FUNCTIONS EXPERIMENT
COFFEE FILTER DROP

Introduction

When air resistance is ignored, the speed of a falling object increases by 9.8 meters per second for every second that the object is in motion. So if we dropped a basketball and a coffee filter from the same height in a vacuum (where there is no air resistance), both would reach the ground at the same time. However, we would find that the same is not true if we dropped a basketball and a coffee filter from the same height in our classroom. As the coffee filter moves through the air, air resistance or a *drag force* tends to slow its motion. When the coffee filter is first released, its speed increases from zero, but the air resistance acting on the coffee filter also increases. Eventually, when the air resistance becomes great enough, the coffee filter almost stops accelerating and falls the rest of the way nearly at a constant speed, known as its terminal velocity. At all times the acceleration of the coffee filter is given by

$$\text{Acceleration} = \text{Acceleration due to gravity} - \text{Retardation from air resistance.}$$

The retardation from air resistance can be modeled as rV^2, where r is a constant known as the drag coefficient and V is the velocity. In this lab we will drop a coffee filter, measure the distance, and use this to determine the terminal velocity of the coffee filter and the drag coefficient of the coffee filter.

Equipment and Setup

For this experiment you will need a TI calculator with the Vernier PHYSICS program loaded, a CBL unit, a motion detector, and a coffee filter.

Plug the motion detector into SONIC on the CBL unit. Select the PHYSICS program on the calculator. In the home menu choose SET UP PROBES. When asked for the number of probes, enter 1. In the next menu choose MOTION. The screen will display the home menu again. Now select COLLECT DATA, and choose TIME GRAPH. Set the calculator to take 40 measurements 0.05 second apart.

Procedure

When the calculator is ready to begin taking measurements, have a tall group member stand on a chair and hold the motion detector facing the ground while another group member holds the coffee filter directly under the motion detector. Press ENTER on the calculator to begin taking measurements, and release the filter when the motion detector begins clicking. After collecting the data, press ENTER on the calculator to get the graph menu. Select DISTANCE. The calculator will display the graph of the distance of the filter from the motion detector versus time. Note that distance is in meters and time is in seconds.

Data

While viewing the graph of distance versus time, use TRACE to recover the data collected by the CBL unit. Record the distances collected by the CBL unit in the table below. Discard the data points taken before the drop and after the filter hit the floor. After recording the data, quit the PHYSICS program by pressing ENTER to get back to the graph menu, then choose RETURN. When asked to repeat select NO, and then in the main menu select QUIT.

Time in seconds	0.05	0.10	0.15	0.20	0.25	0.30	0.35	0.40	0.45	0.50
Distance in meters										
Time in seconds	0.55	0.60	0.65	0.70	0.75	0.80	0.85	0.90	0.95	1.00
Distance in meters										
Time in seconds	1.05	1.10	1.15	1.20	1.25	1.30	1.35	1.40	1.45	1.50
Distance in meters										
Time in seconds	1.55	1.60	1.65	1.70	1.75	1.80	1.85	1.90	1.95	2.00
Distance in meters										

Analysis

1. Input the data in the table above into your calculator by entering times in L1 and distances in L2. Then enter the last five data points in your table in lists L3 and L4. Using these last five data points, find the equation of the regression line for distance D (in meters) as a function of time t (in seconds). (Enter LinReg L3, L4.)

2. Plot the data from the table above and add the regression line from Part 1 to your graph. Sketch the graph below.

3. Use the graph in Part 2 to help you describe how the velocity of the coffee filter changes as it falls.

4. Explain why the slope in your formula in Part 1 is the terminal velocity of the coffee filter.

5. Use your answers to Parts 2 through 4 to help you carefully sketch a graph of the velocity of the coffee filter. Label your horizontal axis with the correct times and your vertical axis with the terminal velocity.

6. Use your graph in Part 5 to help you carefully sketch a graph of the acceleration of the coffee filter.

7. About how long does it take the coffee filter to reach terminal velocity? How did you determine this?

8. Recall that the retardation from air resistance can be modeled as rV^2, where r is a constant known as the drag coefficient and V is the velocity. In this part of the lab we will show one way in which the drag coefficient of an object can be experimentally determined. Let A represent the acceleration of the coffee filter and g the acceleration due to gravity. Then we have the basic equation

$$A = g - rV^2$$

for the acceleration of the coffee filter during the drop.

i. What is the acceleration of the coffee filter once it has reached terminal velocity?

ii. Use the basic equation above to compute the drag coefficient of the coffee filter. (Use your answer to Part i above, the terminal velocity you computed earlier in the lab, and the fact that acceleration due to gravity is about 9.8 meters per second per second.)

Note: The way we have things written here, the drag coefficient depends on the density of air and on the cross-sectional area, the mass, and the shape of the falling object. Do not concern yourself with the proper units.

Conclusions

Describe how the velocity of a falling feather would differ from the velocity of a falling bowling ball when dropped from just a few meters above the ground.