College Physics 201
Constant Acceleration

Materials: Large air track with glider, air supply and stopwatches.

1 Purpose

Study the motion of a glider with (i)constant velocity (zero acceleration) and (ii)constant but non-zero acceleration. Emphasis is placed on analyzing data by using linear graphing techniques and also comparing an experimental result to a predicted value.

2 Theory

The nature of the gravitational acceleration can be investigated by the use of an inclined air track, glider, and a stopwatch. In this laboratory, the experimenters will work together to gather information on the motion of an air track glider on a level air track and a slightly inclined air track. The data will then be analyzed using linear graphing techniques to find the acceleration of the glider for both experiments.

The displacement, Δx, of an object at some point in time, t, that is moving with a constant acceleration, a, and had an initial velocity of v_0 can be determined by using Equation 1.

$$\Delta x = v_0 t + \frac{1}{2} a t^2 \tag{1}$$

For an object sliding down a smooth (frictionless) ramp with inclination angle θ, the net acceleration of the object down the ramp can be calculated by Equation 2.

$$a = g \sin(\theta) \tag{2}$$

Where the gravitational acceleration of an object in free fall ($g = 9.8[\frac{m}{s^2}]$) is scaled by the $\sin(\theta)$ term which will be discussed in lecture. Also see Refs. [1,2].

3 Procedure

Two experiments using a single glider on a ruled air track will be completed. The class will work together to collect data and then split into their usual lab groups to complete the analysis.

3.1 Motion of a Glider at Constant Velocity

A glider will move at a constant velocity along the nearly frictionless air track. Time and position data of the glider will be recorded. For convenience, the track has markings that are separated by ~ 25 [cm]. The specific positions of each mark should be verified and recorded.

1. The instructor will assist in assigning tasks to the different groups for the data collection.

2. For this experiment there needs to be at least 8 timers (preferably 2 per position for redundancy for a total of 16) to collect time data for each position on the air track. Good reaction time and focus will yield good results.

3. Another student will be placed in charge of recording the time results on the whiteboard.

4. One student will be in charge of giving the cart a gentle push to start it moving.

5. Any remaining students will observe the operation.

6. Several test runs should be completed (3 or more is suggested) where the glider is given a gentle push and students will time how long it takes to move from the first mark (this will be $x_o = 0$) to the mark for which they are responsible. Students should discuss their times to verify the results are reasonable.

7. Once students are comfortable with the procedure, perform one (1) data run and record the data in a table on the board. If there are multiple timers per mark then use an average of the collected times from each mark for the analysis.

3.2 Constant Non-Zero Acceleration of a Glider

For this experiment, the glider will be released from rest ($v_{0x} = 0[\frac{m}{s}]$), at the beginning of the track ($x = x_0$) and when $t = 0[s]$. These known and easily reproducible starting conditions constitute a usable data point. Be sure to make the appropriate position measurements so that displacement can be calculated. Since the initial conditions have changed, these displacement data may be different from the previous experiment.

1. The instructor will elevate the air track with a block of wood.

2. Each group will have to determine the angle of the incline via distance measurements and trigonometry. This is much more accurate (and precise) than using the angle measuring equipment we have available.

3. A minimum of 8 timing groups is needed but there can be as many as 9 since we can now use all the marks on the track.

4. The glider is then released from rest from the top of the incline.

5. Each student will start their stopwatch when the glider is released and stop their stopwatch when the glider passes the position for which they are responsible. Another student will record the data on the whiteboard.

6. Since the starting conditions in this part are easily duplicated, this experiment can be reliably repeated. Collect two more sets of data that will then be averaged to ultimately help reduce some of the experimental uncertainty.

4 Analysis

Analyze the data using the following steps. Analysis will be done via EXCEL on your laptop. Make sure you generate nice tables for each data set and that you follow the rules for graphing.

4.1 Motion of a Glider at Constant Velocity

1. Generate a *Displacement* versus *time* plot for the first data set. Perform a linear fit, display the equation (with units) and R^2 value on the plot. Choose 2 points on the fit line (not *data* points) to use and show the slope calculation (by hand) to verify the software–determined value.

2. *Generate the velocity data.* If one assumes a linear change in velocity between data points (e.g. i and j) then the velocity is determined by dividing the glider's *displacement* between two points by the *elapsed time* between those two points. That is: $v_{i,j} = (x_j - x_i)/(t_j - t_i)$

3. *Generate the velocity's time data.* Do this by taking the first data point's time (t_i) and adding 1/2 of the elapsed time between the two points. That is, the time for velocity point $v_{i,j}$ is calculated by: $t_{i,j} = t_i + (t_j - t_i)/2$. Be sure that $t_i < t_j$.

   Note: The average velocity value 'occurs' exactly half way between the two points because we are assuming linearity between adjacent points.

4. Generate the plot of *Velocity* versus *time*. Perform a linear fit, display the equation (with units) and R^2 value on the plot. Verify the software–determined slope value, by hand.

4.2 Constant Non-Zero Acceleration of a Glider

1. In the data table for this second experiment, calculate the average of the measured times for each position on the air track. This helps reduce the data collection uncertainties. Use these averages as *the* 'time' for the plots and calculations.

2. Generate the plot of *Displacement* versus *time* for the second data set. Notice that these data are not linear and therefore a linear fit would be inappropriate.

3. Generate the velocity data, as done in the previous section.

4. Generate the time data associated with each velocity point, as done in the previous section.

5. Generate a *Velocity* versus *time* plot. Perform a linear fit, display the equation (with units) and R^2 value on the plot. Verify the software–determined slope value, by hand.

5 Questions

5.1 Motion of a Glider at Constant Velocity

1. What is the value (with units) of the slope of the *Displacement* versus *time* plot? What is the physical meaning of the slope in terms of the glider system? What is the physical meaning of the y-intercept in terms of this system?

2. What is the value of the slope from the *velocity* versus *time* plot (with units)? What is the physical meaning of the slope in terms of the glider system? What is the physical meaning of the y-intercept in terms of this system?

5.2 Constant Acceleration of a Glider

1. What is the slope of the *velocity* versus *time* plot with units? What is the physical meaning of the slope in terms of the glider system? What is the physical meaning of the y-intercept in terms of this system?

2. Derive an expression for the inclination angle θ of the track in terms of easily measured lengths. Include a diagram that includes clearly labels and identifies the relevant parameters.

3. Calculate the expected (theoretical) value for the glider acceleration down the track using the inclination angle and Equation 2

4. Compare the *measured* to *predicted* acceleration using a percent error calculation.

6 References

1. OpenStax, *College Physics* (2012). Download for free: http://cnx.org/content/col11406/latest

2. Cutnell and Johnson, *Physics*, 8^{th} Ed.