New York City College of Technology
The City University of New York

Kinematics: Speed and Acceleration

Laboratory activity description
Physics Department
Physics PHYS 1433, PHYS 1441, Summer session, 2020.

Introduction

In this lab activity, you will determine the average speed and acceleration of a paper plane that you make out of a letter-size (or similar) piece of paper, and analyze the sources of experimental uncertainty.

In the lab you will do the following:

1. Design an experiment to measure the paper plane speed when it flies in the air and the plane acceleration when you launch it;
2. Make a paper plane, launch it, and following your designed experiment, collect data.
3. Identify sources of experimental uncertainty;
4. Calculate the mean value for the speed of the plane and the plane acceleration; calculate the uncertainty of these values.

Materials you need:

- letter-sized (or similar) paper
- stopwatch
- tape measure (or ruler and tiled floor).

Some ideas:

1) How to make a paper plane – you can find here: https://www.diynetwork.com/made-and-remade/learn-it/5-basic-paper-airplanes . Pick any design you like.
2) Stopwatch. You can use a stopwatch on your phone, or you can google “stopwatch online”.
3) Tape measure or ruler. You can use same tool as you use before in the lab “measurement and density”. With a tiled floor you can measure the size of one tile and then count tiles.

Theory

Kinematics:
You can use the general kinematics theory learned in the class. Specifically, the linear uniformly accelerated motion equations considered in the class provide enough theoretical background for this lab.

Data analyses:
If you have N measurement results for the speed, the *average* speed is calculated as

$$\bar{v} = \frac{1}{N}\sum_{i=1}^{N} v_i$$

For example, if you measured the speed three times (N=3) and the results are v_1, v_2 and v_3, the average speed is

$$\bar{v} = \frac{v_1 + v_2 + v_3}{3}$$

The *uncertainty* of the results can be evaluated via the standard deviation *s* (see, e.g., this Wikipedia page https://en.wikipedia.org/wiki/Standard_deviation):

$$s = \sqrt{\frac{\sum_{i=1}^{N}(v_i - \bar{v})^2}{N-1}}$$

If, as in the previous example, the results of your measurements were v_1, v_2 and v_3, the standard deviation is

$$s = \sqrt{\frac{(v_1 - \bar{v})^2 + (v_2 - \bar{v})^2 + (v_3 - \bar{v})^2}{2}}$$

In this case, the speed is reported as the average value plus/minus the standard deviation,

$$v = \bar{v} \pm s \ \ (m/s)$$

Lab Assignment

This is a group activity. Please work in groups to complete the lab assignment. In this specific lab, each group submit only one report per group.

1. Make a paper plane out of a piece of paper.
2. Launch it. Practice a little bit – you need a place flying along an approximately straight line.
3. Collaborate with your group to design an experiment to measure the speed of a flying plain.
4. Each person in your group makes three measurement of the speed. Document all measured data and calculations that give you the result.

5. You combine the results of the speed from your group as a single data set. For example, if your group is three students, and each student measures three times, you have nine measurements.
6. Organize your measurement as a table (you design the format of the table).
7. Find the average speed of the flying plane and the standard deviation from this data set. Report your result in the form “the average value plus/minus the standard deviation”.
8. As a group, design a measurement that enables you to determine the acceleration of the plane in the launch phase. In other words, what is the acceleration of the plane when you launch it?
9. Each student in the group makes three measurement to determine the plane acceleration during the launch. Document all measured data and calculations that give you the result.
10. Again, combine the data from each student from your group in a single table, find the average acceleration and its standard deviation. Report your finding in the form “the average value plus/minus the standard deviation”.
11. Analyze possible sources of experimental uncertainty in your measurements.
12. Write and submit the report for this lab activity.

Report

Only one report per group is needed. The report should describe your designed experiments, obtained data, calculations, analyses of experimental uncertainty, and conclusions. A photo of a plane or a sketch is an advantage. Submit your report via Blackboard. At the beginning of your report, list all names of the students who contribute to the report.

This lab activity is design by Dr. Kolmakov based on the ideas of Ref. [1].

1. F. Moosvi, S. A. Reinsberg, and G. W. Rieger, “Can a Hands-On Physics Project Lab be Delivered Effectively as a Distance Lab?”, International Review of Research in Open and Distributed Learning, Vol. 20 (1), 21-42, 2019.