

Lab N: 1-D Motion with Constant Acceleration

Introduction

Being able to describe how objects move when accelerated is fundamental to understanding any physical situation. Galileo very cleverly used an **inclined plane** over 400 years ago to measure the motion of **falling objects**. We will do a similar experiment using modern equipment to address the following questions:

- How does the position of an accelerated object change with time?
- How does an object move under the influence of **gravity**?
- How may we more precisely measure the motion of quickly falling objects?

Pre-Lab Questions

Please answer on a separate sheet.

1. Very briefly explain how a photogate works.
2. How far would you go if you traveled at a speed of 30 miles per hour for 3 hours?
3. What acceleration would be needed to travel the same distance in the same time as in #2 when starting from rest? What would be your final speed?
4. Refer to Figure 3. Given a track length of 90 cm and a height of 18 cm, what is $\sin \theta$?
5. Draw the force diagram for an object on an inclined plane (see Figure 2). What would be the acceleration given the inclination from #4 and $g = 9.8 \text{ m/s}^2$?

Equipment

An **air track** minimizes friction in the experiment by creating a cushion of air between the moving **glider** and the track. All data will be obtained through the **Pasco interface** and recorded, plotted and analyzed on the **computer**.

Photogates record the passage of the glider. The flag on the glider breaks the beam of light in the photogate, triggering the timers in the computer (Figure 1).

You will record the **travel time** of the glider between the starting position and two photogates at a variety of positions along the air track.

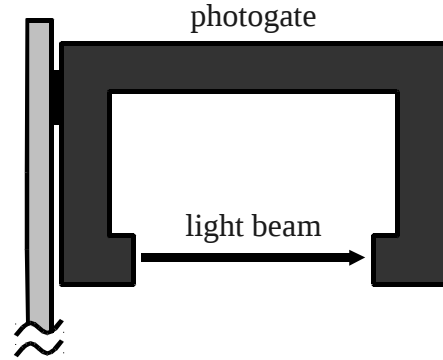


Figure 1.

Theory

The **external forces** acting on an object on an inclined plane are the object's weight, mg , and the normal force, F_N (Figure 2, we will ignore friction for now). The component of the weight perpendicular to the plane and balancing the normal force is $mg \cos\theta$. The **resultant force** on the object is the component of the weight along the plane, $mg \sin\theta$. Therefore, the object moves down the plane with an **acceleration**:

$$a = \frac{mg \sin\theta}{m} = g \sin\theta$$

You will find the acceleration by calculating the glider's speed at the two photogates and using $a = (v_2 - v_1)/\Delta t$, where Δt is the time the glider takes to move between the gates. Furthermore, the glider's position should vary as $x_0 + \frac{1}{2}at^2$.

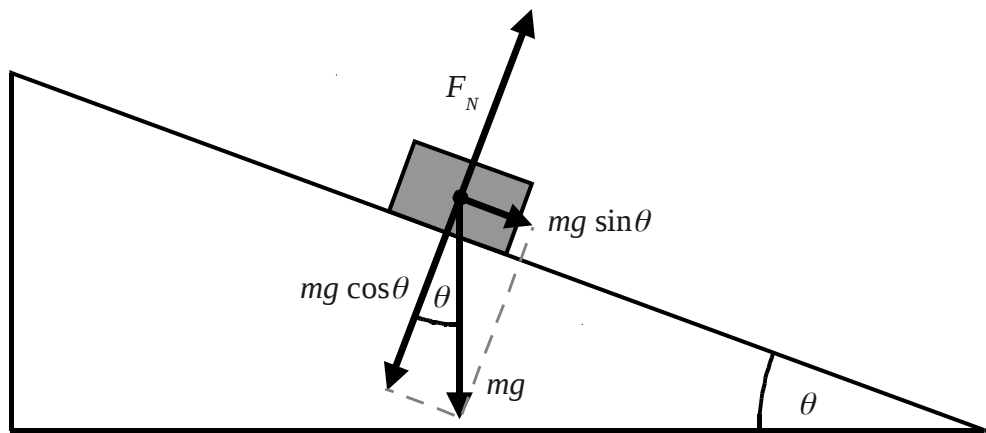


Figure 2.

Procedure

1. Measure the length (m) of the **flag** in the glider twice.
2. Find the value of $\sin\theta$ by measuring the **height** of two points on the air track and the **length, l** , along the track between them (Figure 3).

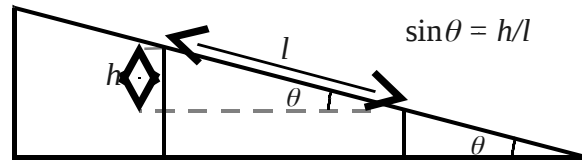


Figure 3.

3. Place the **first photogate** so that it is barely blocked by the back end of the flag when the glider is at the top of the air track. Record the position (m) of the *center* of the glider, x_0 . Take data with the **second gate** at: 0.2 m, 0.3 m, 0.5 m, 0.9 m, and 1.70 m.
4. Turn on the Pasco interface box. Double-click on the **DataStudio** icon on the computer and choose **Create Experiment**.
5. Click on the first digital **channel port** in the image of the Pasco interface and choose the **photogate**. In the Measurements tab check “State, Ch 1” and uncheck all others.
6. Click on the second channel port and choose photogate also. Check “Time in Gate, Ch 2” only and uncheck all others in both Measurement tabs.
7. Click the **Sampling Options** button and choose Delayed Start. Check Data Measurement, which should be State, Ch 1 above 0 V. Click OK. The timer will now start only once the glider moves and the flag no longer blocks the first gate.
8. Drag the line “Time in Gate, Ch 2” in the upper left window to the **Table** line in the lower window.
9. Open a new Excel spreadsheet. Enter values for $\sin\theta$, flag length (m), and x_0 (m). Make **column headings** for Run #, x (m), t (s), dt (s), v (m/s), and a (m/s²).
10. Turn on the **fan motor** and wait a few seconds for the air flow to stabilize. Place the glider at the top of the track. Click **Start** and *then* release the glider. Do not let the glider bounce back up through the second gate. Click **Stop** and put the glider back at the top of the track. Once more, click Start and *then* release the glider.
11. Move the second gate to the **next** position and do two runs. Repeat for all photogate positions. **Record** in the spreadsheet the gate position x (m), the time t (s), and the elapsed time dt (s). If the Table gets crowded, use the Data button to deselect runs.
12. Change the **angle** of the inclined plane, measure the new value of $\sin\theta$, and **repeat** the experiment making two runs at all five photogate positions.

Analysis

1. In the spreadsheet, calculate the **speed** of the glider through the gates using the flag length and elapsed time in the gate. Review your results; how should the speed vary, if at all, with distance down the incline or with $\sin\theta$?
2. In the spreadsheet, calculate the **acceleration** of the glider between the gates in each run using the speed (initial $v = 0$) and the time to the second gate. Review your results; how should a vary, if at all, with distance down the incline and with $\sin\theta$?
3. Calculate the average value of g from a and $\sin\theta$. Review the result; what is the percentage error in your value?
4. Make a chart to **plot** the distance $x-x_0$ (y-axis) versus time squared t^2 , (x-axis) using all the data from all valid runs.

Please save your spreadsheet on the computer. Print the spreadsheet or save it to an external drive to turn in to the instructor.

Questions

Please answer on a separate sheet.

1. How does the position of the glider change with time? How do your results compare with the expectation?
2. Add a **trendline** to your plot (under the Chart menu) using the option to display the equation. Review the result; what is the percentage error in your value given the expected slope of the line? Use the **slope** to calculate an average value of g and compare it to your previous estimate.
3. What is the advantage to measuring falling objects using the inclined plane? (Consider the difference in the experiments using different inclinations.)
4. Would the results of the experiment change if a heavier glider were used? If so, how? If not, why?
5. Does **friction** affect this experiment? If so, how? If not, why?
6. How might this experiment be improved to illustrate better the behavior of falling objects?