One Dimensional Motion – Constant Acceleration

In this lab we examine the motion of an object moving with constant acceleration in one dimension. We use a cart with low-friction wheels running down an inclined plane. We will find the acceleration of the cart using two different graphing techniques. The two values found for the acceleration should be similar, but we don't expect them to be *exactly* the same.

If the acceleration is constant, the following relationship holds
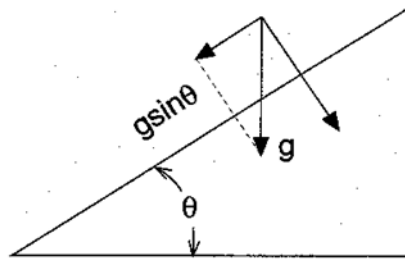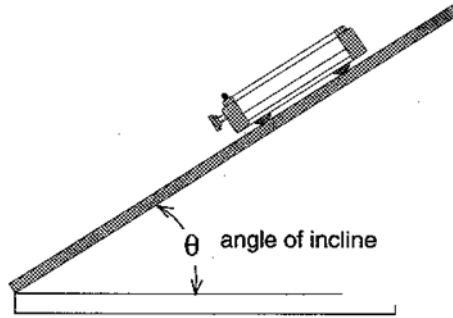
$$\Delta x = v_0 t + \frac{1}{2} a t^2$$

where Δx is the displacement down the incline, v_0 is the initial velocity, a is the acceleration, and t is the elapsed time.

θ angle of incline

If the cart on the incline is released from rest, then $v_0 = 0$ and we can write this equation as:

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

gsinθ

g

θ

This is the relationship we are going to test in this lab.

Experimental Procedure

The experimental apparatus is shown below.   The angle of inclination is greatly exaggerated. The dynamics cart will be placed onto its track at various marks and released from rest. A stopwatch will be used to measure the time it takes for the cart to travel down the track until the front of it reaches the 160 cm mark.

To increase the accuracy of your measurements, consider the following as you perform this experiment:

HYPOTENUSE

HEIGHT OF TRACK

θ
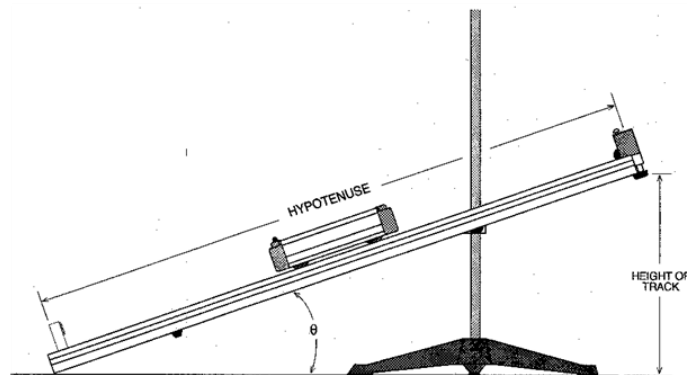
1. Practice. It may look easy, but especially at shorter distances, coordinating the cart release and starting the timer takes a few tries. Whenever, you are performing a new experiment, it is always better to do a few practice runs that you do not count in the experiment. These practice runs will also help point out some difficulties that may not be obvious at first.

2. The cart is not a point. We shall use the front of the cart as our reference point. At the bottom of the track is a bumper which will keep the cart from going off the track. This bumper will stop the cart. Our end reference point will therefore be the 160 cm mark. Time until the cart's front edge passes this point.

3. Even after a few practice runs, measuring one time for each distance is not the most accurate way to conduct this experiment. For each distance, make four runs and record each time. We shall use the average time for each distance in our analysis.

4. The data will be more accurate if the same person who releases the cart also does the timing. Having a second person time while the other releases the cart introduces an additional reaction time to the measurement. However, one person should not take all the data. Have each partner take two of the four data runs for each distance. This will minimize reaction time differences. Having one person do all four for one distance, and the other do all four for the next, could introduce more error in the data. If you have the rare situation of three people in your group, then have each person take two times. Throw out the highest and the lowest times, to get your four times. Your times will have a variation, but the largest time should be within a half of a second of the smallest time.

5. Consider "Significant Digits"! When you use any measuring device, you should record all digits available. When it is time to do calculations, then you should reduce the digits to only use digits that have significance. Your Lab Instructor will help you with understanding this. For the distance measurements, since you have a printed scale on the track that goes to millimeters, you should be able to provide a distance as 100.0 cm rather than 100 cm. The .0 says you saw millimeters but you did not have any.

6. Start with a release point at the 20.0 cm distance and work down to a release point of 110.0 cm at the end. Recall your finish line is 160.0 cm. Since, as you work towards a travel distance of 50.0 cm, your times will get shorter and therefore harder to measure, you will be gaining experience before you get to these smaller times. If there is an obvious problem with a data run, such as friction on a wheel, or an error starting the timer, you may throw the run out and do another one. Do not discard a run because you don't think the time is right unless you have the gap greater than the one-half of a second between the largest and smallest times as mentioned previously.

In Excel all members of the lab group should create a new workbook save it with a name something like "PH 201 1D motion Lab.xlsx" Your name and date of the work should be on the worksheet. The upper left corner makes a good place. Then create a table with headings Such as:

PH 201 1D	Motion Lab					
D.W. Donovan	Jan 17 2023					
	Distance Δx	time t_1	time t_2	time t_3	time t_4	Average t
	(cm)	(s)	(s)	(s)	(s)	(s)
	140.0					
	130.0					

Obviously, you would have rows going down to a distance of 50.0 cm

Experimental Analysis

We will create three graphs to analyze the motion of the cart. You will be learning to use EXCEL to create these plots. Your Lab instructor will explain how to use the program, how to have the program do the calculations, and how to produce the graphs with the required formats we used in the Hand Graphing Lab in Week 1 of PH 201. While the data gathered was done with your lab group, each member of the lab group must produce and turn in pages from the EXCEL program on their own laptop. **Printed graphs should each be full page plots.** You should also provide a printout of your workbook pages as used. Note: as with a graph, your workbook pages should also have **your name and the date** of the work on them. The upper left corner of the workbook page is probably the most reasonable. For this experiment since you are going to create one larger table, you can make a single workbook printout. If you had a different table for each graph, you should print out the Workbook work for each graph you print out.

Graph #1 – Δx vs t

First plot Δx versus t (Δx on the vertical axis and t on the horizontal axis) and see what the relationship looks like. If the data agrees with the theoretical relationship, the plot should be a parabola. You should be able to verify that the plot is not straight.

Create the graph, ensuring that it has the required elements: a title, your name, the date, axes labeled with the name, symbol, and units of the variable, etc. Since the data does not form a straight line, **do not include** a best-fit line through the data.

Graph #2 – Δx vs t^2 – Linearize by Powers

To determine constants in equations we want to linearize the equation. So, we will first use the powers technique. Since the basic equation is

$$\Delta x = \frac{1}{2}at^2$$

Plotting Δx on the y axis and t^2 on the x axis. Then the slope will be $\frac{1}{2}a$. We can find a using

$$a = 2(Slope)$$

Add a new column to your data table now

Average t	Time Squared
(s)	t^2 (s^2)

Let EXCEL calculate the time squared. Then plot as mentioned above. This time put in a trendline. Reformat the trendline to change y and x to a and t^2 also add units where appropriate to the numbers. On the worksheet provide the required derivations and the values. Also, printout the full-page graph.

Work out the steps (type them in the Worksheet where directed to) to show how the acceleration is determined from the Slope and/or the Y-intercept. Determine the acceleration and you will compare it to the value you get in the next analysis.

Graph #3 – Logarithmic Analysis

Using a logarithmic analysis, we can obtain a straight-line graph in another way. We will then be able to compare the acceleration obtained by our two methods. The instructor will review how the logarithmic analysis works. Use the space provided on the worksheet to write down the steps. The starting point is the guess for the equation relating the two variables:

$$\Delta x = \frac{1}{2}at^2$$

Once again on the Worksheet for the lab, type out the steps to find the acceleration from the Slope and/or the Y-intercept. The first step of the logarithmic analysis is always to take the natural logarithm of both sides. After a few lines of algebra, you should end up with the equation

$$ln(\Delta x) = 2ln(t) + ln\left(\frac{1}{2}a\right)$$

By comparing this with the standard equation of the line you can determine acceleration a.

To create a graph of $ln(\Delta x)$ versus $ln(t)$, you will need new columns in your data table, with columns for the values of $ln(\Delta x)$ and $ln(t)$. Note that for the logarithmic function, the answer has no unit. So, for example, if you want ln of 0.33 meters, you have ln(length /meter) = ln(0.33) = -1.12, with no units. You should note a "unit" of ln(m) so that when you do analysis back to get an acceleration you know if you used meters or centimeters originally. Here are suggested columns for the table. You should already have the left two columns. Please add the right two columns.

Average t   Time Squared   Ln(Distance)   Ln(time)

(s) t^2 (s^2)   Ln(Δx), Ln(cm) Ln(t), Ln(s)

Let EXCEL calculate the logarithms. Then plot as mentioned above. This time put in a trendline. Reformat the trendline to change y and x to $\ln(\Delta x)$ and $\ln(t)$ also add units (these will be ln(units) where appropriate to the numbers. On the worksheet provide the required derivations and the values. Also, printout the full-page graph and workbook page.

Work out the steps (type them in the Worksheet where directed to) to show how the acceleration is determined from the Slope and/or the Y-intercept. Determine the acceleration and you will compare it to the value you got in the previous analysis.

Comparisons!!

First, as asked for in the Worksheet find the percent difference between two accelerations.

Finally, as indicated in the second picture above, the acceleration down the plane should be in the absence of friction $a = g \sin(\theta)$. Use the angle meter provided and measure the angle and calculate the acceleration. Now compare that to the average of your two found accelerations.

Complete the Worksheet inserting prints of plots and workbook as appropriate.