Experiment 1

Determining *g* on an Incline

1. Objective

1) Use a Motion Detector to measure the speed and acceleration of a cart rolling down an incline.
2) Determine the mathematical relationship between the angle of an incline and the acceleration of cart rolling down the ramp.
3) Determine the value of free fall acceleration, *g*, by extrapolating the acceleration *vs*. sine of track angle graph.
4) Determine if an extrapolation of the acceleration *vs*. sine of track angle is valid.

2. Applying Concept

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 rolling ball or 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 ball in free fall.

If the angle of an incline with the horizontal is small, a ball rolling down the incline moves slowly and can be easily timed. Using time and position data, it is possible to calculate the acceleration of the ball. 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). A graph of acceleration versus $\sin(\theta)$ can be extrapolated to a point where the value of $\sin(\theta)$ is 1. 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 graph.

Galileo was able to measure acceleration only for small angles. You will collect similar data. Can these data be used in extrapolation to determine a useful value of *g*, the acceleration of free fall? We will see how valid this extrapolation can be. Rather than measuring time, as Galileo did, you will use a Motion Detector to determine the acceleration. You will make quantitative measurements of the motion of a ball rolling down inclines of various small angles. From these measurements, you should be able to decide for yourself whether an extrapolation to large angles is valid.

3. Apparatus/ Materials

1) Computer
2) Vernier computer interface
3) Logger *Pro*
4) Vernier Motion Detector
5) Ramp
6) Dynamics cart
7) Meter stick

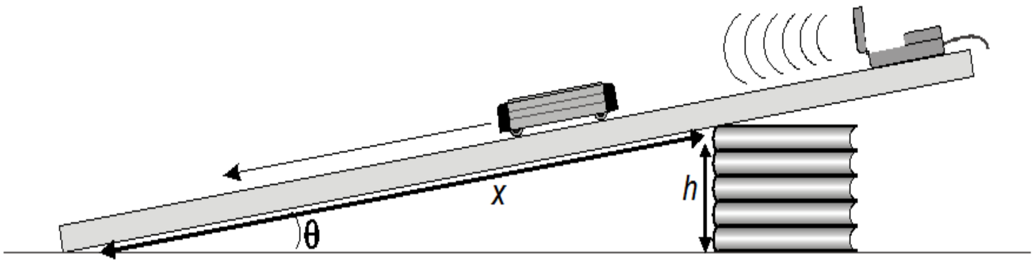

Figure 1. Apparatus

4. Procedure

1) Connect the Motion Detector to the DIG/SONIC 1 channel of the interface.
2) Place a single book under one end of a 1 – 3 m long board or 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) Place the Motion Detector at the top of an incline. Place it so the ball will never be closer than 0.4 m.
4) Open the Logger Pro program on your computer
5) Hold the hard ball on the incline about 0.5 m from the Motion Detector
6) Click [Collect] to begin collecting data; release the ball 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 rolling of the ball

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 Linear Fit button, , 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 ball was freely rolling. From the fitted line, find the acceleration of the ball. 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 ramp.
10) Measure the height, *h*, the height of the book(s). These last two measurements will be used to determine the angle of the incline.
11) Raise the incline by placing a second book under the end. Adjust the books so that the distance, *x*, is the same as the previous reading.
12) Repeat Steps 5 – 10 for the new incline.
13) Repeat Steps 5 – 11 for 3, 4, and 5 books.
14) Repeat Steps 5 – 13 using a low-friction dynamics cart instead of the ball.

Data Table:

Data using cart						
Number of books	Height of books, *h* (m)	Length of incline, *x* (m)	sin(θ)	Acceleration		
				trial 1 (m/s^2)	trial 2 (m/s^2)	trial 3 (m/s^2)
1						
2						
3						
4						
5						

5. Data Analysis

1) 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 Page 3 of the experiment file or graph paper. Carry the $\sin(\theta)$ axis out to 1 (one) to leave room for extrapolation.
4) Draw a best-fit line by hand or use the linear fit feature of Logger *Pro*, and determine the slope. The slope can be used to determine the acceleration of the ball on an incline of any angle.
5) On the graph, carry the fitted line out to $\sin(90°) = 1$ on the horizontal axis, and read the value of the acceleration.
6) How well does the extrapolated value agree with the accepted value of free-fall acceleration ($g = 9.8$ m/s^2)?
7) Repeat the analysis, including the extrapolation, for the low-friction dynamics cart.
8) Why do you think the data for the dynamics cart resulted in an extrapolated value of g that was closer to the accepted value than the rolling ball data?
9) Discuss the validity of extrapolating the acceleration value to an angle of 90°.

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