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

- Measure distance and velocity.
- Produce distance *vs*. time and velocity *vs*. time graphs.
- Analyze and explain the results.

MATERIALS

TI-83 Plus or TI-84 Plus graphing calculator
EasyData application
CBR 2 or Go! Motion and direct calculator cable
or Motion Detector and data-collection interface
ring stand
metal rod
right angle clamp
basket coffee filter
3 books
meter stick
masking tape

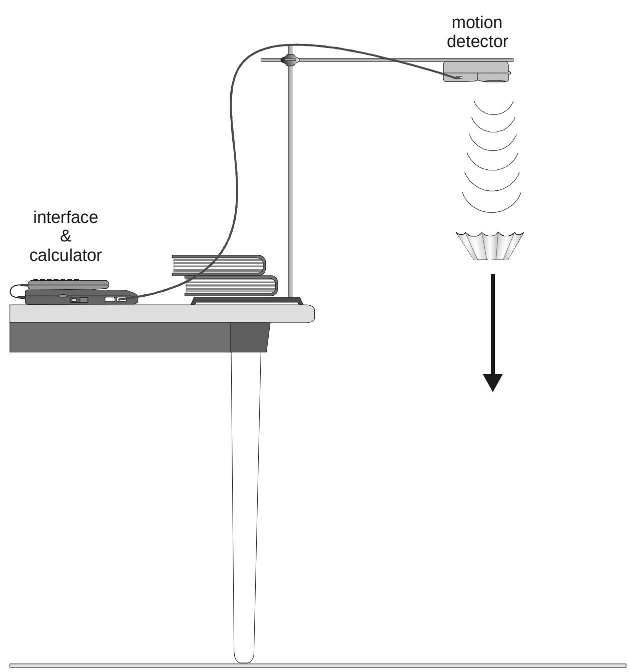
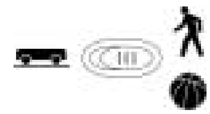


Figure 1

PROCEDURE

Part A Falling Coffee Filter



1. Connect the Motion Detector.
   a. Open the pivoting head of the Motion Detector.
   b. If the Motion Detector has a sensitivity switch, set it to Normal.
   c. Turn on the calculator and connect it to the Motion Detector. (This may require the use of a data-collection interface.)

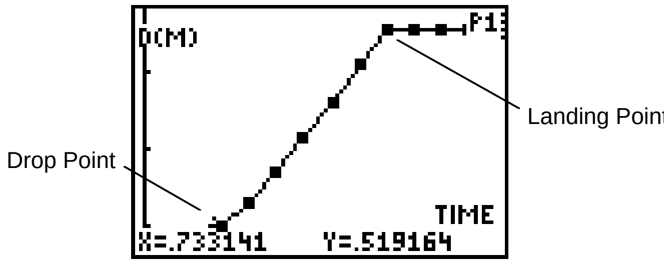
2. Set up the apparatus as shown in Figure 1.
   a. Place two books on the base of a ring stand to keep it from falling.
   b. Use a right-angle clamp to fasten a metal rod to the ring stand.
   c. Fasten a Vernier Motion Detector under one end of the rod. The Motion Detector should face down and be 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.

3. Set up EasyData for data collection.
   a. Start the EasyData application, if it is not already running.
   b. Select **File** from the Main screen, and then select **New** to reset the application.
   c. Select **Setup** from the Main screen, then select **Time Graph…**
   d. Select **Edit** on the Time Graph Settings screen.
   e. Enter **0.1** as the time between samples in seconds and select **Next**.
   f. Enter **30** as the number of samples and select **Next**. Data collection will last 3 seconds.
   g. Select **OK** to return to the Main screen.

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 0.5 m mark on the ring stand) and directly below the Motion Detector.
   b. Select **Start** to begin data collection.
   c. When you hear the Motion Detector clicking quickly, allow the coffee filter to drop straight down.

5. Examine the distance *vs.* time graph for the falling coffee filter.

   a. Examine the distance *vs.* time graph and discuss it with your lab partners. If it is satisfactory, sketch the graph in the space provided in the Data section. Label the important features of your graph. If necessary, repeat the drop.



Coffee Filter Distance vs. Time Graph

   c. Position the cursor at the filter's drop point. See the example above. Record the time (x) and distance (Y) in the data table (round to the nearest 0.01). In the example above, the time is 0.73 s and distance is 0.52 m.

   d. Position the cursor at the filter's landing point. See the example above for the location of the landing point. Record the time (X) and distance (Y) when the filter landed (to the nearest 0.01).

6. Examine the velocity *vs.* time graph for the falling coffee filter.

   a. To see the velocity graph, select **Plots**, then select **Vel(m/s) vs Time**.

   b. Examine the graph and discuss it with your lab partners. Sketch the graph in the space provided in the Data section. Label the important features of your graph.

   c. Position the cursor at the highest point on the velocity *vs.* time graph. Record this highest velocity (Y) (round to the nearest 0.01 m/s).

Part B Falling Book

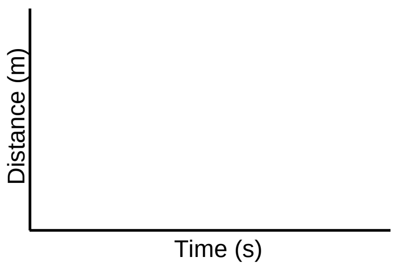
7. Collect data for a falling book.

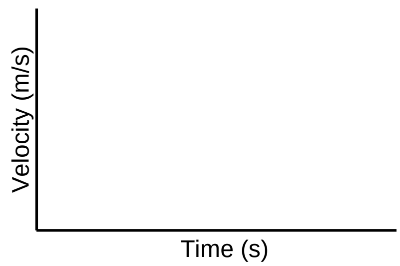
   a. Select **Main** to return to the Main screen.

   b. Repeat Steps 4–6 using a book. **Note**: After selecting **Start** to begin data collection, select **OK** to overwrite the latest run and start collecting data.

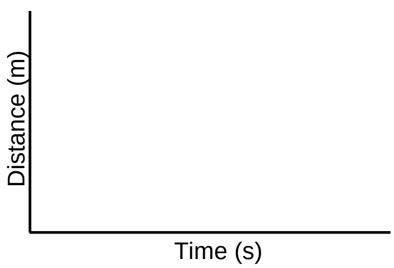
DATA

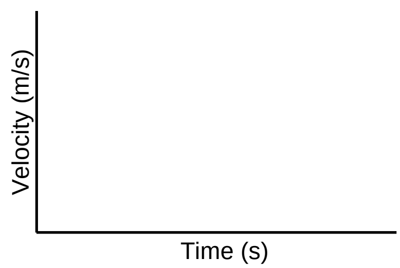
Falling Coffee Filter





Falling Book





	Falling Coffee Filter		**Falling Book**	
	Time (X)	Distance (Y)	Time (X)	Distance (Y)
Drop Point	_______ s	_______ m	_______ s	_______ m
Landing Point	_______ s	_______ m	_______ s	_______ m
Maximum Velocity	________ m/s		________ m/s	

PROCESSING THE DATA

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

Falling Coffee Filter Falling Book

2. How do the falling times compare?

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

   Falling Coffee Filter Falling Book

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

5. Which object fell faster? Why?

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

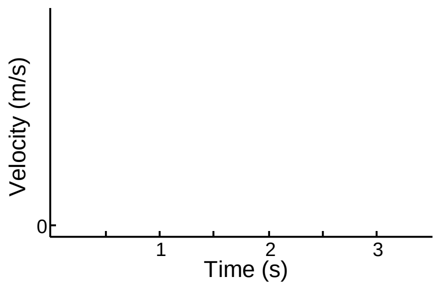
7. How are the two velocity *vs*. time graphs different? Explain the differences.

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?

EXTENSION

1. Determine the average terminal velocity of a coffee filter in five falls.

TEACHER INFORMATION

Falling Objects

1. This activity can be performed with calculators from the TI-83 Plus or TI-84 Plus families and a LabPro or CBL 2. It cannot be performed with EasyLink because Motion Detectors cannot be connected to an EasyLink.

   There are four Motion Detectors that can be used for this lab activity. Listed below are the best methods for connecting your type of Motion Detector. Optional methods are also included:

   Go! Motion: This sensor does not include any cables to connect to a graphing calculator. The cable that is included with it is intended for connecting to a computer's USB port. To connect a Go! Motion to a TI graphing calculator, select one of the options listed below:

   Option I–the Go! Motion connects to a CBL 2 or LabPro using the Motion Detector Cable (order code: MDC-BTD) sold separately by Vernier Software & Technology.

   Option II–the Go! Motion connects to the graphing calculator's I/O port using an extended length I/O cable (order code: GM-CALC) sold separately by Vernier Software & Technology.

   Option III–the Go! Motion connects to the TI-84 Plus graphing calculator's USB port using a Calculator USB cable (order code: GM-MINI) sold separately by Vernier Software & Technology.

   CBR 2: The CBR 2 includes two cables: an extended length I/O cable and a Calculator USB cable. The I/O cable connects the CBR 2 to the I/O port on any TI graphing calculator. The Calculator USB cable is used to connect the CBR 2 to the USB port located at the top right corner of any TI-84 Plus calculator.

   
   I/O cable

   
   USB cable

   Optionally, the CBR 2 can connect to a CBL 2 or LabPro using the Motion Detector Cable. This cable is not included with the CBR 2, but can be purchased from Vernier Software & Technology (order code: MDC-BTD).

   Vernier Motion Detector: Connect the Vernier Motion Detector to a CBL 2 or LabPro using the Motion Detector Cable included with this sensor. The CBL 2 or LabPro connects to the calculator using the black unit-to-unit link cable that was included with the CBL 2 or LabPro.

   
   MDC cable

   CBR: Connect the CBR directly to the graphing calculator's I/O port using the extended length I/O cable that comes with the CBR.

   Optionally, the CBR can connect to a CBL 2 or LabPro using a Motion Detector Cable. This cable is not included with the CBR, but can be purchased from Vernier Software & Technology (order code: MDC-BTD).

   
   I/O cable

2. Have the experiment area as free of obstacles as possible. Ultrasound reflections from tables, desks, and their edges can give unexpected results.

3. 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.

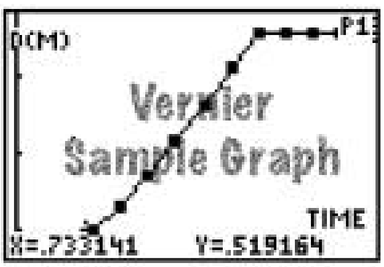
4. We gratefully acknowledge the contributions to the design of this experiment by Rick Sorensen of Vernier Software & Technology.

ANSWERS TO QUESTIONS

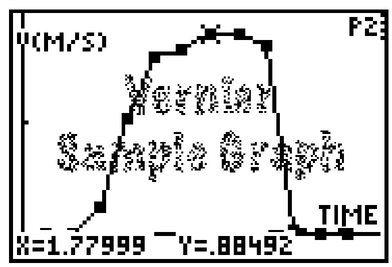
Answers have been removed from the online versions of Vernier curriculum material in order to prevent inappropriate student use. Graphs and data tables have also been obscured. Full answers and sample data are available in the print versions of these labs.

SAMPLE RESULTS

Falling Coffee Filter

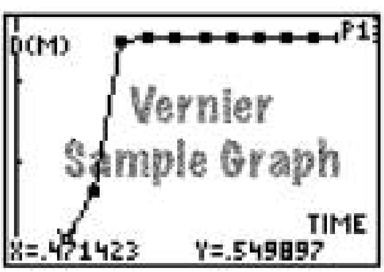


Distance vs. Time

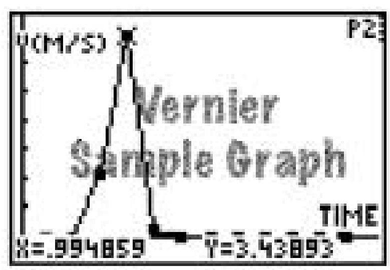


Velocity vs. Time

Falling Book



Distance vs. Time



Velocity vs. Time

	Falling Coffee Filter		**Falling Book**	
	Time (X)	Distance (Y)	Time (X)	Distance (Y)
Drop Point	xxxx	xxxx	xxxx	xxxx
Landing Point	xxxx	xxxx	xxxx	xxxx
Maximum Velocity	xxxx		xxxx	