On the Descent of Balloons: A Theoretical Perspective[1]

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Introduction

Below you will find an excerpt from a paper detailing a theory about free-falling balloons. Your job is to read the paper below and devise an experiment that will allow you to test the theory and determine its validity.

On the descent of balloons: a theoretical perspective

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Abstract. Balloons fall more slowly than rocks in most situations. We present an extension to the traditional Newtonian view of objects to include free-falling balloons.

We consider a balloon filled with ordinary air that is roughly spherical, with a diameter of about 25 cm and a mass between 3.0 g and 4.0 g. If you drop a balloon, it will fall.

It has been observed, however (Galileo and Snerd 2008), that if you drop a rock and a balloon simultaneously from the top of a tower, the rock lands first.

Evidently air resistance slows the balloon more than the rock. We suggest that its effect is greater because the balloon is lighter.

Our reasoning is this: Each air molecule, on impact, imparts a small force to a falling object. Using the traditional force formula $F = ma$ (Newton 1687), we see that each collision effectively reduces the gravitational acceleration of any object falling through air by an amount that is inversely proportional to that object's mass (i.e. $a = F/m$). Thus the light balloon is slowed more than a comparably sized (and heavier) rock. Therefore we should modify the formula for the distance s fallen in time t. Instead of the traditional

$$s = \tfrac{1}{2} g t^2 \qquad (1)$$

where g is the acceleration of gravity, we suggest that the correct model for falling balloons is

$$s = \tfrac{1}{2} k t^2 \qquad (2)$$

where k is a constant acceleration smaller than g. Though the truth of our theory seems self-evident, we await confirmation from experiment.

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

Experiment

1. Your job is to design an experiment to test the theory in the description above. Use the skills, analysis and reporting techniques you've been practicing all semester. The materials available to you are the following: a balloon, a timer (which you will tape to the bottom of the balloon), a piece of cardboard and a meter stick. Please ask your instructor if you would like to use anything else. Some additional notes:

    a. Place the piece of cardboard on the floor as a target for the balloon and timer to hit. This produces a less-jarring impact than the balloon striking the floor directly, and keeps the timer from breaking.
    b. Tape the timer *sideways* to the bottom of the balloon. This will prevent the timer button from hitting the floor, which resets the time.
    c. Start the timer as follows: press and hold the button on the timer, and then release the button at the same time you release the balloon. The timer will stop when it hits the ground. Record the time and then press the button one more time to reset.

2. Make sure that you follow normal laboratory procedures
    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 theory is valid or not AND WHY using your data and graphs to justify your conclusion.**