On the Descent of Balloons[1]

Fall 2023

Tasks 1 and 2 are to be completed before coming to lab.
Show your instructor your work as soon as you come into lab.
1 point will be deducted from your grade if these tasks are not completed beforehand!

Introduction

In class, you studied systems moving under the influence of a time-independent net external force (that is, a net force that does not change with time). We treated an object falling near the surface of the Earth as an example of such a system; gravity was the only force acting on the object (recall that we neglected air resistance in our studies). We found that the acceleration, a of the object does not depend on time, and its position, z as a function of time, t can be modeled by the following equation:

$$z(t) = z_o + v_o t + \tfrac{1}{2} a t^2 \qquad \text{(Eqn. 1)}$$

where z_o is the initial position of the object and v_o its initial component of velocity. If the object is released from rest from a height h above the ground (see *Figure 1*), Equation 1 simplifies to:

$$h = \tfrac{1}{2} g t_{tot}^2 \qquad \text{(Eqn. 2)}$$

Here, t_{tot} is the total time it takes for the object to fall distance h.

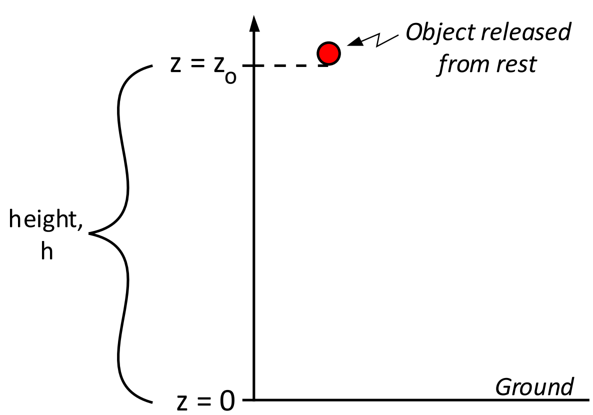

Figure 1: An object released from height, h above the ground.

[1] *Adapted from Physics Education, November 2005, Vol. 40, pp. 550-555, by Tim Erickson and Eric Ayars*

Task 1: Show how to get Equation 2 from Equation 1 for this situation.

Task 2: Let's do a thought experiment (this will help you gauge whether you understand Equation 2, which is crucial for Task 3). Let's say you record how long it takes for a **brick** to fall to the ground from different heights, and then, you plot h as a function of t_{tot}^2 (that is, h is on the y-axis and t_{tot}^2 is on the x-axis), what kind of trend do you expect to see in your data (linear, quadratic, or cubic)? Be sure to explain your answer.

→ If you put a linear fit through your data points, what value do you expect to get for the slope of the line?

Task 3: You have been contracted by *SpaceY* to study the mock-up of a system that they intend to use to deliver payload from the atmosphere of the Earth to the ground. They want to know if they can use Equation 2 to model their system. So, your job is to determine if their system follows Equation 2 as it falls to the ground. If it does not, they want you to speculate on why the behavior of their system deviates from the model.

- Design an experiment to test whether their system can be modeled with Equation 2. The materials available to you are the following: the mock-up system which is a balloon (due to proprietary reasons, *SpaceY* is hiding the actual details of their system but are confident that the balloon approximates it well) and a meter stick. Please ask your instructor if you need anything else. Think carefully about what you will plot on the y-axis and on the x-axis, and what fit you will use through your data points to determine if the mock-up system obeys the model described by Equation 2.

- Additional notes:

  a. We can provide you with a rudimentary stopwatch, but since they tend to be unreliable you may use the stopwatch app on your smartphone.
  b. Feel free to use any additional functions of your smartphone that you feel might improve the quality of your data.

- Make sure that you follow normal laboratory procedures. Use the skills, analysis and record keeping techniques (for example, making a proper table to store your measurements) you have been practicing all semester.
  a. Give an introduction.
  b. Make a sketch of your experiment that defines your variables.
  c. Briefly describe your experiment and how you collect your data.
  d. Include a data table.
  e. Include your calculations and graphs.
  f. Plot your data as it is collected.
  g. Restate and discuss your results, as well as any sources of error. **Be sure to explain whether the system can be modeled by Equation 2 or not. Use your data and graphs to justify your conclusion.**
  h. Attach Tasks 1 and 2 to your journal when you hand it in.