ADVENTURE 5

Falling Down

Math Objectives:
Graph distance as a function of time, Interpret and analyze graphs

Science Objectives:
Understand how a change in mass affects the average speed of a
falling object, Represent motion and the changes in motion graphically
Calculate average speed

Materials:
TI-73 Explorer™, Calculator-Based Ranger™ (CBR 2™), CBL/CBR™ Application
Five large basket-style coffee filters

OVERVIEW
Two mountain climbers climbed the side of a mountain and rested
at the top. There they ate and drank, and contemplated some deep
questions, such as, "If we throw two rocks that are the same shape,
but different weights, off the side of this mountain, would they fall at
the same speed?"
In this adventure, students will drop an object and determine the
average speed the object reaches. The students will make observations
about whether or not changing the mass and keeping the same shape have an effect on the
average speed of the object.

🍎 **NOTE** Demo the activity using the overhead calculator so the entire class can see the process. If you have
only one CBR 2, have each group individually perform this activity. If you have enough CBR 2 units, have
students work in small groups.

SET UP
1. Connect the CBR 2 to the calculator using
    the I/O unit-to-unit cable.
2. Set up the activity as shown in the picture.
    One student should hold the CBR 2 at
    eye level or higher, pointing the CBR 2
    downward.
3. A second student should hold the coffee
    filters, concave side up, about 0.5 meters
    below the CBR 2. These will be released
    shortly after the data collection begins.
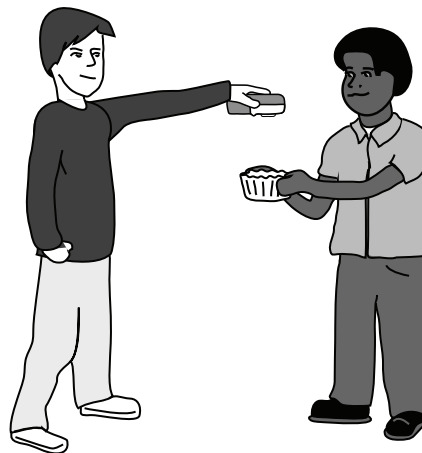
4. A third student should operate the calculator.

5. To launch the CBL/CBR App, press the [APPS] key, select **2:CBL/CBR** and then press [ENTER] to view the CBL/CBR screen. **See Figures 1a-b.**

6. Press [ENTER] to access the application, then select **3:RANGER.** The Ranger start up screen will launch. Press [ENTER] to access the application. **See Figures 2a-b.**

7. From the **MAIN MENU** select **2:SET DEFAULTS. See Figure 3.**

8. Use the arrow keys to move the selector arrow ([▸]) to any setting. Press [ENTER] to select or change any setting. Adjust **REALTIME** to **NO, TIME(S) to 3,** and **SMOOTHING** to **HEAVY**. With the selector arrow ([▸]) at **START NOW**, press [ENTER].

Figure 1a
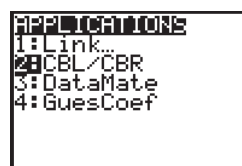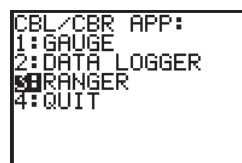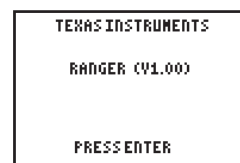

Figure 1b

Figure 2a

Figure 2b

Figure 3

DATA COLLECTION

Time will be plotted on the horizontal axis. The distance from the CBR 2 to the coffee filters (in meters) will be plotted on the vertical axis.

NOTE You may wish to have students predict the shape of the graph first.

Trial 1

1. Hold one coffee filter 0.5 meter below the CBR 2.

2. When everyone is ready, the student operating the calculator should press [ENTER] to begin data collection.

3. The student holding the coffee filter should release the filter only after the CBR 2 can be heard collecting data. There is more than enough time allotted for data collection, so there is no need to rush.

4. For best results, place your hands together and hold the coffee filter in both hands. Quickly move your hands outward to drop the filter. Be sure to separate your hands wide enough so that they do not interfere with data collection.

5. The student holding the CBR 2 should continue to hold it steady at the same height until the CBR 2 can no longer be heard collecting data.

6. The resulting plot should begin with a horizontal segment, then have a segment rising from left to right, and then have another horizontal segment. **See Figure 4.**

Figure 4

7. If you are satisfied with your plot, sketch it on the axes on your worksheet. If not, press [ENTER], choose **5: REPEAT SAMPLE,** and then repeat the data collection. **See Figure 5.**

8. Use [▸] and [◂] to move along the Distance-Time plot. Keep in mind that the *x*-coordinate represents the time in seconds since the beginning of data collection and the *y*-coordinate represents the distance in meters from the CBR 2 to the coffee filter. Answer the questions about Trial 1 on your worksheet.
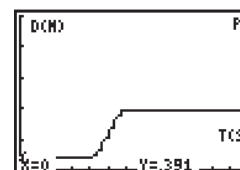

Figure 5

Trial 2

1. Repeat the steps from Trial 1 with one change. Use 5 coffee filters that are carefully stacked or nested inside of each other.

2. Press [ENTER] and choose **5: REPEAT SAMPLE** from the **PLOT MENU.**

3. Follow the directions in steps 2 through 5 from Trial 1 to collect your data. Try to hold the CBR 2 at the same height as in Trial 1.

4. Your plot should consist of a horizontal segment, followed by a section that is rising from left to right, and finally another horizontal segment. Do not worry if the middle section of your plot is curved upward. This is due to the acceleration of the coffee filters during freefall. **See Figure 6.**

Figure 6

5. If you are satisfied with your plot, sketch it on the axes on your worksheet. If not, press ENTER, choose **5: REPEAT SAMPLE,** and then try again.

6. Use ▶ and ◀ to move along the Distance-Time plot. Keep in mind that the x-coordinate represents the time in seconds since the beginning of data collection and the y-coordinate represents the distance in meters from the CBR 2 to the coffee filters. Answer the questions about Trial 2 on your worksheet.
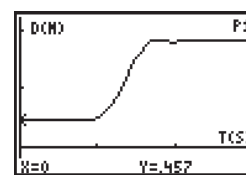
EXTENSION ACTIVITY

1. Suppose the CBR 2 had been placed on the floor. How would the value of the average speed be affected by the filters falling toward, rather than away from, the CBR 2?

2. Look up the term "terminal velocity" or "terminal speed" and relate this to the curvature of the plot of the 5 coffee filters falling.

DISCUSSION NOTES

Explain to students that the average speed is the total distance traveled divided by the total time elapsed and that the speed of an object along the path traveled can vary. The students should know that the velocity of an object is the rate of change of its position and must be described by specifying both the direction and the speed of the object.

Through questioning, draw out that 5 coffee filters were used in Trial 2 in order to change the mass of the falling object without altering the frontal surface area of the object. As a result, the air resistance of the object remained the same.

WORKSHEET ANSWERS

NOTE: The data in these tables is simulated. Actual data will be slightly different.
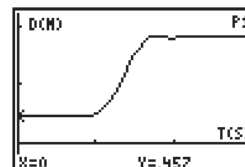
Trial 1

List L1	List L2
0	0.39
0.16	0.39
0.38	0.39
0.54	0.39
0.70	0.39
0.92	0.48
1.08	0.66
1.34	0.80
1.50	1.05
1.59	1.22
1.75	1.32
2.01	1.46
2.42	1.46
2.71	1.46
2.96	1.46
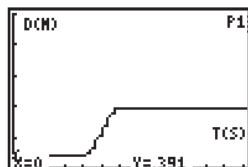
Trial 2

List L1	List L2
0	0.46
0.16	0.46
0.38	0.46
0.54	0.46
0.70	0.46
0.94	0.46
1.07	0.55
1.36	1.11
1.52	1.57
1.61	1.76
1.77	1.85
2.07	1.82
2.42	1.83
2.71	1.83
2.96	1.83

2. The first flat section is a plot of the distance the coffee filter is being held away from the CBR 2 before release. The second flat section is a plot of the distance from the CBR 2 to the coffee filter when it is lying on the floor.

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3. The section that connects the two flat portions is a Distance-Time plot of the coffee filter falling.

	Trial 1	Trial 2
4.	0.39	0.46
5.	1.46	1.83
6.	1.07	1.37
7.	0.92	1.07
8.	2.01	2.42
9.	1.09	1.35
10.	0.98	1.01

11. The stack of 5 coffee filters fell with the highest average speed.

12. The extra mass caused the speed to increase.

13. Yes. The time required to reach the ground will always be the distance traveled divided by the average speed. Since the distance will be the same for both objects, dividing by a larger number, in this case the average speed, will yield a smaller time value.

Extension

1. Since speed tells how fast an object is moving without reference to positive or negative values, it would remain the same. The velocity would be different if students wish to investigate this term.

2. The speed increased for a short period of time before reaching terminal speed. This caused the curve in the plot.

TI-NAVIGATOR™ EXTENSION ACTIVITY

1. Load the **CBRonFloor.act** activity settings file. Students will be able to mark up to 10 points each. Depending on the number of students participating, you may wish to have each student contribute less than that. The activity settings files can be found on the CD located in the back of the book.

2. Tell students to work as a cooperative group to mark points to illustrate what the plot of the coffee filters falling would have looked like if the CBR 2 had been placed on the floor and the filters released above it.

NOTE: In actuality, the CBR 2 cannot collect data that is closer than 0.5 meter. Tell students to ignore that fact while they form their plot.

3. Clear the existing data and have students redraw it under a different condition (heavier, lighter, starting higher or lower).

Falling Down Worksheet

ADVENTURE 5

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Science Objectives:
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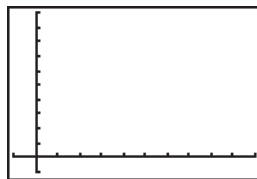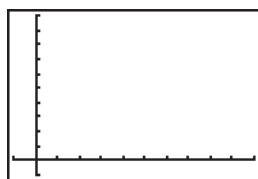Calculate average speed

Materials:
TI-73 Explorer™, Calculator-Based Ranger™ (CBR 2™), CBL/CBR™ Application
Five large basket-style coffee filters

In this adventure, you will drop an object and determine the average speed the object reaches. Then you will drop a heavier, but similar shaped object, to see what effect a difference in mass makes.

Trial 1   **Trial 2**

1. Sketch the plots of each of the two trials on the axes provided.
2. What do the two flat sections for Trial 1 represent?

3. What does the portion of the plot that connects the two flat sections represent?

4. Use ▸ and ◂ to move along the Distance-Time plot. How far from the CBR 2 was the coffee filter when it was dropped? Hint: Find the initial distance.

    Trial 1_____   Trial 2_____

5. How far from the CBR 2 was the coffee filter when the data collection ended?
    Hint: Find the final distance from the CBR 2 to the filter.

    Trial 1_____   Trial 2_____

6. What was the total distance traveled by the coffee filter? **Hint:** Subtract the coffee filter's initial distance from the CBR 2 from its final distance from the CBR 2.

    Trial 1_____   Trial 2_____

7. At what time was the coffee filter released? **Hint:** This is the time value when the line begins to rise.

Trial 1_____   Trial 2_____

8. At what time did the coffee filter reach the ground? **Hint:** This is the time value when the line stops rising.

Trial 1_____   Trial 2_____

9. What was the total time that the coffee filter took to fall to the ground after being released?

Trial 1_____   Trial 2_____

10. The average speed of an object can be found by dividing the total distance it travels by the total time interval that elapses during the motion. Find the average speed of each coffee filter during its fall to the ground. **Hint:** Divide your answers for problem 6 by your answers for problem 9.

Trial 1_____   Trial 2_____

11. Which number of coffee filters resulted in the higher average speed?

12. What do you believe happened? Remember, air resistance remained the same in both trials.

13. If one object travels at a higher speed than another object, and they are dropped simultaneously from the same height, will the object with the higher average speed always reach the ground first? Justify your answer.

EXTENSION
1. Suppose the CBR 2 had been placed on the floor. How would the value of the average speed be affected by the filters falling toward, rather than away from, the CBR 2?

2. Look up the term "terminal velocity" or "terminal speed" and relate this to the curvature in the plot of the 5 coffee filters falling.