LAB 4: The Air Track as an Inclined Plane*

Note: You will write up this lab in a report. You must record all your data in your lab book, but you do not need to answer the questions posed in the lab in your book. You should answer them in your report.

Equipment List:

air track, blower, blower hose and power cord glider one digital photogate and one accessory photogate flat plastic accessory box four or five different riser blocks Vernier calipers

Purpose: To investigate the acceleration of an object on an incline with almost no friction.

Introduction: You will calculate the acceleration of a body on an inclined, near-frictionless plane (the glider on the air track) from measurements of distance and time, assuming the acceleration to be constant. This is the experimental acceleration. Then, from finding the angle of inclination of your track (using trigonometry), you will find a theoretical acceleration. Then you will compare the two accelerations for agreement using two methods: a discrepancy test (percentage difference) and by investigating whether the theoretical acceleration falls within the most probable range of experimental values, by finding a standard deviation.

Theory:

- 1. Derive an equation that gives the acceleration a_t of a body down an inclined plane given the angle of the inclined plane, θ , and g.
- 2. From kinematics, derive an equation that yields the acceleration of a body in terms of the distance it travels and the time it takes, assume a zero initial velocity. You will need this equation to calculate the acceleration a_c of the glider along the track.

Procedure: You will repeat the following steps 5 times at different angles to allow you to plot a graph.

1. Set up your air track equipment following the procedures in the "Introduction to the Air Track" document. This experiment uses the air track as an inclined plane, so with all of the air track's feet on the table you should level your air track coarsely to begin with, but do not spend a very long time on this.

^{*}Based on the lab by Prof. Newton.

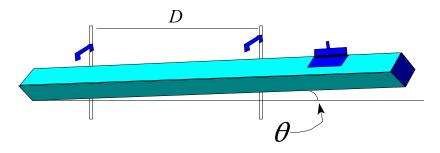


Figure 1: The air track setup with photogates and glider, inclined at an angle θ .

- 2. Using some combination of the small riser blocks provided, raise the end of the air track that has one foot only (the other end has two feet) about one or two centimeters.
- 3. Experiment to determine good placement of the photogates when one end of the track is elevated. Place the two photogates as far apart as possible. Measure the distance between the two photogates. To measure this distance, use the leading edge of the glider and record the position of the glider as it triggers each photogate. To see if the photogate has been triggered, check the red LED on the top of the photogate arm. Subtract the position of the glider at each photogate and you will have the distance between the two photogates.
- 4. The timer should be set to PULSE mode, and have the resolution switch set to 1 ms (use the 0.1 ms setting only if the time the glider is between the photogates is less than two seconds). The memory switch should be turned on so that the small red LED next to the switch is lit. The number on the LCD display is always the time measured in **seconds**. When the photogate is set in this way, it will record the time from when the first photogate beam is blocked until the second beam is blocked.
- 5. Put your glider on the track so that its flag is *just* above the first photogate beam. Release your glider from rest so that its velocity through the first gate is zero. Record the time the glider is between the two photogates from the photogate timer.
- 6. Repeat the same procedure for a total of five trials. This will allow you to calculate five accelerations which, in principle, should all be the same. Of course, due to random fluctuations the accelerations will not be identical. In this lab, calculate the uncertainty using the statistical method. This means you should find the standard deviation of the 5 accelerations (n = 5), and treat that as your absolute uncertainty:

$$\delta a = \sigma_a = \sqrt{\frac{\sum_{i=1}^n (a_i - \bar{a})^2}{n}}$$

The average (or mean) acceleration, \bar{a} , is your best value for the acceleration. You can use your calculator to calculate the standard deviation, but write the formula in your lab book, and make clear notes about what you are doing.

7. Calculate the angle of the plane using trigonometry. One method is to measure the distance between the two feet (it should be very close to one meter) and measure the height of the riser block (use the vernier calipers). The ratio of these two distances (be

careful to use the same units for both) is equal to what trigonometric function of the angle? Using $g = 9.8 \text{ m/s}^2$, you can calculate the "theoretical" acceleration. Treat this acceleration as an exact value with no uncertainty.

Analysis: Compare your two accelerations using a discrepancy test. If the discrepancy is less than 10% that is good. If it is more than 15%, you need to look for a mistake in your calculations and measurements. Did the theoretical acceleration fall within the most probable range of the experimental, *i.e.* within one standard deviation of the best experimental value?

Graphing Analysis: Repeat steps 3-7 for four more angles (four more risers or combinations of them) for a total of five different angles and 25 timing runs. Using a computer, plot the experimental values of the acceleration on the *y*-axis (it is the dependent variable) against the sine of the angle ($\sin \theta$, the independent variable) on the *x*-axis. Calculate *g* from the slope of this straight line graph. Use the "trendline" feature to have the slope of the best-fit line (the computer will use linear regression) printed on your graph. Also have the computer print the correlation coefficient, *r*, on your graph. The closer r is to 1, the more the better your data fits to a straight line. A correlation coefficient of exactly 1 means your data is exactly linear. What does it mean physically if your *y*-intercept is not zero?

Conclusion: Discuss methods that would minimize the discrepancy calculated in the "analysis" section. Which value of the acceleration would you expect to be larger most of the time due to systematic errors? See if you can discover any systematic errors and suggest ways in which they could be eliminated or at least minimized. What other experiments could you do with this equipment? In what ways could you extend your experimental investigations of masses on inclines? What else might you study?