3.2: Activities

Things You Will Need

- a stopwatch that measures hundredths of seconds (like found on a smartphone)
- a meter stick or ruler (or really, just a length of string roughly $20cm$ long)
- a light object that exhibits the effects of air resistance as it falls (though not *too* much – no feathers!):
  - should require no less than about $0.6s$ and no more than about $1.0s$ to fall a distance of about $1m$ from rest
  - should be easy to release quickly/cleanly, and should not drift too much side-to-side
  - examples: coffee filter (flat side down), cotton ball, under-inflated balloon (or inflated zip-lock bag), crumpled tissue paper (this should be a last resort, as its air-resistance properties can change during the course of the experiment if the "degree of crumple" changes (such as if it unravels between runs).

The Problem

It is well-known that an object dropped from rest near the Earth's surface with negligible air resistance will fall a distance as a function of time given by the equation:

$$y = \frac{1}{2}gt^2 \tag{3.2.1}$$

A physics paper written by a classmate seeks to determine the equation of motion that applies when air resistance *isn't* negligible. The author of this paper argues that the opposing force of air resistance reduces the downward net force on the falling object. Then, according to Newton's 2nd law, a smaller net force results in a smaller acceleration. Since the constant g in the equation above assumes acceleration due to a net force that is only due to gravity, we can simply replace this constant with a smaller value (which we will call k) to account for the smaller net force. You classmate therefore proposes that the equation of motion for an object in free fall from rest under the influence of both gravity and air resistance looks like:

$$y = \frac{1}{2}kt^2 \tag{3.2.2}$$

where k depends upon details specific to the falling object, such as its density and its cross-sectional area.

Your task is to perform an experiment that either confirms or refutes this thesis, and if it is confirmed, compute the k-value of the item used in your experiment.

Data Collection

The procedure here is straightforward: Drop an object from several known heights, measure the time elapsed for each journey, and use the best-fit-line method with error bars to draw conclusions. Here are some suggestions that should help you achieve reasonable results:

- Perform at least 5 drops from each height, so that the uncertainty (standard deviation) of the time elapsed for each height can be computed.
- If you "spaz" during a time measurement and know you have made a mistake, there's no reason that you need to keep that data point. But don't keep trying over and over to get close to what you think is about the right value! There *is* supposed to be some uncertainty, after all. [*It generally works better if you don't look at the timer at all, and focus on the falling object – then you know if you made a good measurement without tainting your opinion by seeing the actual number.*]
- Perform drops from 6 different heights, with the lowest being about 1 meter (there is no need for precision on this, since we are looking for a functional dependence as the heights change). The other heights should be equally-spaced by about $20cm$, so that the highest drop height is about 2 meters. The easiest way to mark these heights is on a wall with tape or a light, erasable pencil mark.
- There is uncertainty in both the drop height and the time of drop, but the latter much more significant (you can measure the height accurately to within about $1cm$, which is $\leq 1\%$ of the total height, and time uncertainties will be a much larger percentage). For this reason, you do not need to include error bars for the height variable on the graph – treat height measurements as "exact."
- This lab is designed to be performed in the very basic manner described above (and works very well that way), but if you have the resources and are so inclined, you are free to greatly reduce the uncertainties by having someone assist you by taking video

of the dropping process (with a stopwatch running in the video).

Data Analysis and Additional Discussion

1. Create a table of your data.
2. Use the data in your table to compute the standard deviations for each data point.
3. Plot the points and error bars on a graph.
4. If you find it is possible to sketch an acceptable best-fit line, do so. If you cannot, sketch a line that shows an acceptable best-fit line is not possible. Draw a conclusion about the author's theory.
5. Assume for a moment that the theory is correct. In this case, what physical properties of the system do the slope and intercept of the line represent?
6. Discuss any issues that you feel need to be addressed regarding the physics behind this experiment. If you find that the theory is confirmed, this is your opportunity to explain why it had to be so, and if you find that it is refuted, you can explain the theory's fatal flaw.

Lab Report

Download, print, and complete this document, then upload your lab report to Canvas. [*If you don't have a printer, then two other options are to edit the pdf directly on a computer, or create a facsimile of the lab report format by hand.*]