PHYSICS
LAB 2
SP211

2D Kinematics

I. Introduction

NOTE: Take a straight edge (ruler), colored pencils, an eraser, and a parallel (rolling) ruler with you to laboratory. Although a laptop is not required to complete this lab, use of an Excel spreadsheet will simplify the calculations and thus improve your ability to complete this lab on time. Ask your instructor if he/she wants you to bring your laptop too.

Galileo (1564-1642) figured out that you can “weaken” the effect of gravity if you perform experiments on an inclined plane.

In this laboratory, we will construct a motion diagram for 2D motion with an approximately constant acceleration. The resultant value of the acceleration will then be compared with a value predicted using the acceleration of gravity and the geometry of the system.

In other words, we will draw a motion diagram for the trajectory of an air puck on an inclined air table, and use the diagram to analyze the puck’s parabolic motion.

Your instructor will show you how to operate the air table and take the data.

Analyzing your data will be much like the pre-lab homework assignment (if assigned), but nonetheless will be explained in the instructions later.
II. Objectives

At the end of this activity, you should:

1. Be able to create a 2-D motion diagram and fully annotate it.

2. Be able to prove that the acceleration of an object on an inclined plane (the air puck) = \( g \times \sin(\theta) \) within uncertainty.

3. Be able to discuss the relationship between the velocity vector and the acceleration vector.

4. (Optional based on your instructor) Be able to use an Excel spreadsheet and specifically the Excel function "Linest," a powerful linear regression tool.

III. Needed Equipment

We will be working with an inclined plane which is the square table (tilted up at the back) shown in the next picture. Two-dimensional motion occurs if an object is given an initial velocity with a horizontal component. The moving object will be one of the pucks shown in the picture. The puck is connected to an air source that blows through the puck and enables it to "float" above the flat table.

![Inclined Plane Diagram](image)

The puck is also connected to an electrical source that is capable of causing sparks at equal time intervals. The sparks are activated by pushing down on the control pad shown in the picture below the front of the table. Most importantly, by placing white paper above a piece of carbon paper on the table, the sparks will leave a mark on the white paper indicating the position of a moving puck at equal time intervals. Consequently the first part of a motion diagram, points that represent the position of an object at equal time intervals, will be created for us by the equipment.

IV. Turn in your Pre-lab/homework problem if assigned.
V. Discussion

Your instructor will demonstrate how to operate the air table and take the data.

**WARNING!** In order to avoid getting an electrical shock, do NOT simultaneously push on the pad and touch a puck. Instead first launch the puck and then quickly operate the pad.

VI. Procedure

A. Preliminary Data: Measure the angle of inclination for the table by measuring the height of the edge of the air table as a function of distance along the edge. Draw a figure, and do the calculations in a spreadsheet. If directed by your instructor, use of the Excel function “Linest” could greatly simplify your calculation.

B. Experiment 1: Motion Diagram for an air puck on inclined air table.

B1. Take data as described by your instructor in the discussion.

B2. **Note:** Draw lightly so you can erase errors easily. Once your motion diagram is complete, you can go back over your work and draw neatly and legibly. (This is the way professional drafts people do it.)

Construct first the vertical axis, then the horizontal axis, and then number your points. Number the highest point on your trajectory #6, for reasons that will become clear as you continue working.

B3. We wish to use the theorem for Uniformly Accelerated Motion that says that the velocity at the mid-instant of a time interval is equal to the average velocity over that interval. Point #6 occurs at the mid-instant of the interval between points #5 and #7, so the instantaneous velocity at point #6 is equal to the average velocity over the time interval between points #5 and #7.

Use your rolling ruler to measure the length of the displacement vector between points #5 and #7, but don’t draw it there! The length of this displacement vector is proportional to the average velocity, which, in turn, is equal to the instantaneous velocity at point #6. Roll your ruler over to point #6, and draw that displacement vector with its tail at point #6.

Without lifting the rolling ruler off the paper, draw an exact copy of that vector with its point about 1/4 inch from the vertical axis; this will be the first element of your acceleration diagram.
Note that the velocity vector points in the same direction as the displacement vector, and is proportional to the displacement, the proportionality constant being one over the time interval. So we can use the displacement vectors to represent the velocities, as long as we keep the proportionality constant in mind.

B4. Repeat the instructions in Paragraph B3 for points #4 and #2, and also for points #8 and #10, EXCEPT draw the exact copy vectors with their TAILS exactly on the TAIL of the copy of vector $\vec{V}_6$; in this way, you will build your acceleration diagram.

B5. Use your rolling ruler to draw the x- and y-components of each of your five displacement vectors. If friction is truly negligible, then the x-components should all be the same.

Is the horizontal component of the puck’s velocity constant, or do you see evidence of friction? Be sure to answer this question in your conclusion.

B6. Return, now, to the acceleration diagram: Since this is Uniformly Accelerated Motion, the differences between one velocity vector and the next will be proportional to the acceleration.

Draw the difference vectors in another color.

C. Experiment 2: Analysis of Motion Diagram.

1. Do the analysis suggested in the email attached Excel spreadsheet; you may use the format as provided, or improve it. Use your spreadsheet results to address the following points in a paragraph or two.

   a. Is horizontal component of velocity constant? What is the percent spread in the horizontal component data?

   b. Is the acceleration constant? What is the percent spread in the acceleration data?

   c. Is the acceleration vertical?

   d. Does your measurement of the acceleration agree with $g \sin \theta$?
VII. Lab Report to Hand In:

A. Motion Diagram from Part B above. Write the names of all of your lab partners on your motion chart.

B. Spreadsheet from Part C with discussion form Part C on the back.

VIII. Clean-Up

A. Golden Rule: “Do unto others as you desire them to do unto you.”

This applies as much here in the lab as it does in the Fleet. As future Naval Officers, how can you expect your enlisted sailors to maintain a clean work area if your stateroom, work areas, mess area, etc is a “pig sty?” So as officers it is imperative that we clean up after ourselves not only to follow the Golden Rule, but also to lead by example for the enlisted personnel under our charge.

1. End of Lab Checkout: Before leaving the laboratory, please tidy up the equipment at the workstation and quit all running software.

2. The lab station should be in better condition than when you arrived and more importantly, should be of an appearance that you would be PROUD to show to your legal guardians during a “Parents Weekend.”

3. Have your instructor inspect your lab station and receive their permission to leave the Lab Room.

4. You SHALL follow this procedure doing every lab for BOTH SP211 and SP212!

Many thanks to Dr. Huddle for his assistance in producing this Laboratory procedure; specific references can be supplied on request. LCDR Timothy Shivok