

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. The 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 going to investigate the velocity dependence of the drag force. We will start by assuming the drag force F_{drag} has a simple power law dependence on the speed given by

$$(1) \quad F_{\text{drag}} \sim (\text{speed})^2$$

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 this point, the speed becomes constant (acceleration is zero from Newton's 2nd law). We call this 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 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 a 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. A blank position versus time graph should be displayed on the monitor. 2) Choose a suitable time and position scale and place labels on the axes of the graph. 3) Create an appropriate title for the graph. Set the data collection rate to 30Hz.

4) Place the motion detector on the floor facing upward and hold the packet of nine filters at a minimum height of 1.5 meter directly above the motion detector. Be aware that other nearby objects which can cause spurious reflections. 5) Start the computer collecting data, and then release the packet. What should the position versus time graph look like? Verify that the data are consistent. If not, repeat the trial. Examine the graph and using the mouse, select 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.

6) Use the automatic curve fitting option from the **analysis** menu to fit a linear curve ($Mx+B$) 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. 7) Repeat this measurement at least four more times, and calculate the average velocity. Record all data in a data table.

8) Carefully remove one filter from the packet and repeat the procedure in steps (4) and (6) for the remaining packet of 8 filters. Keep removing filters one at a time and repeat the above steps until one coffee filter remains. Print a copy of one of your position versus time graphs that show the motion and the linear curve fit to the data.

9) Create a summary table for the packet weight, and the average terminal speed. Open the **Graphical Analysis** software and make a plot of packet weight (vertical, units: Newton) versus terminal speed (horizontal, units m/sec). Give a title to the graph and label the axes with the appropriate units. 10) Perform a power fit of the data and record the power, n , given by the computer. Obtain a print out of your graph. 11) Compare the computer result for the power with that from equation (1) by doing a percentage difference calculation.

12) Since the drag force is equal to the packet weight, we have found the dependence of drag force on speed.

