Physics 12 Informal Parabolic Motion Lab (2-D)

Parabolic Motion on a Frictionless (almost ..) Inclined Plane

Problems/Questions addressed in this lab:

- Investigate parabolic motion in 2-D: horizontal (x) and vertical (y) components of motion are investigated separately
- Interpret graphs of *position vs time*, *velocity vs time*, and *acceleration vs time* for an object accelerating at a constant rate (both horizontal and vertical components).

Materials:

- Air table apparatus (f=20.0 Hz)
- 3 pieces of mm rule graph paper

Useful Equations:

* ***Percent error calculation:*** This equation is used when comparing a measured value to a widely accepted value

$$\%\text{ error} = \frac{(\text{measured value - accepted value})}{\text{accepted value}} \times 100\%$$

* ***Percent difference:*** This equation is used when comparing two measured values -

$$\%\text{ difference} = \left| \frac{x_1 - x_2}{\frac{x_1 + x_2}{2}} \right| \times 100\%$$

Lab Procedures:

1. Set up the air table so that the x component is parallel to the ground (horizontal) and the y component

2. Record the angle that the inclined air table makes with the horizontal _______________

3. Launch and release the air puck as demonstrated by your teacher. You will obtain a spark record of the trajectory of the puck.

4. Complete the data tables provided, and answer all graphing and analysis questions.

<u>Data Table #1 – Horizontal Position “d_x” (m) vs. Time “t” (s)</u>

Total time elapsed (s)	**Horizontal Position d_x (m)**
0.00	0.00
1/20 s	
2/20 s	
3/20 s	
4/20 s	
5/20 s	
6/20 s	
7/20 s	
8/20 s	
9/20 s	
10/20 s	
11/20 s	
12/20 s	
13/20 s	
14/20 s	
15/20 s	
16/20 s	
17/20 s	
18/20 s	
19/20 s	
20/20 s	

A. **DRAW THE *Horizontal Position vs Time* GRAPH:** Use the information on **Data Table #1** to plot the graph of ***Horizontal Position “d_x” (m) vs. Time “t” (s) of an Air Puck on an Inclined Plane*** (plot *horizontal position* on the y axis, and *time* on the x axis)

B. Analysis of *Horizontal Position vs Time* Graph:

a. Determine the slope of the line of best.

b. What variable does the slope of this graph represent?

c. Develop the equation of the graph in the form $y = mx + b$

d. Does the graph support projectile motion theory? Explain. *(compare the expected, theoretical, shape of the graph with the actual shape of the graph)*

Data Table #2 – Data for the Vertical Component of Motion

NOTE: The raw data you collect for the puck includes only position and time. Through mathematical analysis of the position and time data, you will determine the average velocity of the puck within each time interval between sparks. This is the same as the instantaneous velocity of the puck midway in time between the position data points collected.

1. First, choose a spark near the beginning of the spark chart to serve as t = 0.00s. You will use a total of 21 sparks, so choose the t = 0.00s spark so that the next 20 sparks include the peak of the parabola (you need to include some sparks before and some after the peak).

2. Use your t = 0.00s spark to position the horizontal baseline of your spark chart. Carefully draw the horizontal baseline across the width of the spark chart (use a ruler or meter stick).

3. Carefully measure the vertical position of each spark (“d_y”). Measure the vertical distance from the baseline to the spark, along a line perpendicular to the baseline. Write the value in the column titled “d_y” (*Column 2).*

4. Determine the vertical displacement (Δd_y) during each time interval. To do this, subtract the position at the beginning of the interval (d_{yi}) from the position at the end of the interval (d_{yf}). Write these values in *Column 3.*

5. Calculate the average velocity in each time interval $v_{ave} = \Delta d/\Delta t$ (for the time interval) *(Column 3 divided by Column 4*). Plot these values in *Column 5.*

**** ***Note:*** *For an object accelerating at a constant rate, the average velocity in a time interval equals the instantaneous velocity (v_{inst}) of the object at the midpoint in time within the interval. When you plot the points on the Vertical Velocity vs Time graph, you must plot the instantaneous velocities midway in time between the data collection time (i.e. the average velocity of the puck between 4/20 s and 5/20 s equals the instantaneous velocity of the mass at 4.5/20 s.*

Column 1	*Column 2*	*Column 3*	*Column 4*	*Column 5*	*Column 6*
Time (s)	**d_y (m)**	**Δd_y (m) = d_{yf} - d_{yi}** *[during each interval]*	**Δt (s)** interval	**v_{inst} (m/s)** $v_{ave} = \Delta d_y / \Delta t$	**Time (s)** *[midpoint of interval]*
0.00	0.00	////////	////////	////////	////////
////////	////////		1/20		0.5/20
1/20		////////	////////	////////	////////
////////	////////		1/20		1.5/20
2/20		////////	////////	////////	////////
////////	////////		1/20		2.5/20
3/20		////////	////////	////////	////////
////////	////////		1/20		3.5/20
4/20		////////	////////	////////	////////
////////	////////		1/20		4.5/20
5/20		////////	////////	////////	////////
////////	////////		1/20		5.5/20
6/20		////////	////////	////////	////////
////////	////////		1/20		6.5/20
7/20		////////	////////	////////	////////
////////	////////		1/20		7.5/20
8/20		////////	////////	////////	////////
////////	////////		1/20		8.5/20
9/20		////////	////////	////////	////////
////////	////////		1/20		9.5/20
10/20		////////	////////	////////	////////
////////	////////		1/20		10.5/20
11/20		////////	////////	////////	////////
////////	////////		1/20		11.5/20
12/20		////////	////////	////////	////////
////////	////////		1/20		12.5/20
13/20		////////	////////	////////	////////
////////	////////		1/20		13.5/20
14/20		////////	////////	////////	////////
////////	////////		1/20		14.5/20
15/20		////////	////////	////////	////////
////////	////////		1/20		15.5/20
16/20		////////	////////	////////	////////
////////	////////		1/20		16.5/20
17/20		////////	////////	////////	////////
////////	////////		1/20		17.5/20
18/20		////////	////////	////////	////////
////////	////////		1/20		18.5/20
19/20		////////	////////	////////	////////
////////	////////		1/20		19.5/20
20/20		////////	////////	////////	////////

A. Vertical Position "d_y" vs Time "t" Graph:

a. DRAW THE GRAPH: Vertical *Position "d_y" (m) vs Time "t" (s) of an Air Puck on an Inclined Plane*. On the y-axis plot "Vertical Position" (data from Column 2). On the x-axis plot "time", using the values from *Column 1.*

b. Analysis of Graph: Determine the instantaneous velocity at *t = 15/20 s*. At *t = 15/20 s*, draw the tangent to the curve. Calculate the *slope of the tangent*.

c. Does the graph support projectile motion theory? Explain. *(compare the expected, theoretical, shape of the graph with the actual shape of the graph)*

B. Vertical *Velocity "v_y" (m/s) vs Time "t" (s) of an Air Puck on an Inclined Plane*.

a. DRAW THE GRAPH: On the y-axis plot "Vertical Velocity" (data from Column 5). On the x-axis plot "time" (*Column 6).*

b. Does the graph support projectile motion theory? Explain. *(compare the expected, theoretical, shape of the graph with the actual shape of the graph)*

c. Analysis of the Graph: Equation of the line, and acceleration

i. Calculate the slope of the *vertical velocity vs time* graph (with correct units).

ii. Write the equation of the graph in the form $y = mx + b$

iii. Use the equation developed in (ii) to calculate the velocity of the puck if it had continued in the same state of motion until t = 30/20 s.

iv. Use the equation developed in (ii) to calculate the time at which the vertical velocity of the puck would be $v_y = -50.0$ *m/s*, if it had continued in the same state of motion.

v. The slope of the velocity vs time graph represents the acceleration of the puck. The accepted value for the acceleration of an object on a frictionless inclined plane is:

$\boldsymbol{a = g\sin\theta}$ (where g = 9.80 m/s^2).

a. Use the measured angle of incline of the air table to calculate the *accepted value* of the acceleration: $\boldsymbol{g\sin\theta}$ = ________________

b. Use the slope of your graph and the accepted value of acceleration to calculate the percent error of your results (your slope).

c. Analysis of the Graph: Determining Vertical Displacement from a *v vs t* Graph

i. The most direct method for determining total vertical displacement is to subtract initial position (d_{yi}) from the final position (d_{yf}), at t = 20/20 s.

$$\Delta d_y = d_{yf} - d_{yi} = \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_$$

ii. Another method for determining displacement is to calculate the total area under the *velocity vs time* graph (this is useful in cases when you have velocity data but do not have position data). For you graph, calculate the area from t = 0.00s to t = 20/20 s (with correct units!). Area above the baseline is positive in sign, and area below the baseline is negative in sign.

iii. Calculate the percent difference between the displacement calculated in (i), and displacement calculated in (ii) by the "area under the graph" method.

d. **Sketch** the shape of the *acceleration vs time* graph

e. Sources of Error: Describe and explain the sources of error associated with this lab. Why might there be a discrepancy between your measured values and the accepted values? (explain)