Physics 3A Lab ◒ Accelerated Motion in 1-Dimension

Name ______________________________ Instructor OK ______

This lab will be completed in a JuypterLab notebook with all calculations being performed using Python and text will be in Markdown. Once the notebook is complete, please export an HTML version of the notebook and add that to your repository as well. When you push your repository to GitHub, be sure that both the *.ipynb* and *.html* versions are included.

INTRODUCTION

In this experiment we shall analyze motion in 1-dimension. We will consider a body accelerating at a *nearly constant rate* down a nearly frictionless slope to test a hypothesis originally proposed by Galileo.

MOTION WITH UNIFORM GRAVITATIONAL ACCELERATION

Galileo was the first physicist to systematically study accelerated motion. He concluded that, in the absence of air resistance, all bodies accelerate *vertically* under the influence of gravity at *exactly the same rate*,

$$\mathbf{a} = \mathbf{g} = 980.0 \text{ cm/s}^2 \qquad \text{Vertical Motion}$$

independent of their weight. On the other hand, a body placed on a *horizontal* frictionless surface has NO acceleration,

$$\mathbf{a} = \mathbf{0} \qquad \text{Horizontal Motion}$$

What will happen to a body placed on a sloping surface, like that shown below, which is neither vertical (**a** = **g**) nor horizontal (**a = 0**)?

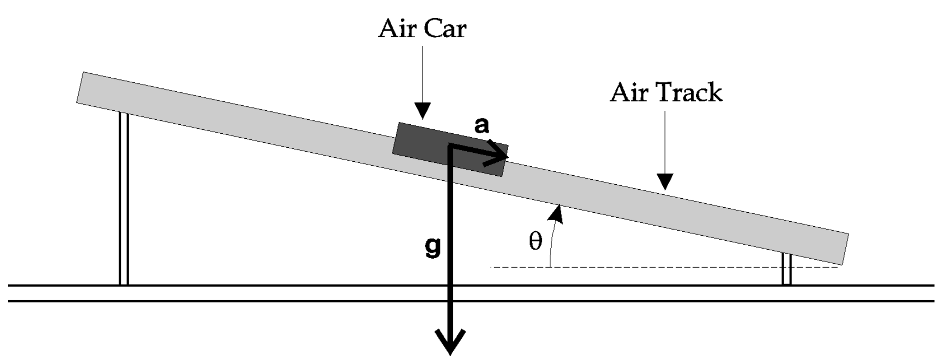

Figure 1: Geometry of air track inclined at angle θ. **a** is the acceleration of the air car down the track. **g** is the vertical acceleration of gravity.

It seems reasonable that such a body will accelerate at a rate somewhere between **0** and **g**, the exact value depending on the SLOPE of the surface. A detailed analysis led Galileo to the prediction:

$$a = g \sin\theta$$

where θ is the angle between the slope and the horizontal. We will test this hypothesis in today's experiment by measuring the acceleration of an air car on a nearly frictionless air track inclined at various angles.

PROCEDURE:

1. Watch the introduction video by Tim McKnew to become familiar with the operation of the air track and video analysis software, Tracker. Then watch the data run video which shows the raw video of a run followed by the Tracker analysis of it. The data video also includes each run's height, h.

   Links:
   Data run video
   https://www.youtube.com/watch?v=tKaLO0VD7wA

   Introduction video
   https://www.youtube.com/watch?v=PSRaSouIm6M

2. Obtain a value for the acceleration of gravity in the lab.

   g = ________________ cm/s²

3. The air track is lifted under one leg by a certain height h. The distance between the legs on the air track is exactly 100.0 cm. Based on this information, calculate the angles of inclination of the air track. $\sin(\theta) = h/100$. A small error in calculation will make a big difference in the accuracy of the results.

Run Number	Height, h (cm)	Angle, θ

4. The video analysis produces motion data in columns as time t, position along the track x, position perpendicular to the track y, and velocity along the track v_x. Make a copy of the Accelerated Motion Data Google Sheet. For all four data runs, make a plot of x versus t. Sketch the plots below. Describe the motion shown in two of the plots, especially any features. [Hint: use the data video to help!]

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5. For ***EACH ANGLE***, do ***ALL*** of the following:

   a. Record your precise angles in the table below.

   b. Use Galileo's equation to calculate a theoretical acceleration, $\mathbf{a_{th}}$, for each angle. Enter them into the table.

   c. Plot a graph of **v** vs **t** below the plot of x vs t. Add a linear trendline to the velocity plot [Customize -> Series -> check "Trendline" and under Label -> "Use Equation"]. Study both plots to determine a reasonable range of values over which to perform a linear fit on the v vs t data. Adjust the data range of the velocity and time data.

   d. Use the linear trendline equation to determine the average acceleration of the air car. Enter the experimental value of a_{exp} into the Table. Calculate the % error of the experimental value of **a** from the **a** predicted by Galileo's theory.

   e. If the % error is large, summon your instructor for *immediate help*.

Results for Acceleration on Inclined Air Track				
Run	θ (º)	$\mathbf{a_{th}}$ (cm/s^2)	$\mathbf{a_{exp}}$ (cm/s^2)	% Error
Level track				N/A
1st angle				
2nd angle				
3rd angle				

6. For a level track the acceleration should be **zero**. How do you account for the difference between theory and measurement, if any? How could this affect your later results?

7. Have your work checked by your instructor.

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QUESTIONS TO ANSWER:

1. How do your measured accelerations compare with the theoretical ones? Are they consistently high or low? Can you explain the discrepancies between the values?

2. Testing certain values of Galileo's prediction

(a) Show that Galileo's hypothesis gives reasonable results for acceleration in the limiting cases of a horizontal air track and a vertical air track.

(b) At what angle would you get an acceleration equal to ½ g?

3. Suppose the acceleration, *a*, of the air car in this experiment was not actually constant. How could you tell this from your graphs of *v* versus *t*? What would the graphs look like if *a* were decreasing? Increasing?

4. It is often stated that Galileo never actually **measured** the acceleration of a body falling vertically but always used an inclined plane at a relatively shallow angle. Considering the technology available in his time, why might he have done this?

5. On the basis of your measurements, how valid is Galileo's hypothesis?

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