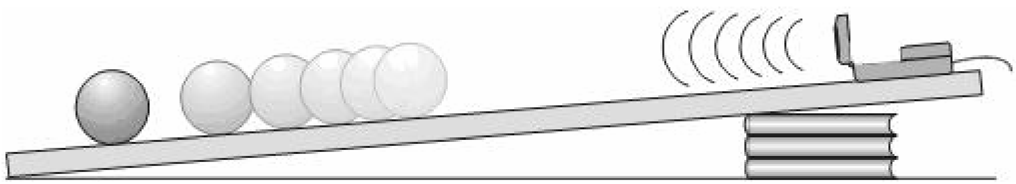
Experiment: Modern Galileo Experiment

OBJECTIVES

1. Use a Motion Detector to measure the speed of a ball down an incline.
2. Determine if Galileo's assumption of uniform acceleration is valid.
3. Analyze the kinematic graphs for a ball on an incline.
4. Model uniformly accelerated motion with algebraic equations.

INTRODUCTION

When Galileo introduced the concept of uniform acceleration, he defined it as equal increases in speed in equal intervals of time. This experiment is similar to the one discussed by Galileo in his book, *Dialogues Concerning Two New Sciences*, in which he assumed that a ball rolling down an incline accelerates uniformly. Rather than using a water clock to measure time, as Galileo did, you will use a Motion Detector connected to a computer. This makes it possible to very accurately measure the motion of a ball rolling down an incline. From these measurements, you should be able to decide for yourself whether Galileo's assumption was valid or not.



Galileo further argued in his book that balls of different sizes and weights would accelerate at the same rate down a given incline or when in free fall. This was contrary to the commonly held belief of the time that heavier objects fall at a greater rate than lighter objects.

Since speed was difficult for Galileo to measure, he used two quantities that were easier to measure: total distance traveled and elapsed time. However, using a Motion Detector it is possible to measure much smaller increments of time, and therefore calculate the speed at many points down the incline. The data you will be able to gather in one roll of a ball down an incline, is more than Galileo was able to acquire in many trials.

MATERIALS

Windows PC	incline (1 – 3 m long)
Logger *Pro* software	balls (5 – 10 cm diameter)
Vernier Motion Detector	LabPro Interface

PRELIMINARY QUESTIONS

1. List some observations that led people of Galileo's time to believe that heavier objects fall faster than lighter objects.

2. Drop a small ball and a large ball from the same height at the same time. Did the larger one hit first, last, or at the same time?

3. What would happen if you again simultaneously dropped the two balls, but this time held the small ball about 30 cm above the larger one. Would the distance between the two balls increase, decrease, or remain the same as they fall? Since the fall time is short, it is hard to tell just what happens by eye. You will see why Galileo and the people of his day had a difficult time answering the questions of motion. Try to answer this question using Galileo's assumption of constant acceleration.

PROCEDURE

1. Connect the Motion Detector to Ch1 of the LabPro Interface.
2. Place the Motion Detector at the top of a 1 to 3 m long incline. The incline should form an angle between 5° and 10° of horizontal.
3. Strat the LoggerPro the open the experiment file, "02 Cart on a Ramp" from the *Physics with Vernier* experiment files for Logger *Pro*.
4. Position a ball about 0.4 m down the incline from the Motion Detector.
5. Begin data collection. Release the ball when you hear the Motion Detector start to click.
6. Sketch the graphs of distance *vs*. time and velocity *vs*. time.

7. Click on the position *vs.* time graph. Using the Examine tool, , on the toolbar, move the cursor to a point about one-fourth of the way down the incline. Record in the data table below the value of time and position for that point. Starting from that point, record time and position data for every 0.2 s until you have recorded 10 points, or until you reach the point that corresponds to the end of the acceleration.
8. Try fitting the graph to the portion of the data corresponding to free-rolling to various functions. Do this by dragging across that time interval and clicking the Curve Fit button. Select a function to see how the function fits the data. Choose the most ***simple*** function that still fits the data well.

9. Which curve or line best describes the position *vs*. time graph? Record both the equation and the parameters (including the error) for the fitted equation.

10. Cut-and-paste the graph into Microsoft Word, include the curve fit information.
11. Repeat steps 7 and 8 for the velocity *vs.* time graph. Using the curve fit function, choose the ***simplest*** function that still fits the data well and record the parameters (including the error) of the fitted equation.

12. Cut-and-paste the graph into Microsoft Word, include the curve fit information. Print out the graphs on a single page.

DATA TABLE

Data point	**Time (s)**	**Position (m)**	**Velocity (m/s)**	**Change in Velocity (m/s)**	**a_{avg} (m/s^2)**
1					
2					
3					
4					
5					
6					
7					
8					
9					
10					
slope of v-t graph	**±**				
average a_{avg}	**±**				

ANALYSIS

1. Calculate the change in speed between each of the points in your data table above. Enter these values in the right column of the data table.

2. As stated earlier, Galileo's definition of uniform acceleration is *equal increases in speed in equal intervals of time.* Do your data support or refute this definition for the motion of an object on an incline? Explain.

3. Was Galileo's assumption of constant acceleration for motion down an incline valid? How do your data support your answer?

4. Calculate the average acceleration of the ball between each time point recorded (i.e. t_1 and t_2, etc.) using your data and the definition of average acceleration:

$$a_{avg} = \frac{\Delta v}{\Delta t} = \frac{v_2 - v_1}{t_2 - t_1}$$

   Record the values in the data table then calculate the average value for a_{avg} and the associated error (using the standard deviation or max-min method).

5. Look at the curve fit equation for the distance *vs*. time graph. How does the constant "A" in this curve fit relate to the slope of the velocity *vs*. time graph?

6. Look at the curve fit equation for the velocity *vs*. time graph. Does the fitted function have a constant slope? What does that slope mean? What are its units? Record the slope in the data table.

7. What can you conclude from questions 5 and 6.