Calc II Rocket Assignment 3: Terminal Velocity and Measuring Drag

Due March 14, 2025

- If you want, you can do this assignment in pairs and submit only one write-up.
- We'll start (and finish?) this in class today (Monday 10 March).

Background: is a force that acts to oppose the motion of a moving object. The direction of the drag force is always opposite to the direction of motion.
The magnitude of the drag force on an object moving at speed v is given by:

$$F_{\text{drag}} = \frac{1}{2}\rho A C_d v^2 \,, \tag{1}$$

where ρ is the density of air (or whatever), A is the cross-sectional area of the object, and C_d is the drag coefficient. We can group all these constants together and write Eq. (1) as

$$F_{\text{drag}} = cv^2 \,, \tag{2}$$

where c is a constant. At terminal velocity, the drag force upward equals the force of gravity (weight) downward:

$$cv_{\text{t}}^2 = mg \,. \tag{3}$$

Rearranging, this equation becomes:

$$v_{\text{t}}^2 = \left(\frac{g}{c}\right) m \,. \tag{4}$$

1. **Set Up:** Get a motion sensor. Go to https://sparkvue.pasco.com/. Get your motion sensor talking to the Sparkvue software. You might have to fiddle around a little bit. Noelle or I can help. Get a feel for how the sensor works by doing a few tests where you move your hand and the sensor records your hand's motion.

2. **Measure a Terminal Velocity:**

   (a) Get a coffee filter. Weigh it.

   (b) Drop it directly above the motion sensor so you get a y vs. t graph. It will take several tries to get reasonable data.

   (c) Once the filter has reached terminal velocity, its y vs. t graph will be linear. Select the linear region and use the linear fit tool in sparkvue to determine the slope of this line. Try this several times. Is v_{t} consistent from trial to trial?

   (d) Start compiling a table of data with the following four columns: Number of filters, total mass m, terminal velocity v_{t}, terminal velocity squared v_{t}^2.

No. of Filters	Mass m	v_t	v_t^2
1			
2			
3			
4			
5			
6			
7			

3. **Grab another Filter** and add it to your current filter(s). Repeat step 2. Repeat until you have around 6 or 7 terminal velocities, each for a different number of coffee filters.

4. **Analyze the Data:**. Type the four columns of data into a google spreadsheet. Then use the spreadsheet to make a scatterplot of v_t^2 vs. m. Hopefully the plot will look approximately linear. I can show you how to do this with google sheets, or you could check out this video: https://www.youtube.com/watch?v=iwIpiea2voI.

   (a) What is the slope of the best-fit line?

   (b) What are the units of the slope?

   (c) What is the R^2 value? This is a measure of the goodness of fit. The closer R^2 is to one, the better the fit.

5. **Calculate c:** Use the value for your slope to determine a value for the coefficient c.

6. **Units?** What are the units for c?