ÇANAKKALE ONSEKIZ MART UNIVERSITY

DEPARTMENT OF PHYSICS

GENERAL PHYSICS LABORATORY MANUAL AND WORKBOOK

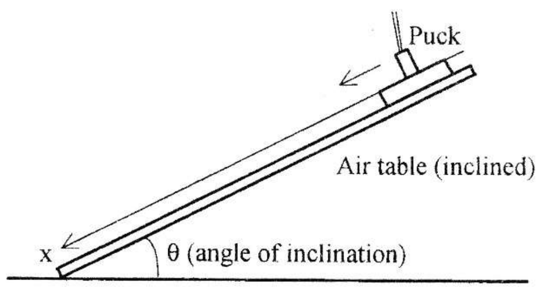
EXPERIMENT 2
STRAIGHT LINE MOTION WITH CONSTANT ACCELERATION AND MOTION IN A PLANE

PURPOSE

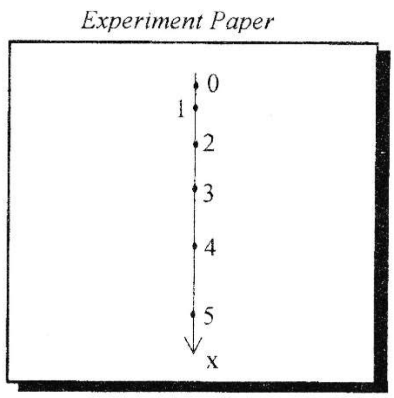
The purpose of this experiment is to study and analyze the straight line motion with constant acceleration, and to find this acceleration of a puck moving on an inclined air table. The motion of a horizontally projected puck on the inclined air table also will be studied and analyzed.

THEORY

In this experiment, we will consider the motion of a puck, moving in a straight line in such a way that its velocity changes uniformly. Consider an air table whose backside is raised to form a smooth inclined plane as shown in Figure 2.1a. If we put a puck at the top of the incline and allow it to move down, we observe that the puck moves in a straight path, but the dots produced on the datasheet are no longer evenly spaced, as shown in Figure 2.1b. This means that the velocity of the puck increases as it goes down the incline. If the velocity of the puck changes with time, we say that it has acceleration. Just as the velocity is the rate of change of the position, acceleration is the rate of change of the velocity.



(a)



(b)

Figure 2-1. (a) The set up for the puck, moving down on an inclined air table. b) The dots produced by the puck on the datasheet.

Note that, the positive x-axis is taken to be in the direction of the puck's motion. The type of motion that you observe is straight-line motion with constant acceleration.

Suppose that at time t_1 the puck is at point A and has velocity v_1 and that at a later time t_2 it is at point B and has velocity v_2. The average acceleration of the puck in the interval Δt is defined as:

$$a_{avg} = \frac{\Delta v}{\Delta t} = \frac{v_2 - v_1}{t_2 - t_1} \tag{2.1}$$

Similar to the definition of the instantaneous velocity the instantaneous acceleration of the puck in the x-direction is:

$$a = lim_{\Delta t \to 0} \frac{\Delta v}{\Delta t} = \frac{dv}{dt} \qquad (2.2)$$

The acceleration is also a **vector quantity** and is always in the direction of Δv. Suppose that at the time t_1=0, the puck is at position x_0 and its velocity is v_0, and at a later time t_2=t it is at position x and has velocity v. If the acceleration of the puck is constant, the average and instantaneous acceleration are equal to each other, and therefore we find,

$$a = \frac{v - v_0}{t - 0} \qquad (2.3)$$

or,

$$v = v_0 + a.t \qquad (2.4)$$

The expression for the position x of the puck is a function of time and it can be written as

$$x = x_0 + v_0 t + \frac{1}{2} a t^2 \qquad (2.5)$$

where x_o=x(t = 0) is the position of the puck at t = 0.

This equation may is easily be checked by taking to derivative dx/dt and comparing it with the equation for the velocity v. If the puck starts from rest (v_o = 0), then its position at any instant of time is given as

$$x = x_0 + \frac{1}{2} a t^2 \qquad (2.6)$$

Therefore if the graph of x versus t^2 is plotted, we obtain a straight line that has a slope 1/2a and intercept x_0. If, x_0 =0, then this straight line will pass through the origin.

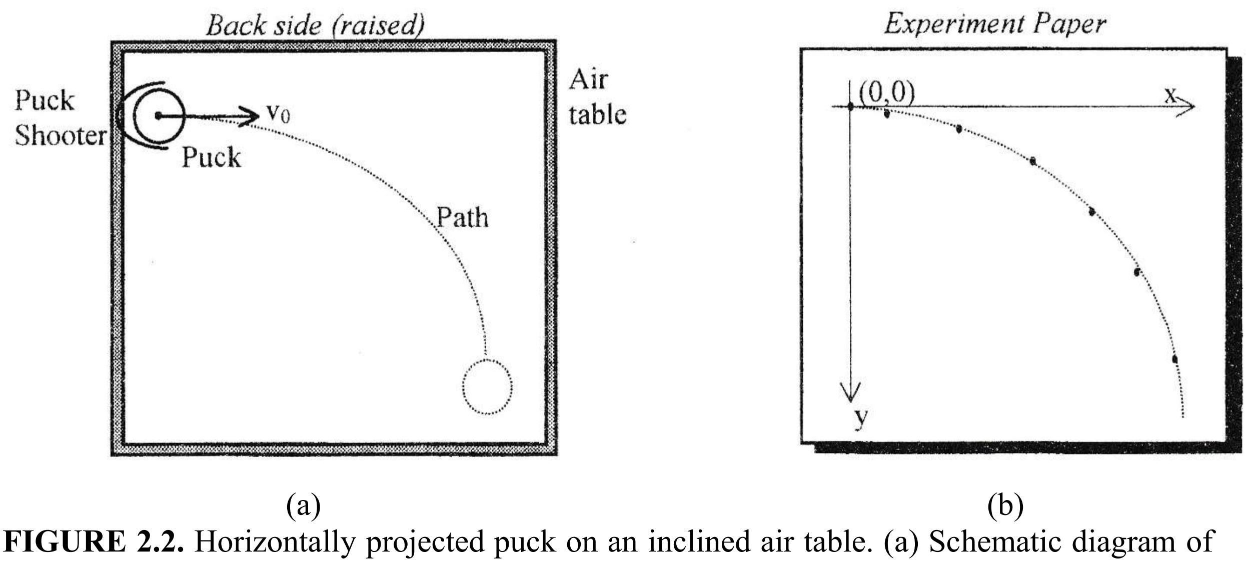


FIGURE 2.2. Horizontally projected puck on an inclined air table. (a) Schematic diagram of the trajectory. (b) The data points, produced by the puck on the datasheet.

The other type of motion that we are going to investigate in this experiment is the motion of a horizontally projected object.

Here, the puck is projected horizontally with an initial velocity $v_0 = v_{0x}$ as shown in Figure 2.2a. The dots produced on the datasheet will look like those shown in Figure 2.2b. In order to analyze the motion, we will investigate the motion of the puck along the horizontal and the vertical axis independently. For this purpose, we draw the x and y-axes as shown in Figure 2.2b taking the first dot as the origin. The positive direction of the y-axis is taken downwards. If we project the x and y-components of each dot to the axes, then this will look as in Figure 2.3.

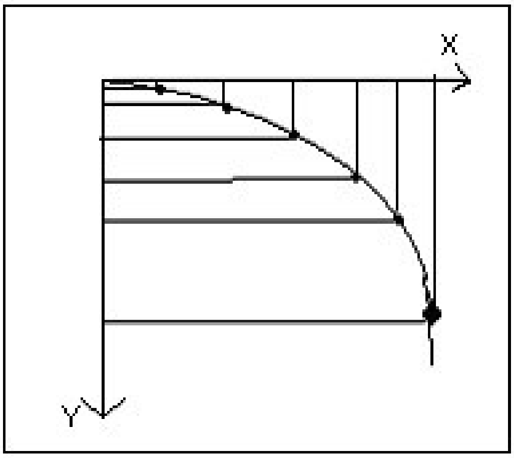


FIGURE 2.3. The projection of the dots on the datasheet along the x and y-axes.

Note that the intervals between the x-projections of the dots are equal, meaning that the motion in the horizontal direction is just a straight line motion with constant velocity. In other words, the x-component of the velocity of the puck is constant. As for the motion along the y-axis, note that the distance between the y-projections of the puck increases with time. This situation is identical to the one we encountered earlier. The acceleration of the puck along the y-axis is the acceleration of a puck released to fall from rest down the same inclined air table. Therefore, quantitatively, the motion along the x-axis will be given by the equations

$$v_x = v_{0x} \tag{2.7}$$

and

$$x = v_{0x}.t \tag{2.8}$$

As for the motion along the y-axis, we have

$$v_y = a.t \tag{2.9}$$

and

$$y = \frac{1}{2}at^2 \tag{2.10}$$

If we eliminate the time t in Equation 2.10 using Equation 2.8, then we get y as a function of x and v_{ox} :

$$y = \frac{1}{2} a \left(\frac{x}{v_{0x}}\right)^2 = \frac{a x^2}{2 {v_{0x}}^2} \tag{2.11}$$

This is the equation of a parabola that passes through the origin in the x-y plane, which is indeed the shape of the trajectory of the puck.

EQUIPMENT

An air table, a puck shooter, wooden blocks, a ruler, millimetric graph paper.

PROCEDURE

This experiment has two parts, both of which will be carried out using the inclined air table. One side of the datasheet will be used at the time. First, level off the air table, and then tilt it to an inclined position by using the wooden block. Note that the value of the inclination angle ϕ is written on the wooden block. Keep one of the pucks at rest over the carbon paper at the lower right corner of the air table. In both experiments, only one puck will be used.

PART A: STRAIGHT LINE MOTION WITH CONSTANT ACCELERATION

1. Put the puck at the top of the inclined plane of the air table. Activate only the (P) switch. Check that the puck falls freely down on the plane. Set the spark timer frequency. Put the puck at the top of the inclined plane. Put the (P) and (S) switches on top of each other and activate them simultaneously. Take your foot off the switches after the puck reaches the bottom of the inclined plane.
2. Remove the datasheet from the air table and examine the dots produced on it. Have your data approved by your instructor. Take the trajectory of the puck as the positive x-axis. Number the data points starting from the first dot as 0, 1, 2, …, 5. Take x = 0 and t = 0 at the first dot, and measure the distance of the remaining four dots from the dot 0. Also, determine the time t for each of these dots. Fill in your data in Table 2.1, along with their corresponding measurement errors.
3. Using the data in Table 2-1, plot x versus t^2 graph. Draw best and worst lines, and find the acceleration ($a \pm \Delta a$) of the puck.

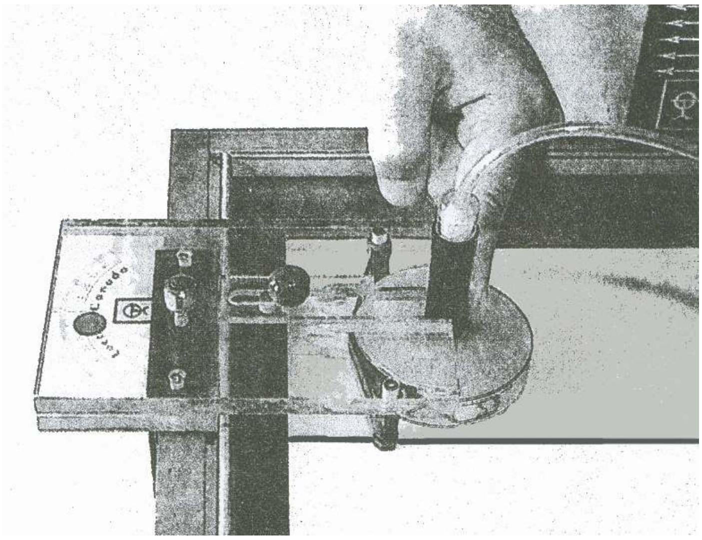


FIGURE 2.4 Adjusting the shooter on the edge of the inclined air table.

PART B: HORIZONTAL PROJECTION

1. Use the other side of the data sheet in this part.
2. Keep one of the pucks stationary by placing it on a folded piece of paper at the lower right corner of the inclined air table.
3. Attach the shooter to the left side of the inclined plane of the air table about 10 cm from the upper edge, and adjust the shooting angle to 0 degrees.
4. Activate only the (P) switch and place the puck into the shooter, and make a few test shots to adjust the tension in the rubber belt of the shooter to give a convenient trajectory
5. Now activate the (P) switch and place the puck into the adjusted shooter, then release it while simultaneously activating the S switch to trigger the spark timer. Keep the switches on until the puck comes to the bottom of the datasheet and then release your feet from them.
6. Before removing the datasheet, place the puck outside the shooter, and activating both the P and S switches simultaneously, make it slide freely down the inclined plane.
7. Now take the datasheet from the air table, and examine the trajectories. You should get something like the trajectories illustrated in Figure 2.5. Denote the two trajectories by A and B as in the figure. If your data points are inconvenient for analysis, make another run and get new data.
8. Circle the data of both trajectories, and starting from the first dot, number them as 0, 1, 2, 3, …, 5, etc.

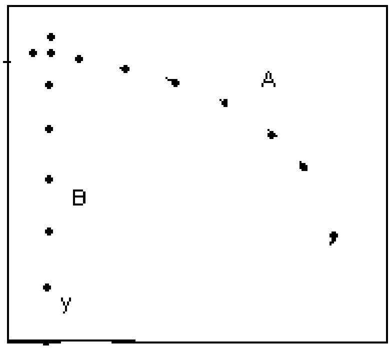


FIGURE 2.5 The dots on the datasheet.

9. Draw the x and y-axes for trajectory A. This can be done by first drawing a line parallel to the trajectory B that passes through the first dot of the trajectory A. This line will give the y-axis. Then draw a horizontal line perpendicular to it from dot 0 to have the x-axis. Take the positive y-direction to be downwards.
10. Now, draw lines from each dot of trajectory A that are normal to the x and y-axes to get the x and y-projections of these dots. What type of motion does the puck have along the horizontal and vertical axis?
11. Measure and record the time of flight t_f (The total time that elapsed during the motion of the puck), and the range R of the projectile (the horizontal distance traveled during the motion). Using R and t_f find the projection velocity v_{0x}.
12. Starting from dot 0 of trajectory A, measure the distance from the y-projections of 5 data points from this point. Determine also the time corresponding to each of these points. Record your results in the left margin of Table 2.2. Also, measure and record the distances of the dots in trajectory B from dot 0 along with the corresponding times. Record these in Table 2.2.
13. Taking y to be the distance of dot 5 from dot 0, use Equation 2.10 to find the accelerations a_A and a_B for both trajectories A and B. Compare these with the acceleration you obtained in Part A of this experiment.

ENGINEERING FACULTY
DEPARTMENT OF ENVIRONMENTAL ENGINEERING
Year: 2021-2022 Semester: Fall

Course Name: ENV-1021 – **General Physics Laboratory**

EXPERIMENT 2: STRAIGHT LINE MOTION WITH CONSTANT ACCELERATION AND MOTION IN A PLANE EXPERIMENT REPORT

INSTRUCTOR'S NAME & TITLE:						SIGNATURE:		EXAM DATE:
STUDENT'S NAME/SURNAME: STUDENT ID #:						SIGNATURE:		EXAM DURATION:
Question								TOTAL POINT:
Point								
Prog. Outcomes	**PO1,2**							

REPORT OF EXPERIMENT 2: STRAIGHT LINE MOTION WITH CONSTANT ACCELERATION AND MOTION IN A PLANE

Name-Surname:

Student No:

Group:

Laboratory and Examination Rules:

1- The most important thing in the laboratory is your safety. The dangers mostly result from a lack of knowledge of the equipment and procedures.
2- Personal safety rules must be obeyed with extreme discipline.
3- When you enter the laboratory never play with the equipment until it has been explained and the instructor has given permission.
4- Keep your experimental equipment and tabletop clean.
5- Report any accident to your instructor immediately.
6- Most of the equipment used in the laboratory is expensive and some of them are delicate. Even after you are familiar with the equipment, always have your experimental setup checked and approved by the instructor before putting it into operation.
7- If any of the equipment is broken or does not function properly, report it to the instructor.
8- Read and study the experiments before you come to the laboratory.
9- It is forbidden to share the questions and answers of this assignment on the internet or in another environment.
10- Students must answer the assignment by themselves. It is forbidden to do the assingment with others or to get help from others.
11- **Write your name and surname and student number and sign your signature on the top right of each answer page.**

RESULTS AND DISCUSSION

PART A: STRAIGHT LINE MOTION WITH CONSTANT ACCELERATION

1. How do the dots you've got in this experiment differ from those you got in experiment 1?
……………………………………………………………………………………………
…………………………………………………………………………………………

2. What type of motion did you have in each of these experiments?
………………………………………………………………………………………………
……………………………………………………………………………………….

3. Fill in your data in the table below. Report your measurements with the correct number of significant figures and include the errors.

TABLE 2.1

Dot Number	$x \pm \Delta x$ (cm)	$t \pm \Delta t$ (sec)	$t^2 \pm \Delta(t^2)$ (sec^2)
0			
1			
2			
3			
4			
5			

4. In the space provided below show how to find the error $\Delta(t^2)$ in t^2 for only one data point.
………………………………………………………………………………………………
……………………………………………………………………………………….

5. Using the data in Table 2.1, plot x versus t^2 graph on a linear graph paper. In the space provided below report the slopes of the best (m_B) and worst (m_W) lines of the x versus t^2 graph.
   m_B = ……………………..cm/ sec^2
   m_W = ……………………..cm/ sec^2

6. Find the acceleration of the puck along with its error from the slopes and record it with the correct number of significant figures.

$a \pm \Delta a =$ …………………..cm/sec^2

PART B: HORIZONTAL PROJECTILE

1. What kind of motion does the horizontally projected puck have along the x and y-axes? Explain your answer.
………………………………………………………………………………………………
……………………………………………………………………………………….

2. Report t_f and R.
   t_f= …………..sec.
   R=……………cm.
3. Calculate the projection velocity $v_0 = v_{ox}$.
   V_0 = ……………………..cm/sec.
4. Record your measurements for the trajectories A and B in the table below. Report them with the correct number of significant figures and errors.

TABLE 2.2

	Trajectory A (y-projection)		Trajectory B	
Dot Number	$y \pm \Delta y$ (cm)	$t \pm \Delta t$ (sec)	$y \pm \Delta y$ (cm)	$t \pm \Delta t$ (sec)
0				
1				
2				
3				
4				
5				

10. Using Equation 10, and taking y is the distance of the fifth point, find the accelerations a_A and a_B, and report them with the correct number of significant figures. Compare these two accelerations and compare them with the acceleration you found in Part A.

a_A = ………………………cm/sec^2
a_B =………………………..cm/sec^2

11. Write down any comments related to the experiment, and/or elaborate on and discuss any points.

………………………………………………………………………………………
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