Name ______________________________

Date ______________________________

EXPLORATIONS

ACTIVITY 12

Falling Down

By dropping objects of different masses from the Leaning Tower of Pisa and observing that they reached the ground at the same time, Galileo tried to show that an object's mass has no effect on the rate at which it falls. But his assumption that all bodies fall with the same acceleration due to gravity doesn't take *air resistance* into account. No one would expect a feather and a rock to fall to the ground in the same amount of time because their different shapes meet different levels of air resistance. But what if the air resistance on two objects was the same? If they had identical shapes but different masses, would they fall at the same speed?

Objectives

In this activity you will:

- ♦ Drop an object and determine the average speed the object reaches.
- ♦ Observe whether or not changing the *mass* and keeping the same shape have an effect on the *average speed* of the object.

You'll need

- ♦ CBR unit
- ♦ TI-82 or TI-83 and calculator-to-CBR cable
- ♦ Five large basket-style coffee filters

CBR Setup

1. Connect the CBR to the calculator using the link cable.
2. Turn on your calculator. If you have not already loaded the **RANGER** program into your calculator, follow these steps:
   - **a.** Press [2nd] [LINK] [▸] [ENTER]. The calculator displays **Waiting …**
   - **b.** Press the (82/83) transfer button on the CBR.

3. Run the **RANGER** program on your calculator:

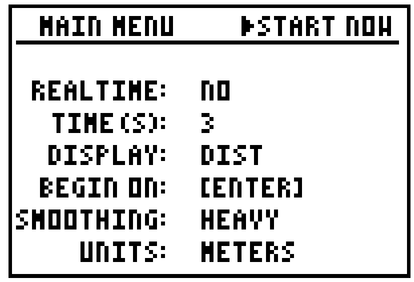
   a. Press [PRGM].

   b. Choose **RANGER**.

   c. Press [ENTER].

4. From the **MAIN MENU**, select **1: SETUP/SAMPLE**.

5. Use the arrow keys to move the selector arrow (▸) to any setting. Press [ENTER] to select or change a setting. Adjust the setting so that they exactly match those shown to the right.



6. When you are finished adjusting the settings, move the arrow (▸) to **START NOW** and press [ENTER] to prepare the CBR for data collection

Collecting the Data —Trial 1

In this activity, you will drop coffee filters from a height of approximately 1.5 meters and record their motion with the CBR.

1. To begin, one student should hold the CBR at eye level or higher, pointing the CBR downward.

2. A second student should hold the coffee filters, concave side up, about 0.5 meter below the CBR. These will be released shortly after data collection begins.

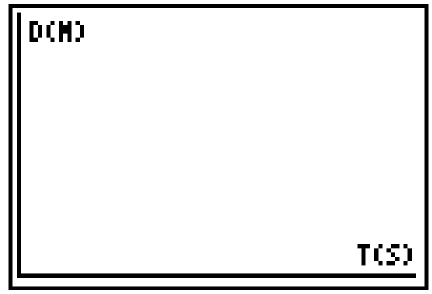
3. A third student should operate the calculator.

4. Hold one coffee filter 0.5 meter below the CBR.

5. When everyone is ready, the student operating the calculator should press [ENTER] to begin data collection. The student holding the coffee filter should release the filter only after the CBR can be heard collecting data. The student holding the CBR should continue to hold it steady at the same height until the CBR can no longer be heard collecting data.

   The resulting plot should begin with a horizontal segment, next have a linear segment rising from left to right, and finally another horizontal segment.

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



Looking at the Results — Trial 1

1. What do the two flat sections on the plot represent?

    ____

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

    ____

3. Use the arrow keys to move along the plot. Keeping 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 to the coffee filter, answer these questions.

    a. How far from the CBR was the coffee filter when it was dropped?
    Hint: Find the initial distance. ______________________________

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

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

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

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

    f. What was the total time that the coffee filter took to fall to the ground after being released?
    Hint: Subtract the time at which the filter was released from the time at which it hit the ground. ______________________________

4. 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 the coffee filter during its fall to the ground.
    Hint: Divide your answer for 3c by your answer for 3f.______________

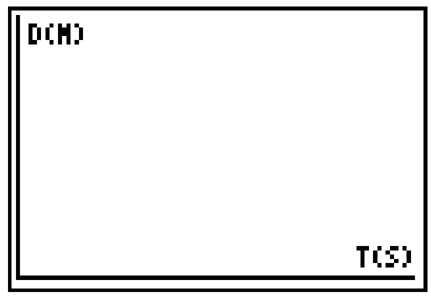
Collecting the Data — Trial 2

Repeat Trial 1 with one change — use 5 coffee filters that are carefully stacked or nested inside of each other. This way you will change the mass of the falling object without altering the frontal surface of the object. As a result, the air resistance on the object will remain the same.

1. To begin this trial, press [ENTER] and choose **3: REPEAT SAMPLE**. Follow the directions from Trial 1 to collect your data.

   Your plot should once again consist of a horizontal segment, followed by a section that is rising from left to right, and finally another horizontal segment. Don't worry if the middle section of your plot is curved upward. This is due to the acceleration of the coffee filters during freefall.

2. If you are satisfied with your plot, record it on the axes to the right. If not, press [ENTER], choose **3: REPEAT SAMPLE**, and repeat the data collection.



Looking at the Results — Trial 2

1. Press the arrow keys to move along the plot. Keeping 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 to the coffee filter, answer the following. Refer to the hints in Trial 1 if you need help.

   a. How far from the CBR were the coffee filters when they were dropped? ____________________

   b. How far from the CBR were the coffee filters when the data collection ended? ____________________

   c. What was the total distance traveled by the coffee filters? ________

   d. At what time were the coffee filters released? ____________________

   e. At what time did the coffee filters reach the ground? ____________

   f. What was the total time the coffee filters took to fall to the ground after being released? ____________________

2. 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 the coffee filters during their fall to the ground.

   ____

Summing It Up

1. Which number of coffee filters resulted in a higher average speed?

 ____

2. Why do you believe this happened? Remember, air resistance remained the same in both trials.

 ____

3. If one object travels at a higher average 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.

 ____

4. Summarize your findings on the effect of mass on the average speed of a falling object. Be sure to mention air resistance in your answer.

 ____

 ____

 ____

Going Further

Answer these questions on a separate piece of paper. Show all work.

1. Discuss how the plot of the coffee filters falling would have been different if the CBR had been placed on the floor and the filters released above it.
2. How would the value of the average speed be affected by the filters falling toward rather than away from the CBR?
3. Look up the term “terminal speed” or “terminal velocity” and relate this to the curvature in the plot of the 5 coffee filters falling.