

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 TI Graphing Calculator, a LabPro or CBL 2 interface, and a Motion Detector to measure distance and velocity
- produce distance vs. time and velocity vs. time graphs
- analyze and explain the results

MATERIALS

LabPro or CBL 2 interface
TI Graphing Calculator
DataMate program
Vernier Motion Detector
ring stand
metal rod

right angle clamp
basket coffee filter
3 books
meter stick
masking tape

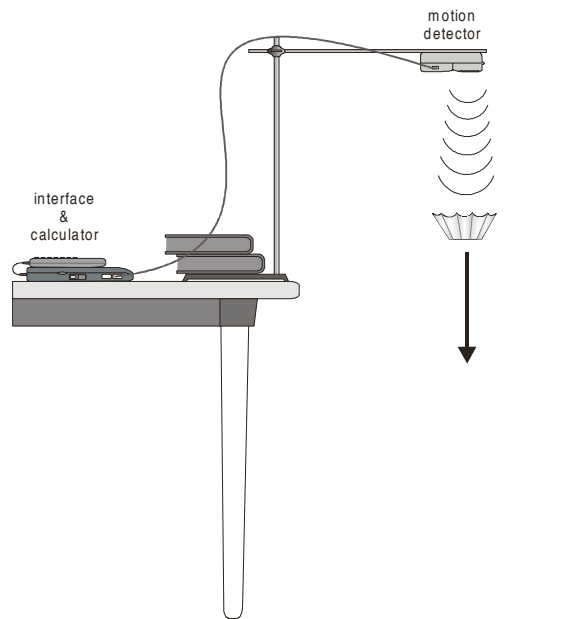


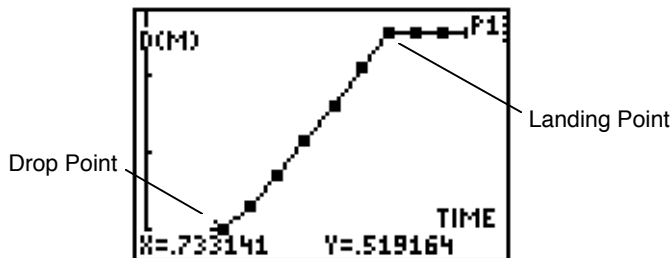
Figure 1

PROCEDURE

Part A Falling Coffee Filter

1. 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.
2. Plug the Motion Detector into the DIG/SONIC 1 port of the LabPro or CBL 2 interface. Use the link cable to connect the TI Graphing Calculator to the interface. Firmly press in the cable ends.
3. Turn on the calculator and start the DATAMATE program. Press to reset the program.
4. Set up the calculator and interface for data collection.
 - a. Select SETUP from the main screen.
 - b. Use and to select MODE and press .
 - c. Select TIME GRAPH from the SELECT MODE menu.
 - d. Select CHANGE TIME SETTINGS from the TIME GRAPH SETTINGS menu.
 - e. Enter "0.1" as the time between samples in seconds.
 - f. Enter "30" as the number of samples. Data collection will last 3 seconds.
 - g. Select OK to return to the setup screen.
 - h. Select OK again to return to the main screen.
5. 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 sound coming from the Motion Detector, allow the coffee filter to drop straight down.

6. Examine the distance vs. time graph for the falling coffee filter.
 - a. After data collection stops, Use to select DIG-DISTANCE and press .
 - b. Examine the 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

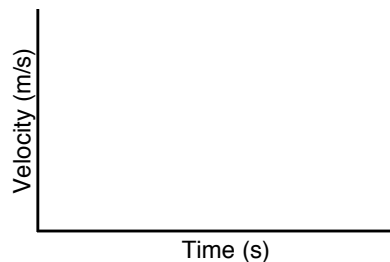
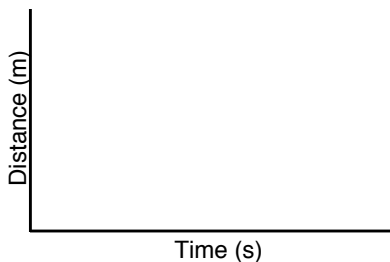
- c. Position the cursor at the filter's drop point. See the example above. Record the time (x) and distance (Y) in the Data table (round to the nearest 0.01). In the example above, the time is 0.65 s and distance is 0.46 m.
 - d. Position the cursor at the filter's landing point. See the example above for the location of the landing point. Record the time (X) and distance (Y) when the filter landed in the Data table (to the nearest 0.01).
7. Examine the velocity vs. time graph for the falling coffee filter.
 - a. Press .
 - b. Use to select DIG-VELOCITY and press to display a velocity vs. time graph.
 - c. 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.
 - d. Position the cursor at the highest point on the velocity vs. time graph. Record this highest velocity (Y) in the Data table (round to the nearest 0.01 m/s).

Part B Falling Book

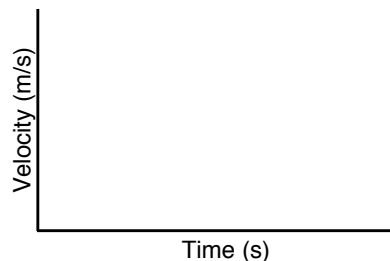
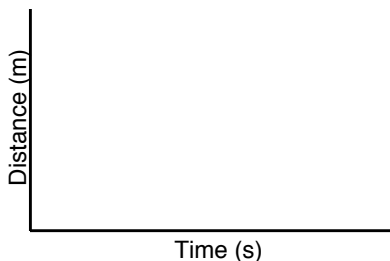
8. Collect data for a falling book.
 - a. Press .
 - b. Select MAIN SCREEN to return to the main screen.
 - c. Repeat Steps 5-7 using a book.

DATA

Falling Coffee Filter



Falling Book



Falling Coffee Filter

	Time (X)	Distance (Y)
Drop Point	_____ s	_____ m
Landing Point	_____ s	_____ m

Falling Book

	Time (X)	Distance (Y)
	_____ 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

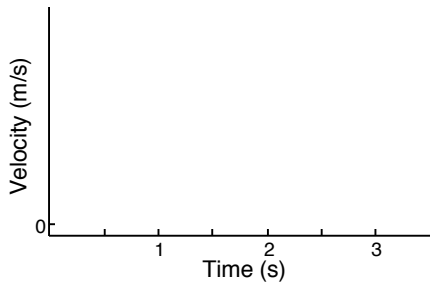
Falling Book

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?

Experiment 40

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

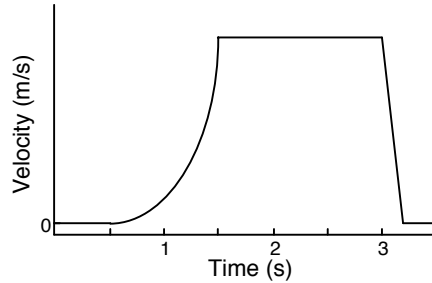
1. Have the experiment area as free of obstacles as possible. Ultrasound reflections from tables, desks, and their edges can give unexpected results.
2. The Motion Detector must extend 50 cm beyond the table edge. Alternatives to the ring stand, right-angle clamp, and rod for suspending the Motion Detector include taping it to a board or rigid meter stick supported by a book shelf, cabinet, or stack of books on a table.
3. If you are using an old Motion Detector with a non-detachable cable, the interface will not be able to identify it. Instead, set up DataMate for the Motion Detector manually:
 - a. Select SETUP from the main screen.
 - b. Use the cursor keys and to select DIG (CBL 2) or DIG 1 (LabPro)
 - c. Press .
 - d. Choose MOTION from the SELECT SENSOR list.
 - e. Select OK to return to the main screen.
4. We gratefully acknowledge the contributions to the design of this experiment by Rick Sorensen of Vernier Software & Technology.

ANSWERS TO QUESTIONS

1. Falling times:
Coffee Filter: $2.30\text{ s} - 0.73\text{ s} = 1.57\text{ s}$
Book: $0.99\text{ s} - 0.47\text{ s} = 0.52\text{ s}$
2. The falling time of the coffee filter is greater.
3. Distance fallen:
Coffee Filter: $1.76\text{ m} - 0.52\text{ m} = 1.24\text{ m}$
Book: $1.72\text{ m} - 0.55\text{ m} = 1.17\text{ m}$
4. The distances fallen by the two objects should be nearly equal because the two objects were dropped to the floor from nearly the same point.
5. The book fell faster because it has a greater mass to surface area ratio.
6. The book's distance vs. time graph is steeper because the falling book took less time to reach the floor.
7. The velocity vs. time graph for the coffee filter leveled off as the falling coffee filter reached terminal velocity. In contrast, the book's velocity vs. time graph has a sharp peak because the book increased in velocity until it hit the floor.
8. The book's maximum velocity is greater than that of the coffee filter (3.44 m/s versus 0.88 m/s in the Sample Data). The book was falling faster because it has a higher mass to cross-sectional area ratio.

Experiment 40

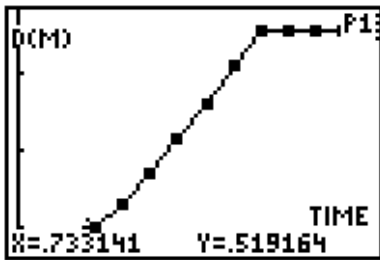
9. Air resistance is more important for the coffee filter because it has a low mass to cross-sectional area ratio.
10. The falling book's velocity vs. time graph looks more like that of an object in a vacuum than that of the falling coffee filter because the book is slowed much less by air resistance. There is no air resistance in a vacuum.
- 11.



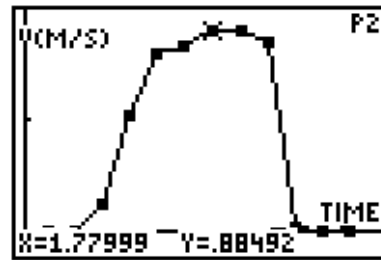
12. A falling coffee filter can reach terminal velocity.

SAMPLE RESULTS

Falling Coffee Filter

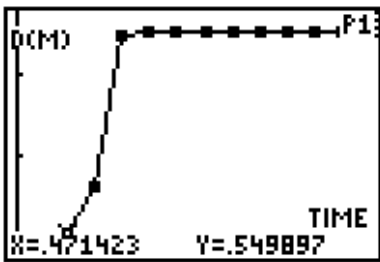


Distance vs. Time

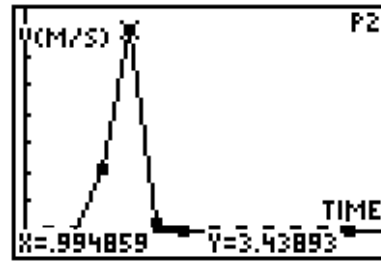


Velocity vs. Time

Falling Book



Distance vs. Time



Velocity vs. Time

	Falling Coffee Filter		Falling Book	
	Time (X)	Distance (Y)	Time (X)	Distance (Y)
Drop Point	0.73 s	0.52 m	0.47 s	0.55 m
Landing Point	2.30 s	1.76 m	0.99 s	1.72 m
Maximum Velocity		0.88 m/s		3.44 m/s

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Using the CD

The CD located inside the back cover of this book contains two folders containing word processing files and one folder with the DatMatch calculator program.

- **Physical Sci w Calculators Word** - For use with this book. Uses the DataMate calculator program with LabPro or CBL 2. This folder contains files for each of the forty experiments in this manual. This provides a way for you to edit the experiments to match your lab situation, your equipment, or your style of teaching. They contain all figures, text, and tables in the same format as printed in *Physical Science with Calculators*.
- **Physical Sci w Computers Word** - Not for use with this book. Uses Logger *Pro* computer software with LabPro, Serial Box Interface, or ULI.
- **DatMatch Calculator Program** — Contains the DatMatch calculator program required only for Experiment 35 Graphing Your Motion. See Appendix B for information on loading this program.

Using the *Physical Science with Calculators* Word-Processing Files

Start Microsoft Word, then open the file of your choice from the Physical Sci w Calculators folder. They can be opened directly from the CD or copied onto your hard drive first. These files can be used with any version of Microsoft Word that is Version 6 or newer. All file names begin with the experiment number, followed by an abbreviation of the title; e.g., Exp 01 Temp Response is the file name used for *Experiment 1 Temperature Probe Response Time*.