Union College **Spring 2025**

Physics 110
Lab 2: A study of Air Resistance

Names: ____

In lab 2, we made measurements of the motion of a projectile ignoring its interaction with the air. We know, though, that the force of air resistance can be significant, as a sheet of paper falls more slowly than a metal ball. In this lab, you will experimentally determine the strength of the force of air resistance. One interesting (and useful) consequence of air resistance is the concept of **terminal speed**. As a body falls, at some point, it stops accelerating and falls at a constant speed – this is its terminal speed.

1. What is the net force acting on a body that is falling at terminal speed?

2. List all the forces acting on the falling body?

3. Write the Newton's second law equation for this situation.

4. Take a flat-bottom coffee filter, stand on the table top, hold the coffee filter as high up as you can, right-side up, as it would be in a coffee maker. Let go of the coffee filter, letting it drop to the floor, and watch. Does it reach terminal speed? How quickly?

5. Now drop a pack of 4 coffee filters. Does the pack reach terminal speed?

6. Drop one coffee filter and pack of 4 at the same time. Do they reach the ground at the same time? Do they reach the same terminal speed?

7. Considering the answer to #3, what must the magnitude of the force of air resistance equal to in both cases. (There is a measurement that you'll need to make to complete the calculation.)

8. Are the magnitudes of the air resistance forces the same?

9. The very instant after you let go of the coffee filter, when its speed is zero, what is the force of air resistance?

10. Considering the answer to #9, does the force of air resistance depend on the body's mass?

11. Why might the strengths of air resistance forces in the two cases be different? What parameter(s) differ(s) in the two cases that could have an effect on the force of air resistance?
Hint: Consider your own experience with air resistance. Imagine sticking your hand out of the window in a moving car and consider when the force on your hand is larger?

The Experiment: Work in groups of 2 or 3.

- Select a single coffee filter and measure its mass.
- Start by dropping the filter from the ceiling to the floor and measure the time it takes to fall from 1 meter to the ground. Repeat this step 5 times.
- Stack 2 coffee filters (one inside the other), and repeat the drop process (taking five measurements) to get an average drop time for the stack.
- Do the same for stacks of 4 and 8 filters.

Analysis:

The goal is to determine, empirically, how the force of air resistance depends on the velocity of the falling object. Since most laws of physics involve power laws, we start with the assumption that

$$F = (\text{some numbers}) \times v^{p},$$

where p is the "power" index of the speed in the drag force of air resistance equation. The goal in this lab is to determine the value of p. A clever way to determine this power is to make a log-log plot, that is, plot log(F) on the y-axis and log(v) on the x-axis. Taking the log of both sides of the equation above, and applying some rules of logarithms we get:

$$\log(F) = \log[\ (\text{some numbers}) \times v^{p}\ ]$$
$$\log(F) = \log(\text{some number}) + \log(v^{p})$$
$$\mathbf{\log(\mathit{F}) = \log(some\ number) + \mathit{p}\log(\mathit{v}).}$$

Note that this is the equation of a straight line: $y = mx + b$, where the slope (m) equals the power index (p) of the velocity. So, if the force of air resistance is indeed a power-law, the plot of log(F) vs. log(v) should be a straight line AND the slope of that straight line equals the power index of velocity.

1) Use Excel to make a plot of log(F_{air}) vs. log(v):
- make a column to calculate F_{air} (= mg) for each run,
- make a column of values equal to log(F_{air}) and another column of values equal to log(v),
- insert a plot with log(F_{air}) on the y-axis and log(v) on the x-axis.

2) Do the data fit a straight reasonably? If so, then your first conclusion is that the relationship between F_{air} and v is indeed a power law.

3) Fit a "linear" trendline (select "show equation on chart"), read the slope from the equation and set that equal to the p.

4) Do the following in Excel to perform a regression analysis to obtain *the uncertainty* in the slope:
- Go to a cell and type =LINEST(*y* data, *x* data, TRUE, TRUE)
- Select the columns of data for the x axis and y axis data (these will go into the first two entries of LINEST).

In the new chart that appears, the slope, y-intercept, and their uncertainties are the four numbers in the lower left corner.