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Non-Free Fall

What a Drag

Purpose

To investigate the how the terminal speed and weight of an object are related.

Required Equipment and Supplies

coffee filters, large and small
meterstick
two-meterstick

Discussion

Drop a feather and its large area-to-weight ratio quickly finds it falling at terminal speed. Common paper coffee filters demonstrate this nicely, since they too have large area-to-weight ratio. Drop a couple of filters simultaneously from the same height and they fall together. Drop a single filter and a double-weight filter—two stuck together—and the heavier one hits the floor first. For this case, is air resistance proportional to speed, or the square of the speed? We can find out by seeing how much higher a twice-as-heavy filter should be dropped to reach the floor at the same time as a dropped single filter.

At terminal speed, v_T, the air resistance equals the weight of the falling object, and the distance fallen is

$$d = v_T t$$

First Hypothesis

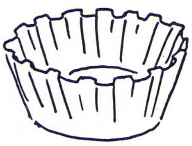
Air resistance is proportional to the speed ($R \sim v$).

If resistance $R \sim v$, then $v_T \sim W$. Then the falling distance

$$d \sim Wt$$

It follows that the double filter of weight $2W$ will fall $2d$ in the same time, a triple filter of weight $3W$ will fall $3d$ in the same time, etc.

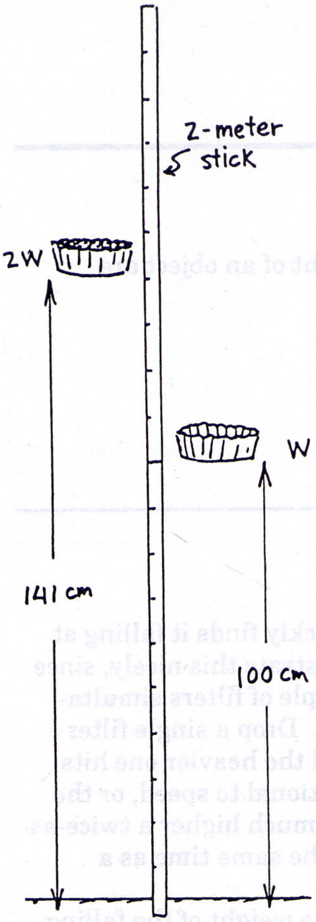
Procedure



Step 1. Drop the single filter from 1 meter above the floor and at the same time drop the double filter 2 meters from the floor. If they land at the same time, the hypothesis $R \sim v$ is confirmed. Drop the filters and see. Do they hit the floor at the same time?

Second Hypothesis

Air resistance is proportional to the speed squared ($R \sim v^2$).



If $R \sim v^2$, then $R \sim W \sim v^2$. Then $v \sim \sqrt{W}$, and

$$d \sim \sqrt{W}t$$

where for two filters, the weight $2W$

$$D \sim \sqrt{2W}t \sim \sqrt{2}\sqrt{W}t \sim 1.4d$$

Procedure

Step 2. Now test a single filter 1 meter above the floor and at the same time drop the double filter 1.4 meters from the floor. If they land at the same time, the hypothesis $R \sim v^2$ is confirmed. Drop the filters. Do they hit the floor at the same time? What is your conclusion? Test it by simultaneously dropping four stuck-together filters 2 meters high and a single filter one meter high.

Analysis

1. What model of friction is confirmed by your experiment?

2. How does air friction vary with speed?