3.1: Background Material

Text References

- free-body diagrams
- Newton's 2nd law
- air resistance

Improving Time Measurements

In many labs throughout the 9-series, we will need to measure the time interval between two events. Starting and stopping timers is rife with human error. To see the problem, consider what we have to do in this lab. We will be measuring the time it takes an object to fall a known distance. For some of these drops, the time span will be less than one half of a second. This means that if an error as little as one-tenth of a second is made, then the measurement is off by more than 20%. So how do we fix this problem?

The answer to this rests in our pockets. With a smartphone, we can make a decent-quality video recording of the fall of the dropped object. This video can be slowed to frame-by-frame, to determine the moment at which the drop and landing occurred. How do we measure these moments? When making the video, place a running stopwatch (another smartphone, or a laptop, if larger numbers are needed) in the frame. No need to start or stop it at the exact moment of the drop/landing, just pause the video at the appropriate frames after the recording and read the two times off. In this manner, the time of an event can typically be measured with an accuracy range smaller than ±0.03s.

Terminal Velocity and Mass

As discussed in the text reference on air resistance, a special case arises when an object's falling speed is fast enough that the drag force equals the weight of the falling object. With these oppositely-directed forces equal in magnitude, we have:

$$F_{drag} = mg \tag{3.1.1}$$

Since the drag force depends upon the speed of the object, this equation implicitly results in a relationship between the terminal velocity and the mass of the object (there are other factors involved as well, but we will focus on mass and hold the others constant). Most scientific references of the relationship between drag force and velocity indicate that it typically varies between linear ($m \propto v$) and quadratic ($m \propto v^2$). What decides between these two is complicated, but it can be experimentally determined.