Drag Force on a Coffee Filter

Purpose: To study the relationship between air drag forces and the velocity of a falling body.

Equipment: Computer with Logger Pro software, lab pro, motion detector, nine coffee filters, meter stick

Introduction:

When an object moves through a fluid, such as air, it experiences a retarding or drag force that opposes its motion. This force generally increases with the relative velocity between the fluid and the object. The drag force also depends on other quantities such as the size, shape, and mass of the object, as well as the density and viscosity of the fluid. In this lab we are only going to investigate the velocity dependence of the drag force. We will start by assuming the drag force, F_D, has a simple power law dependence on the speed given by

1) $F_D = k|v|^n$, where the power n is to be determined by the experiment.

When an object is released from rest, it initially experiences no drag force. As it falls its speed increases and so does the drag force acting on it. Eventually, the drag force is as large as the force of gravity and then the net force acting on the object is zero. At that point, the speed becomes constant. We call this final speed the terminal speed for the object. This lab will investigate drag forces acting on a falling coffee filter. Because of the large surface area and low density of these filters, they reach terminal speed soon after being released.

Procedure:

NOTE: You will be given a packet of nine nested coffee filters. It is important that the shape of this packet stays the same throughout the experiment so do not take the filters apart or otherwise alter the shape of the packet.

1. Connect the lab pro to the computer and the motion detector to the lab pro. On the computer, start the **Logger Pro** software, open the **Mechanics** folder and the **graphlab** file. You should see a blank position vs time graph on the monitor. Choose a suitable time and position scale that will clearly display the motion. Put labels on the axes of the graph and create an appropriate title for the graph. Set the data collection rate to 30 Hz.
2. Place the motion detector on the floor facing upward and hold the packet of nine filters at a minimum height of 1.5 m directly above the motion detector. Be aware of other nearby objects which can cause spurious reflections. Start the computer collecting data, and then release the packet. What should the position vs time graph look like? Verify that the data are consistent. If not, repeat the trial. Examine the graph and using the mouse, select (click and drag) a small range of data points near the end of the motion where the packet moved with constant speed. Exclude any early or late points where the motion is not uniform.
3. Use the **curve fitting** option from the **analysis** menu to fit a linear curve (y = mx + b) to the selected data. Record the slope (m) of the curve from this fit. Physically, this slope should represent the terminal speed of the falling packet. Repeat this measurement at least four more times, and calculate the average velocity. Record all data in a neat original data table.
4. Carefully remove one filter from the packet and repeat the procedure in parts 2 and 3 for the remaining packet of eight filters. Keep removing filters one at a time and repeating the above steps until you finish with a single coffee filter. Print a copy of one of your x vs t graphs that show the motion and the linear curve fit to the data.
5. Create a two column data table with packet weight (number of filters) in one column and average terminal speed (|v|) in the other. Open the **Graphical Analysis** software and make a plot of packet weight vs terminal speed. Choose appropriate labels and scales for the axes of your graph. Be sure to remove the “connecting lines” from the plot. Perform a power law fit of the data and record the power, n, given by the computer. Obtain a printout of your graph.
6. Since the drag force is equal to the packet weight (see introduction above), we have found the dependence of drag force on speed. Write equation 1 above with the value of n obtained from your experiment. Put a box around this equation. Look in the section on drag forces in your text and write down the equation given there for the drag force on an object moving through a fluid. How does your value of n compares with the value given in the text? Explain the other terms in the text equation.