the ramp.
- Determine the value of free fall acceleration, g , by measuring the slope of the acceleration vs. sine of track angle graph.
- Compare the results with the standard value of free-fall acceleration g of 9.8 m/s^2 .

Materials

Macintosh or Windows PC	dynamics cart
LabPro computer experiment interface	meter stick
Logger Pro	lab jack
Sonic Motion Detector	
Graphical Analysis software or graph paper	
ramp	

Procedure

1. Connect the Motion Detector to DIG/SONIC 1 of the LabPro.
2. Place the lab jack under one end of the track so that it forms a small angle with the horizontal. Adjust the points of contact of the two ends of the incline, so that the distance, x , in Figure 1 is between 1 and 3 m.
3. Attach the Motion Detector to the ramp at the top of an incline. Place it so the cart will never be closer than 0.4 m.
4. Start the Logger Pro application by clicking the Logger Pro icon on the bottom toolbar on the Mac screen. Then open the *Experiments* folder, then open the *Physics with Vernier* folder, then the file for Experiment 4, "Determining g.cmbl. Two graphs will be displayed: distance vs. time and velocity vs. time. The vertical axis on the distance graph is scaled from 0 to 3 m. The vertical axis on the velocity graph is scaled from 0 to 2 m/s. The horizontal axis of both graphs is time scaled from 0 to 5 s.
5. Hold the cart on the incline about 0.5 m from the Motion Detector.
6. Click  to begin collecting data; release the cart after the Motion Detector starts to click. Get your hand out of the Motion Detector path quickly. You may have to adjust the position and aim of the Motion Detector several times before you get it right. Adjust and repeat this step until you get a good run showing approximately constant slope on the velocity vs. time graph during the motion of the cart.
7. Logger Pro can fit a straight line to a portion of your data. First indicate which portion is to be used by dragging across the graph to indicate the starting and ending times. Then click on the Regression Line tool, , to perform a linear regression of the selected data. Use this tool to determine the slope of the velocity vs. time graph, using only the portion of the data for times when the cart was freely rolling. From the fitted line, find the acceleration of the cart. Record the value in your data table.
8. Repeat Steps 5 – 7 two more times.
9. Measure the length of the incline, x , which is the distance between the two contact points of the

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ramp. See Figure 1.

10. Measure the height, h , the height of the lab jack surface above the table. First have the lab jack at its minimum extension. These last two measurements will be used to determine the sine of the angle of the incline.

11. Raise the incline by cranking up the height of the lab jack by 4 or 5 cm.

12. Repeat Steps 5 – 10 for the new incline.

13. Repeat Steps 5 – 11 for 3 more heights of the lab jack, increasing by the same amount each time.

Data Table

				Acceleration			
	Height of lab jack, h (m)	Length of incline, x (m)	$\sin(\theta)$	trial 1 (m/s ²)	trial 2 (m/s ²)	trial 3 (m/s ²)	Average acceleration (m/s ²)
1							
2							
3							
4							
5							

Analysis

1. From the values for the three trials calculate the average acceleration for each height.
2. Using trigonometry and your values of x and h in the data table, calculate the sine of the incline angle for each height. Note that x is the hypotenuse of a right triangle.
3. Plot a graph of the average acceleration (y axis) vs. $\sin(\theta)$. Use either the Graphical Analysis program or graph paper.
4. Draw a best-fit line by hand or use the linear-regression feature of Graphical Analysis, and determine the slope. The slope can be used to determine the acceleration of the cart on an incline of any angle.

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6. How well does the value of g determined by the slope agree with the accepted value of free-fall acceleration ($g = 9.8 \text{ m/s}^2$)?
7. Estimate the uncertainty δg in your measurement of the slope of the acceleration vs $\sin\theta$ graph by estimating the maximum and minimum slopes consistent with the variation of your data points away from an ideal straight line. Using this, record your final result in the form of

$$g \pm \delta g$$

Does this interval include the “standardly accepted” value of g of 9.8 m/s^2 ?