Date _____ Period _____ Name _____

CHAPTER 3

Physics Lab 3-1

Safety Precautions

Materials

- ball
- clamp holder
- three-prong extension clamp
- flat board
- meterstick
- photogate
- photogate timer
- support rod or ring stand

How does a ball roll?

The concept of acceleration was not understood by the scientists of Galileo's time. An object that traveled farther in a given time was believed simply to have more speed. Galileo recognized that some objects increase in speed, but he initially thought that this increase in speed was proportional to distance. After performing experiments with balls rolling down ramps, Galileo realized that the increase in speed is proportional to time, and that the distance traveled is proportional to time squared.

$$d \propto t^2$$

Galileo established this law of falling objects by using an experimental setup similar to the one shown in **Figure A**. He used a ramp with a very small slope, such that the rolling ball would accelerate slowly. Galileo had difficulty finding a clock that measured time consistently. The advantage that you have over Galileo is that you will use a photogate timer to measure time. In this lab, you will perform the ball rolling experiment to establish that distance traveled is proportional to time squared when an object is accelerating.

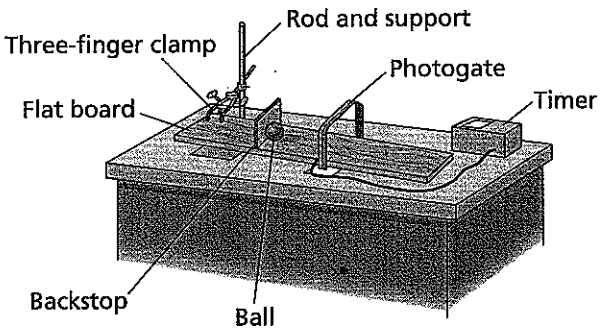


Figure A

Objectives

- **Demonstrate** the relationship between distance and time for an accelerating, rolling ball.
- **Compute** the acceleration of a rolling ball.
- **Discover** a relationship between increasing speed and time using distance and time data.

Procedure

1. Obtain a ball from your teacher.
2. Using a flat board as a ramp, set up the apparatus shown in Figure A. Adjust the slope of the ramp so it is nearly horizontal and is the same as the slope of the ramps of other lab groups. The ball should accelerate steadily but slowly. Make sure the timer is in stopwatch

mode so that time starts when the start button is pressed and stops when the ball passes through the photogate. Adjust the photogate so that the ball has enough room to pass through it but still blocks the light to the sensor.

3. Place the ball at the top of the ramp and hold it against the starting block. Using the meterstick, place the photogate so that the distance along the slope of the ramp from the front of the ball to the photogate is 10 cm.
4. Release the ball and start the timer at the same instant. After the ball passes through the photogate, record the time for 10 cm of travel in the Time 1 column of Table 1.
5. Repeat step 4 three more times and record time measurements for Time 2 and Time 3 in Table 1.
6. Repeat steps 3 and 5 for Data Sets 2–10 identified in Table 1. Each subsequent data set adds 10 cm to the distance of roll.

Data and Observations

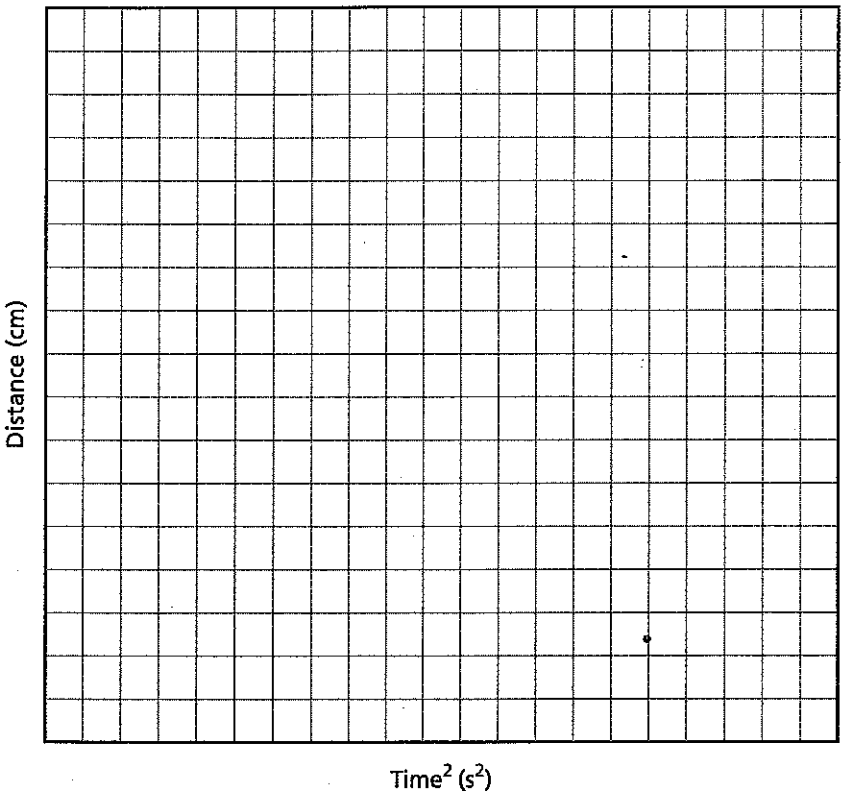
Table 1

Data Set	Distance d (cm)	Time 1 t_1 (s)	Time 2 t_2 (s)	Time 3 t_3 (s)	Average Time $\bar{t}$ (s)	Average Time Squared $\bar{t}^2$ (s^2)
1	10					
2	20					
3	30					
4	40					
5	50					
6	60					
7	70					
8	80					
9	90					
10	100					

Analysis and Conclusions

1. Calculate the average time and the square of the average time for each data set and record the value in Table 1.

2. Use the grid below and plot the data from the table. Plot distance on the *y*-axis and the square of the time on the *x*-axis.



3. Analyze your graph. Can you detect a pattern to the points? Explain.

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4. Draw a best-fit straight line through the points in the graph and compute the slope of the line. What does the slope represent? What are the units of the slope?

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5. Assess the fit of the straight line you have drawn based on the points in the graph. Did the rolling ball experience constant acceleration? Are all of the points on or close to the line? What are some possible reasons for some data points lying away from the line?

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Extension and Application

1. Compare the value of the slope of your line to the values determined by other lab groups. Considering that all lab groups used the same angle of slope, what factor seems to be common among the lab groups with similar data?

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2. Imagine that you are an assistant to Galileo, and you have been directed to make marks on the ramp such that the ball passes over them in equal time intervals. Using the data from your twenty-first century version of the experiment, at what distances from the starting point would you place the next two marks, if your first mark is placed at the 10-cm point?

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3. Using the starting point and your three marks, do you see a pattern in the separation distances of adjacent marks? Explain the meaning of this pattern.

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