

## Experiment: Accelerated Motion

You have probably watched a ball roll off an incline. During the first part of the 17<sup>th</sup> century, Galileo experimentally determined the concept of acceleration using inclines. If the angle of the incline is small, a ball rolling down an incline moves slowly and can be accurately timed. In the first part of this experiment, you will roll a ball down a ramp and determine the ball's velocity with a pair of photogates. The photogates can record the time when the ball passes through them (breaking an infrared beam) and then the LoggerPro software can calculate the time it took the ball to travel between the 2 photogates.

Using the time and the distance, you will then graph distance vs. time and acceleration vs. time graphs. This example will allow you to better understand the concept of acceleration and the kinematic equations.

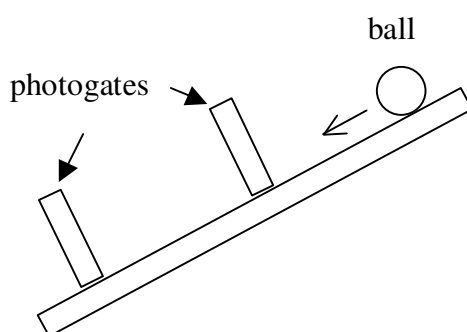


Figure 1: Experimental set-up

### OBJECTIVES

- Measure the travel time for a ball traveling in accelerated motion.
- Construct a mathematical model for the observed accelerated motion
- Compare the mathematical model with the kinematic equations for the accelerated motion
- Determine the significance of the model constants and their role in the kinematic equations

### MATERIALS

• Windows-based computer	• 1-2 ringstands w/clamps
• 2 Vernier Photogates	• a small ball (1- to 5-cm diameter)
• LabPro Interface	• ramp
• Logger Pro software	•

### PRELIMINARY QUESTIONS

1. If you were to drop a ball, releasing it from rest, what information would be needed to predict how much time it would take for the ball to hit the floor? What assumptions must you make?

2. Galileo assumed that the acceleration is constant for free falling objects and for balls rolling down an incline. What shape of the velocity vs. time graph would prove that the acceleration is constant? Explain
  
  
  
  
  
  
  
  
  
  
3. For Galileo, measuring speed was very difficult (inaccurate time measuring devices), so he had to rely on distance and time measurements. Since he assumed that the acceleration is constant for a rolling ball, what type of distance vs. time graph did he expect to obtain?

## **PROCEDURE**

1. Set up a low ramp on the table so that a ball can roll down the ramp, as shown in Figure 1.
2. Position two photogates so the ball rolls through each of the photogates while rolling on the ramp surface. Record the distance between the photogates in the table. Approximately center the detection line of each photogate on the middle of the ball. Connect Photogate 1 to DIG1 of the LabPro and Photogate 2 to DIG2. *To prevent accidental movement of the Photogates, use tape to secure the ring stands in place.*
3. Roll the ball down the ramp starting at the first photogate (from rest). Make sure that the ball does not strike the sides of the photogates (reposition them if necessary). If the red LED comes on when the ball passes through the Photogate, the experimental set up works properly.
4. Prepare the computer for data collection by opening "Exp 08" in the *Physics with Computers* experiment files for LoggerPro. A data table and two graphs are displayed; one graph will show the time required for the ball to pass through the Photogates for each trial.
5. Carefully measure the distance from the beam of Photogate 1 to the beam of Photogate 2. *To obtain accurate results, you must enter an accurate measurement.* Record the distance between the photogates in the table. In addition, estimate the uncertainty in this distance,  $\Delta x$  based on your measurement device and the way you perform this measurement.
6. Start data collection then roll the ball from rest down the ramp through both photogates. Record the measured time in the data table ("Time from Gate 1 to Gate 2") for each distance,  $x$ .
7. Move Photogate 2 to a different distance from Photogate 1. Repeat steps 5-6
8. Repeat steps 5-7 of the experiment for a total of 6 different distances.

<b>Table 1:</b>										
		Time (s)								
x	$\pm \Delta x$	1	2	3	4	5	$t_{avg}$	$\pm \Delta t_{avg}$	$v_{avg}$	$\pm \Delta v_{avg}$

### Analysis Questions:

1. Calculate the average time value ( $t_{avg}$ ) and uncertainty for each distance ( $\Delta t_{avg}$ ), using either the min-max method or calculating the standard deviation. Record these values in the data table above.
2. Using the Graphical Analysis software, construct an average distance vs. time graph. Be sure to label the data columns appropriately.
3. Observe the distance (x) vs. time graph. What is the shape of the graph? What type of motion is the ball's movement down the ramp?
4. Click and drag on the graph and select the appropriate fit from **Analyze→Curve Fit**. What kind of curve fit best matches the graph? Cut-and-paste the graph (with curve fit) into Microsoft Word.
5. What is the physical significance of the coefficients a, b and c for the chosen fit? (Hint: write the equation of the accelerated motion and compare it to the fit equation)
6. The average velocity is related to the distance traveled and the time elapsed, according to the equation:  $v_{avg} = \frac{\text{distance}}{\text{time}} = \frac{x}{t}$ .

LoggerPro can calculate the average velocity for you. From the Data menu, select "New Calculated Column". In the pop-up window, enter the name of the new column ("avg velocity") and the short name ("v-avg"). Define the new function, select the distance column from the Variable menu then divide it by the time column. Click "Done" and the new column will appear in your data table

7. Record the average velocity values in the above data table.
8. Estimate the uncertainty range ( $\pm \Delta v_{\text{avg}}$ ) of each average velocity value. You should either use the min-max method or the analytical method based on following the relation:

$$dv(x, t) = \left( \frac{\partial v}{\partial x} \right) dx + \left( \frac{\partial v}{\partial t} \right) dt \approx \Delta v_{\text{avg}}$$

where  $v$  is the average velocity,  $x$  is the average distance, and  $t$  is the average time, all as measured above. Show your calculations below.

9. Display and observe the average velocity vs. time graph. What is the shape of the graph? What type of motion best describes the travel of the ball?
10. Click and drag on the graph and obtain the most appropriate fit. This will likely be a linear fit. What is physical significance of the slope (or coefficients) of this fit? Cut-and-paste the graph (with curve fit) into Microsoft Word. Print out both graphs on a single page.

**Slope (or coefficients) = \_\_\_\_\_**

11. Is there any relationship between the slope of the velocity graph and the coefficient "a" in step 3? Explain.
12. Does your experiment demonstrate, or at least imply, that the acceleration for the ball is constant? How does your data support your answer?