Experiment
40

Falling Objects

Galileo tried to prove that all falling objects accelerate downward at the same rate. Falling objects do accelerate downward at the same rate in a vacuum. Air resistance, however, can cause objects to fall at different rates in air. Air resistance enables a skydiver's parachute to slow his or her fall. Because of air resistance, falling objects can reach a maximum velocity or *terminal velocity*. In this experiment, you will study the velocities of two different falling objects.

OBJECTIVES

In this experiment, you will

- Use a computer-interfaced Motion Detector to measure distance and velocity.
- Produce distance *vs.* time and velocity *vs.* time graphs.
- Analyze and explain the results.

MATERIALS

computer
Vernier computer interface
Vernier Motion Detector
Logger*Pro*
ring stand
metal rod
right-angle clamp
basket coffee filter
3 books
meter stick
masking tape

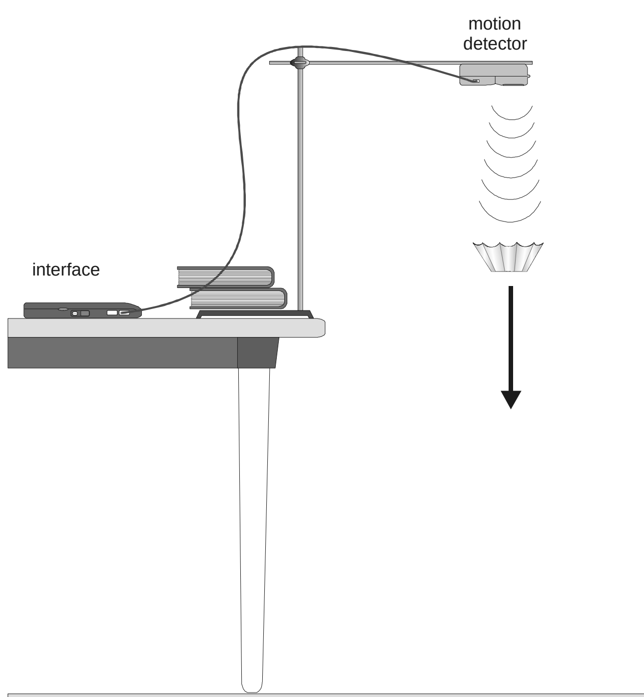


Figure 1

PROCEDURE

1. Set up the apparatus as shown in Figure 1.
   a. Place two books on the base of a ring stand to keep it from tipping.
   b. Use a right-angle clamp to fasten a metal rod to the ring stand.
   c. Fasten a Motion Detector under one end of the rod. The Motion Detector should face down and be parallel to the floor.
   d. Move the right-angle clamp, rod, and Motion Detector to the top of the ring stand.
   e. Use a piece of tape to mark a spot on the ring stand that is 0.5 m from the right-angle clamp.
   f. Place the ring stand, with the Motion Detector attached, at the edge of your lab table. The Motion Detector must extend 50 cm beyond the table edge.
2. Connect the Motion Detector to DIG/SONIC 1 on the computer interface.
3. Prepare the computer for data collection by opening the file "40 Falling Objects" in the *Physical Science w Computers* folder.
4. Collect data for a falling coffee filter.
   a. Hold a basket coffee filter with the open side facing up at a position 0.5 m from (at the 0.5m mark on the ring stand) and directly below the Motion Detector.
   b. Click ▶ Collect to begin data collection.
   c. When you hear sound coming from the Motion Detector, allow the coffee filter to drop straight down.
5. Store data for a good coffee-filter run.
   a. Repeat the coffee-filter drop, if necessary, until you have "smooth" curves for both graphs.
   b. Choose Store Latest Run from the Experiment menu to store your good run. Your coffee-filter run will be stored as Run 1.
6. Repeat Step 4 using a book.
   a. Repeat the book drop, if necessary, until you have "smooth" curves for both graphs.
   b. Do not choose to store this good book run. It will be kept as the Latest Run.
7. Determine and record coffee filter's position data.
   a. Choose Hide Data Set ▶ Latest from the Data menu.
   b. Click the Examine button, .
   c. Move the mouse pointer to the lowest part of the position *vs.* time graph. Record the position value displayed in the examine box. This is a measure of the coffee filter's distance from the Motion Detector at the drop point.
   d. Move the mouse pointer to the highest part of the position *vs.* time graph. Record the position value displayed in the examine box. This is a measure of the coffee filter's distance from the Motion Detector at the landing point.
8. Determine and record coffee filter's time data.
   a. Move the mouse pointer back to the first part of the curves and determine the time when the coffee filter was dropped. Record this value in the data table.
   b. Move the mouse pointer to the highest part of the position *vs.* time graph. Record the time when the coffee filter landed. Consider both curves as you choose this landing time.

9. Determine the velocity at the highest part of the coffee filter's velocity *vs.* time curve.
   a. Move the mouse pointer to highest point on the velocity *vs.* time graph. Record the velocity at this point.
   b. Note and record the shape of the curve in the region of the maximum velocity.
10. Determine and record the falling book's data.
    a. Choose Show Data Set ▸ Latest from the Data menu.
    b. Choose Hide Data Set ▸ Run 1 from the Data menu.
    c. Repeat Steps 7-9 for the book.
11. Print graphs showing the coffee filter and the book results.
    a. Choose Show Data Set ▸ Run 1 from the Data menu.
    b. Print the position *vs*. time and the velocity *vs*. time graphs.
    c. Hand label your graphs with the data you recorded in Steps 7-10.

DATA

	Falling Coffee Filter		**Falling Book**	
	Distance (Y)	Time (X)	Distance (Y)	Time (X)
Drop Point	_______ m	_______ s	_______ m	_______ s
Landing Point	_______ m	_______ s	_______ m	_______ s
Maximum Velocity	________ m/s		________ m/s	
Curve shape in maximum region	____________________		____________________	

PROCESSING THE DATA

1. Calculate the distance fallen (in m) for each object. (Subtract the drop-point distance from the landing-point distance.)

   Falling Coffee Filter　　　　　Falling Book

2. How do the distances compare? Why do the distances compare this way?

3. Calculate the falling time (in s) for each object. (Subtract the drop-point time from the landing-point time.)

Falling Coffee Filter	Falling Book

4. How do the falling times compare?

5. Which object fell faster? Why?

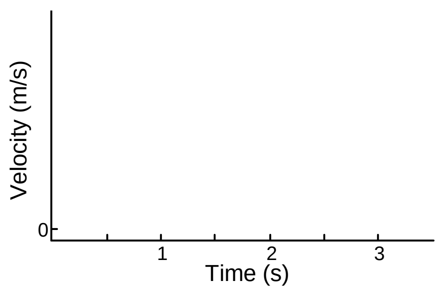
6. How are the two position *vs*. time graphs different? Explain the differences.

7. How are the two velocity *vs*. time graphs different? Explain the differences.

8. Compare the maximum velocities of your two objects. Which object was falling faster when it landed? Why was it falling faster?

9. For which object is air resistance more important? Why does air resistance affect this object more than the other object?

10. Which of your velocity *vs*. time graphs would be more like the velocity *vs*. time graph of an object falling in a vacuum? Why?

11. 

On the graph to the left, sketch a velocity *vs*. time curve for an object that is released at 0.5 s, falls with increasing velocity until 1.5 s, falls at constant velocity from 1.5 s to 3.0 s, and lands at 3.0 s. An object that falls at constant velocity is said to have reached *terminal velocity*.

12. Did either of your objects reach terminal velocity? If so, which one?

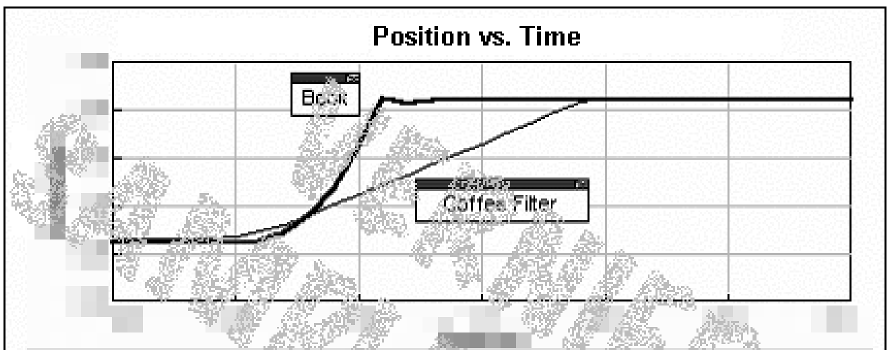
EXTENSIONS

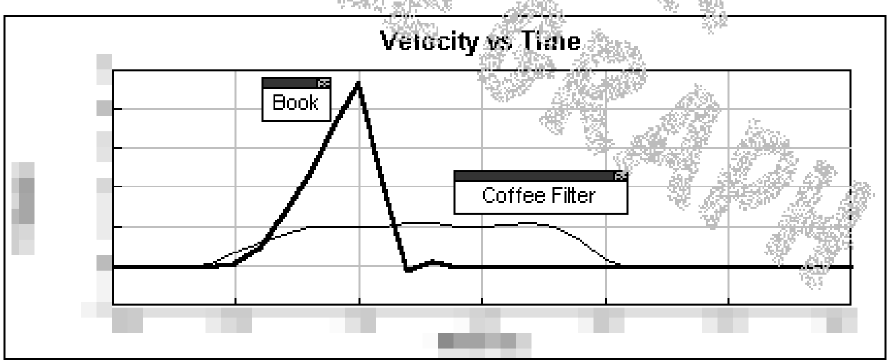
1. Determine the average terminal velocity of a coffee filter in five falls.
2. Study the falling behavior of stacks of 1, 2, 3, 4, and 5 coffee filters.

Falling Objects

1. Have the experiment area as free of obstacles as possible. Ultrasound reflections from tables, desks, and their edges can give unexpected results.
2. The motion detector must extend 50 cm beyond the table edge. Alternatives to the ring stand, right-angle clamp, and rod for suspending the Motion Detector include taping it to a board or rigid meter stick supported by a book shelf, cabinet, or stack of books on a table.
3. We gratefully acknowledge the contributions to the design of this experiment by Rick Sorensen of Vernier Software & Technology.

SAMPLE RESULTS





	Falling Coffee Filter		**Falling Book**	
	Position(Y)	Time (X)	Position (Y)	Time (X)
Drop Point	xxxx m	xxxx s	xxxx m	xxxx s
Landing Point	xxxx m	xxxx s	xxxx m	xxxx s
Maximum Velocity	xxxx m/s		xxxx m/s	
Curve shape in maximum region	xxxx		xxxx	

ANSWERS TO QUESTIONS

Answers have been removed from the online versions of Vernier curriculum material in order to prevent inappropriate student use. Graphs and data tables have also been obscured. Full answers and sample data are available in the print versions of these labs.