Testing Galileo's Hypothesis

Background Information

In 1638, Galileo Galilei published a book that described the motion of freely falling objects. In this book, Galileo hypothesized that freely falling objects accelerate at a constant rate. However, Galileo could not test his hypothesis directly because the precise and accurate instruments needed to measure time and distance did not exist. To solve this problem, he designed an experiment to test his hypothesis indirectly by carefully measuring the time and distance of balls rolling down ramps. When a ball rolls down a ramp with a small incline, it accelerates more slowly than it does during free fall.

In this investigation, you will determine whether a steel ball accelerates at a constant rate as it rolls down ramps of varying lengths. Then, you will determine how the steepness of a ramp affects the acceleration of the ball.

Problem

How do the length and steepness of a ramp affect the rate of acceleration of an object rolling down the ramp?

Pre-Lab Discussion

Read the entire investigation. Then, work with a partner to answer the following questions.

1. **Formulating Hypotheses** State a hypothesis about whether the gravitational force on an object changes as it rolls down a ramp.

   _____

2. **Predicting** Based on your hypothesis, predict how the ball will accelerate as it rolls down the ramp. Explain your answer.

   _____

   _____

   _____

3. **Controlling Variables** Identify the manipulated, responding, and controlled variables in this experiment.

   a. Manipulated variables _____

   b. Responding variable _____

   c. Controlled variable _____

4. **Predicting** How do you expect the steepness of the ramp to affect the acceleration of the ball?

   _____

Name _____ Class _____ Date _____

Materials *(per group)*

1.5-m board	steel ball, approximately 4 cm in diameter
2 books	stopwatch
meter stick	calculator

Safety

Wear safety goggles. Handle the board carefully to avoid splinters. Note all safety alert symbols next to the steps in the Procedure and review the meaning of each symbol by referring to the Safety Symbols on page xiii.

Procedure

Part A: Determining Acceleration

1. Work with a partner. Put one of the books on the floor. Place one end of the board on the book to form a ramp. Then, place the meter stick on the board with its zero end at the bottom of the ramp, as shown in Figure 1. Mark a line at distances of 0.5 m and 1.0 m from the end of the board. Move the meter stick so that its zero is aligned at the 1.0 m mark you just made on the board and mark a line at a distance of 1.5 m from the end of the board. Refer to Data Table 1, which you will use to compile data obtained in Steps 2 and 8 of Part A.

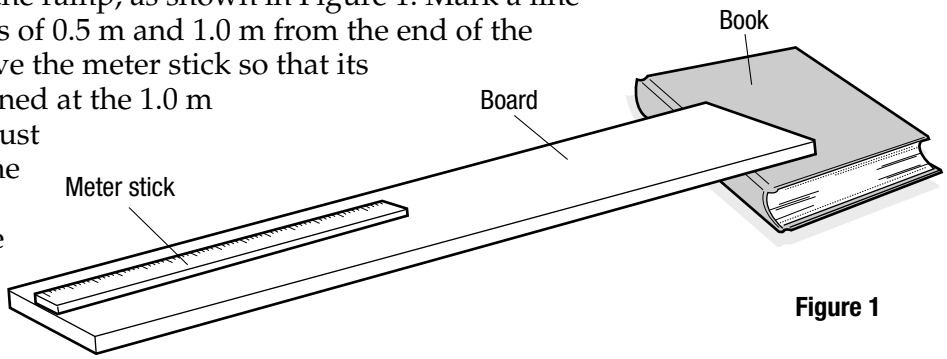

Figure 1

2. Position the steel ball at the mark located 1.5 m from the bottom of the ramp. Have your partner start the stopwatch at the instant you release the ball. Have your partner stop the stopwatch when the ball reaches the bottom of the ramp. **CAUTION:** *Stop the ball when it reaches the bottom of the ramp.* Record the time of Trial 1 for a distance of 1.5 m in the data table.

3. Repeat Step 2 four more times. Record the times of Trials 2 to 5 for a distance of 1.5 m.

4. Position the steel ball at the mark located 1.0 m from the bottom of the ramp. Release the ball and time the ball as it rolls down the ramp, as in Step 2. Record the time of Trial 1 for a distance of 1.0 m.

5. Repeat Step 4 four more times. Record the times of Trials 2 to 5 for a distance of 1.0 m.

6. Position the steel ball at the mark located 0.5 m from the bottom of the ramp. Release the ball and time its roll down the ramp as before. Record the time of Trial 1 for a distance of 0.5 m.

7. Repeat Step 6 four more times. Record the times of Trials 2 to 5 for a distance of 0.5 m.
8. Calculate and record the average time for each distance. To do this, add the five times together and divide the total by 5.

Part B: Determining If the Steepness of the Ramp Affects the Ball's Acceleration

9. Place another book under the elevated end of the board to make the ramp steeper.
10. Repeat Steps 2 through 8. Record your measurements and calculations in Data Table 2.
11. It can be shown that for an object starting from rest and accelerating at a constant rate, the acceleration is equal to $2D/T^2$, where D is the distance and T is the time of travel. Use the values of D and T in Data Tables 1 and 2 to calculate the acceleration of the ball for each distance and ramp height. Record the results in Data Table 3.

Observations

DATA TABLE 1

Ramp Supported by One Book			
Trial	**Distance = 1.5 m Time (s)**	**Distance = 1.0 m Time (s)**	**Distance = 0.5 m Time (s)**
1			
2			
3			
4			
5			
TOTAL			
Average			

DATA TABLE 2

Ramp Supported by Two Books			
Trial	**Distance = 1.5 m Time (s)**	**Distance = 1.0 m Time (s)**	**Distance = 0.5 m Time (s)**
1			
2			
3			
4			
5			
TOTAL			
Average			

Name _____ Class _____ Date _____

DATA TABLE 3

Height of Ramp	Distance = 1.5 m	Distance = 1.0 m	Distance = 0.5 m
	Acceleration (m/s²) = $2D/T^2$		
1 book	0.23	0.21	0.23
2 books	0.41	0.45	0.39

Analysis and Conclusions

1. **Analyzing Data** Compare the accelerations that you calculated for the three distances in Part A. Did your data agree with your prediction? Explain your answer.

2. **Evaluating and Revising** Did your data support your hypothesis? Explain your answer.

3. **Analyzing Data** How did the steepness of the ramp affect the rate of acceleration?

4. **Inferring** Why would it be much more difficult to perform this experiment with a very steep ramp or with a freely falling object?

5. **Evaluating and Revising** How could this experiment be improved to produce more accurate data?

Go Further

How would changing the mass of the steel ball rolling down the ramp affect the results of this experiment? Design an experiment to answer this question. Write a detailed plan for your experiment. Your plan should state the hypothesis to be tested, identify variables, and describe the procedures and safety precautions you will take. Show your plan to your teacher. When your teacher approves your plan, carry out your experiment and report your results.