Constant Acceleration Lab

Directions and Suggestions for Teacher

Purpose:

This lab is designed to give students experience modeling the motion of an object that is accelerating at a constant rate. They will collect data for an object moving with a constant acceleration down an inclined plane and then use the data to create a graph or graphs. Once they have their graphs they will use the graph(s) to create a mathematical model and then use the model to make predictions. This lab should probably be completed early in the school year and will help serve as a template to how labs will be conducted and used throughout the year.

I have always done this lab before I have taught about gravity so I will not doing too much with trying to relate angle to acceleration. I use the incline to create a reliable constant acceleration for my object.

Virtual Part:

(https://www.thephysicsaviary.com/Physics/Programs/Labs/AccelerationOnInclineWithPrediction/)

The virtual part of this lab could be done before students do a live version of the lab or if you have limited lab space you can have half the students working on the virtual part of the lab while the other half work on the live part of the lab.

Measuring Distance:

Students will be measuring the distance the car travels before striking the barrier. They should make sure they measure to the front of the barrier since that is the part that will be hit by the car. Make sure they record and graph their distances in millimeters.

Measuring Time:

I am a firm believer in making students estimate and make judgment calls as frequently as possible. Because of that, they will need to read an analog gauge that shows the time the car was traveling down the incline.

Measuring Speed: (Optional)

Students do not need to measure speed if you want to skip this part, but I often had students measure both time and speed for each trial. This will be helpful later when you are introducing the equations of motion to the students. But feel free to modify the lab to remove the speed data from your data collection.

Working Through the Lab:

Students can change the distance to the barrier by clicking on the barrier. They will start the motion of the car by clicking on it. The will reset the system by clicking on the car after it has reached the bottom of the track.

Although there are over ten different distances on the virtual program, students need not do all levels. I would not suggest less than 5 levels as it is a good practice to collect more data to have greater confidence in your results. The program will randomize the distance for each trial, so all students will get different results. Students should not refresh the website while working or it will generate new values for umbrella distance and thus make all the old data irrelevant. Below is a sample of what potential data might look like.

Data:

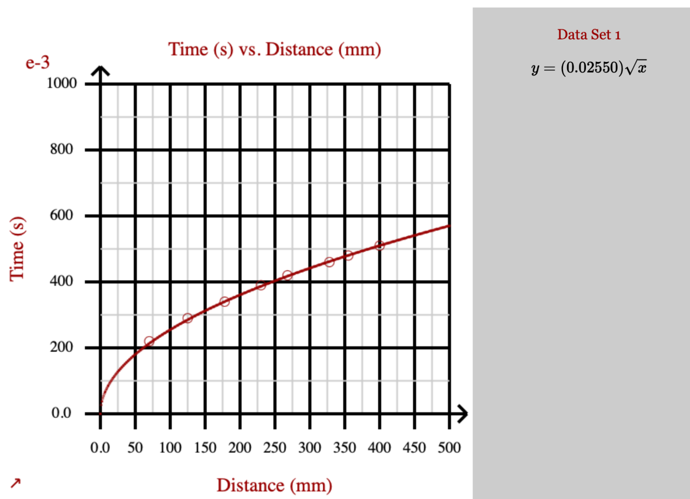
Distance (mm)	Speed (m/s)	Time (s)
70	0.68	0.22
125	0.89	0.29
178	1.02	0.34
230	1.19	0.39
268	1.28	0.42

Graphing Data:

(https://www.thephysicsaviary.com/Physics/Programs/Tools/Graphing/)

Once students have finished collecting data, they should graph it and find a relationship between the variables. The distance traveled by the car (mm) is the independent variable and should be placed on the x-axis and the time of travel (s) should be on the y-axis. Some students are going to be tempted to pick linear as their graph type. Make sure they realize that zero distance would correspond to zero time and thus the graph must pass through the origin. Because of this, a linear fit is not appropriate.

I prefer always having the students transfer their graph onto their lab sheet by hand.



If you also have the students graph the speed vs. the distance, they will get a square root relationship for that graph also. Make sure they use the time vs. distance graph when making their predictions.

Equation:

For this graph students get a square root relationship between the variables. This indicates to them that a larger distance will cause the time of travel to increase in a non-linear fashion. This will be the first non-obvious graph that they get this year. They will be expecting that a doubling of distance will double the time of travel. Emphasize that this means they need to quadruple the distance in order to double the time of travel.

The equation for an inverse relationship is given below.

$$y = A(x)^{0.5}$$

One of the main goals of these first labs is to emphasize to them the idea that each of these letters has real physical significance. Looking at the axes, they should see that the y is the time of travel in seconds and the x is the distance traveled by the car. So the equation becomes:

$$\text{time} = (\text{graph constant})(\text{distance})^{0.5}$$

We then want students to think about the significance of the graph constant. We can prompt them by asking what other factor determines the time of travel beside the distance traveled by the car. Hopefully, at least a few students will realize that it is the angle of the ramp. Some might come up with the gravitational field of the planet, but this one need not be emphasized at this point in the year.

When we go over the equations of motion, we want to remind them of this relationship so that they can see the connection between the equation they developed in lab and the equation $\Delta x = v_i t + 0.5at^2$ when the initial velocity is zero.

If you have the students also graph final speed vs. distance, you will get a similar equation but now it will be

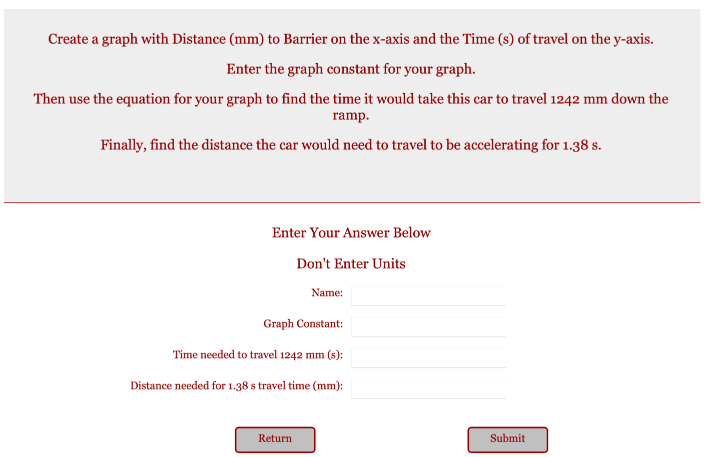
$$\text{final velocity} = (\text{graph constant})(\text{distance})^{0.5}$$

Note that this graph constant will be different from the graph constant for the first graph.

Checking their work:

Once the students have reached the point where they have graphed and created an equation, they will then be able to check their work. They should simply hit “Finished” on the program to be brought to a form they can fill out to see if they did everything correctly. Remind students that they all will be getting different answers and that they shouldn’t worry if their answers differ from those of their classmates.

Make sure to stress that they should have graphed distance in millimeters. Also remind them they are only working with the time vs. distance graph. So if you also had them plot speed vs. distance, that graph will not be used when making predictions. They will be entering their graph constant as the first thing to check. They will then use their equation to make a prediction on how much time is required to travel a certain distance for which they didn’t collect data. Finally, they will be predicting how far their car could travel in a time that was not part of their lab.


Create a graph with Distance (mm) to Barrier on the x-axis and the Time (s) of travel on the y-axis.

Enter the graph constant for your graph.

Then use the equation for your graph to find the time it would take this car to travel 1242 mm down the ramp.

Finally, find the distance the car would need to travel to be accelerating for 1.38 s.

Enter Your Answer Below

Don't Enter Units

Name:

Graph Constant:

Time needed to travel 1242 mm (s):

Distance needed for 1.38 s travel time (mm):

Return

Submit

I would normally offer a small amount of extra credit added to the lab grade if they get all their answers correct. I would have them show me their completion certificate so I could record that they earned the extra credit. If a student doesn’t get everything correct, you can have them redo the lab by refreshing their page if time permits.

Live Part:

I always suggest a live lab counterpart to any virtual lab that you do with your students. For this lab all you need to replicate the virtual part is an inclined surface and a low friction car. Even allowing a ball to roll down the incline should give very similar data. Anyway here are some suggestions for things you can do with the live part of your lab.

1. **Setting up the incline:**
    a. The simplest way to support the incline is to put one end of the incline on a small pile of physics books (you need to do something with those old physics books on the shelf).
    b. Make sure the incline is angled enough to get the car to accelerate, but not so steep that timing becomes difficult.
    c. If you can get an incline longer than a meter, you should be able to get a good spread in distances for your lab.
    d. If you have the ability to measure angle, have each group do a different angle so you can talk about how angle affects the graph constant.
2. **Starting and ending a trial**
    a. Having three or four people per lab group would be very helpful.
    b. One person could use a ruler or meter stick to hold the car stable at the start line.
    c. One person could hold a meterstick as the barrier at the finish line.
    d. One person could time the car from release until hitting the barrier.
    e. Remind the students to redo any trial in which they feel they weren’t properly synchronized.
3. **Timing the car**
    a. The simplest way to time the car will be having one of the students use the stopwatch on their phone or laptop.
    b. Videotaping the motion of the car will allow them to bring it into a program that will give them the ability to get more accurate times.

Conclusion:

I personally like to have students write out a conclusion by hand after they are done with the entire lab (live part and virtual part). Some things you can have students include in the conclusion.

1. **Restatement of the purpose.**
   a. This is a great way to open the conclusion
   b. It helps to reinforce the reason we were doing the lab.
2. **Brief Summary of the steps**
   a. I don't want too much here but I do want students to transition from the purpose to the results with a sentence or two summary of the steps.
   b. This part of the conclusion should paint with a very broad brush what type of data we were collecting and what remained constant when collecting data.
3. **Results**
   a. I want students to clearly state what type of relationship existed between the two variables we were examining.
   b. I want them to clearly explain what this means in simple to understand terms.
   c. Basically, they will be making sense of the equation they have discovered in the lab.
4. **Error**
   a. They should talk about their percentage of error from the lab (you can have them do this for the live part or the virtual part or both).
   b. They should brainstorm at least one possible source of that error and how it can be minimized if they redid the lab.
5. **Limitations to the model**
   a. Whenever possible I want them to think about when the mathematical model for the lab would break down and no longer apply.
   b. For instance, with this lab, the model will be limited to objects moving down an incline with a constant acceleration. If the object is significantly affected by air resistance, the acceleration will decrease as the object gets faster and the equation will become less accurate the greater the distance traveled by the object.

Going Further

If you have the time, you could challenge the students with the following types of things.

1. How would your graph change if we had different angles for the ramp? You can have different lab groups do different angles and then share their graphs with the class. You can ask them to sketch a new curve on the graph in a different color that would show how things would have changed if the angle of the ramp increased.

2. If your cars have the ability to hold masses, you could have them repeat the live part with a significant amount of extra mass and see how it affects (or doesn't affect) the graph.