Acceleration in a Turn Lab

Directions and Suggestions for Teacher

Purpose:

This lab is designed to give students their first taste of acceleration without a change in speed. Specifically, they will be looking at the connection between the radial acceleration of a car going around a turn at a variety of different speeds. Students will envision an accelerometer in a car that goes around a turn at different speeds. Once they have their graphs they will use the graph(s) to create a mathematical model and then use the model to make predictions.

Virtual Part:

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

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 Speed:

The speed the race car will travel is given on the analog speedometer provided in the bottom left hand corner of the program. Students should read the speed to the nearest 0.1 m/s.

Measuring Acceleration:

Students should use the graph produced by the accelerometer to estimate the acceleration of the car while it was going around the turn. The data will be a bit noisy, just like it would be in real life, and students should try to estimate this acceleration as best they can from the graph. They should try to visualize a horizontal line that will be the average of the accelerations during the part of the graph where the car was in the turn.

Working Through the Lab:

There are well over ten different speeds that the students could use in the virtual program. I would suggest students do at least five very speeds. It is a good practice to collect more data to have greater confidence in your results. The program will randomize the available speeds and also randomize the radius of the turn, so all students will get different results. Students should not reload the program once they have started to collect data, for when it reloads, they will get an entirely different turn radius and speeds. Below is a sample of what potential data might look like.

Data:

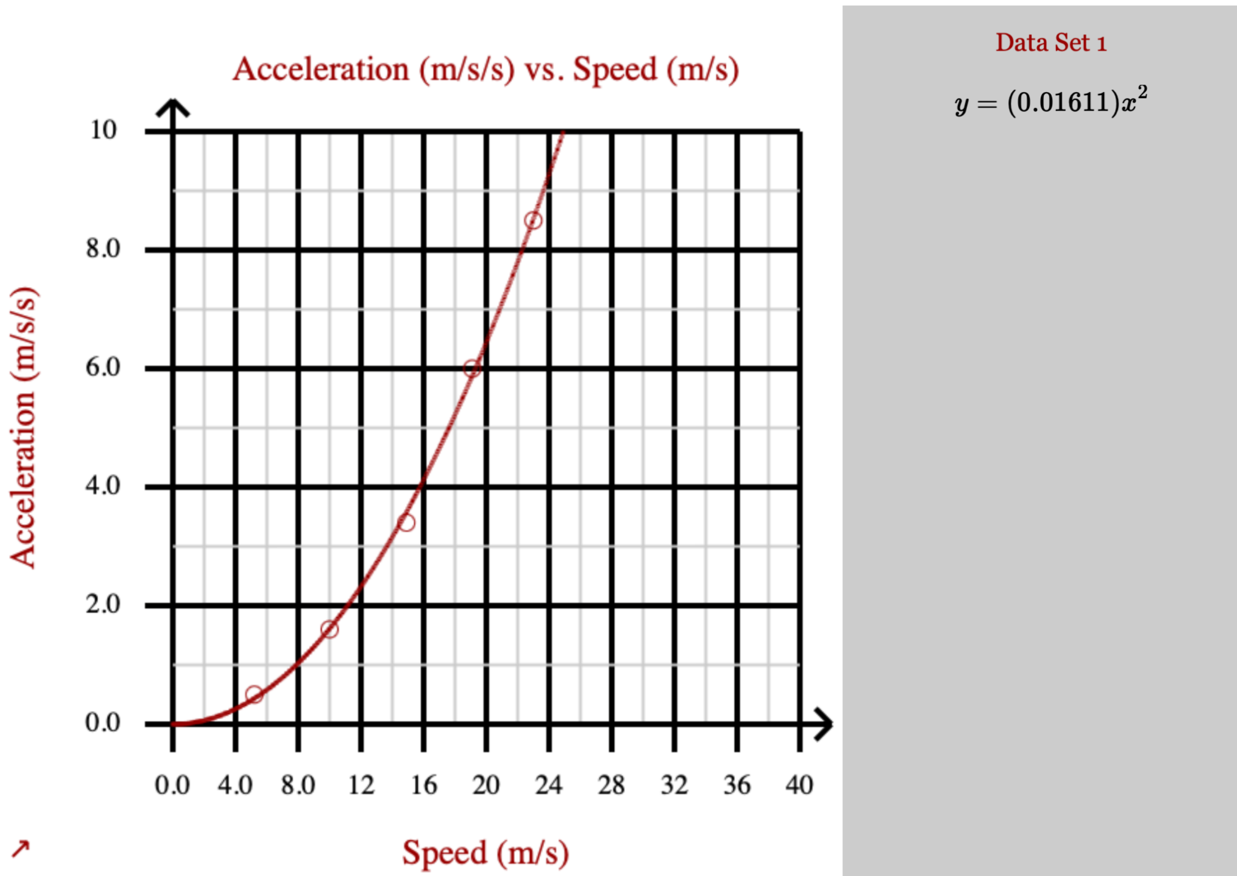
Speed (m/s)	Acceleration (m/s/s)
5.2	0.5
10.0	1.6
14.9	3.4
19.1	6.0
23.0	8.5

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 speed of the car (m/s) is the independent variable and should be placed on the x-axis and the radial acceleration (m/s/s) should be on the y-axis. This graph should come out to be a squared graph.

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



Equation:

For this graph students get a squared relationship between the variables. This indicates to them that a larger speed will produce a larger acceleration, but it will not do so in a proportional way.

The equation for a squared relationship is given below.

$$y = (\text{graph constant})*x^2$$

We want to continue 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 radial acceleration in m/s/s and the x is the speed of the car in m/s. So the equation becomes:

$$\text{Acceleration} = (\text{graph constant})*(\text{speed})^2$$

We then want students to think about the significance of the graph constant. We can prompt them by asking them what else could we change about the turn besides the speed of the car moving through the turn that would affect the acceleration experienced by the driver. I am sure that there will be a variety of answers that are given that turn out not to affect the acceleration. Hopefully, at least one of the students will mention the size or radius of the turn. We then want them to imagine taking a sharp turn and a gentle turn at the same speed. Ask them which would produce more acceleration. Most students should realize that a larger radius, that is a gentler turn, will produce less acceleration. So a bigger radius makes for a smaller graph constant. At this point, you can tell them the graph constant should be the reciprocal of the radius of the turn. So the final equation is one they will use throughout the rest of the year for radial acceleration is

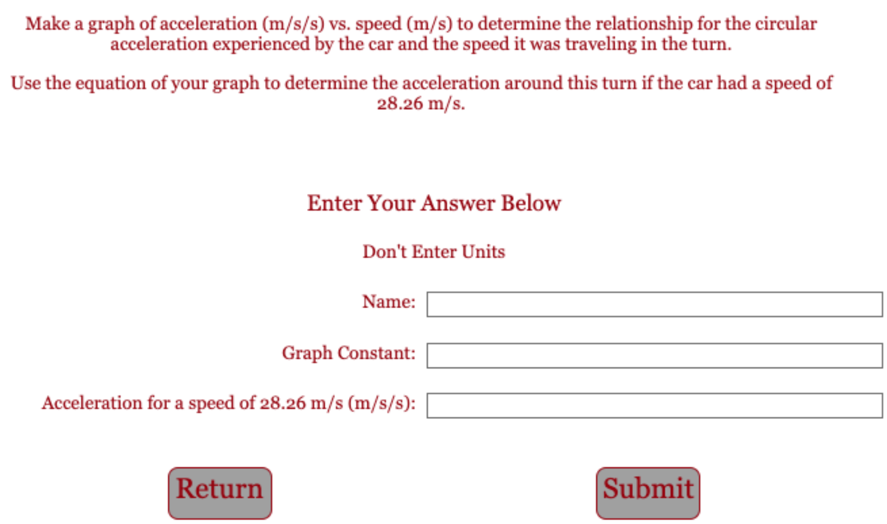
$$\text{Acceleration} = (\text{speed})^2/r$$

$$a = \frac{v^2}{r}$$

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.

Students will be entering the graph constant that they got when they did a curve fit using a squared relationship. They will then be told a car speed that they didn’t collect data for and they are to use their mathematical equation to predict the acceleration.


Make a graph of acceleration (m/s/s) vs. speed (m/s) to determine the relationship for the circular acceleration experienced by the car and the speed it was traveling in the turn.

Use the equation of your graph to determine the acceleration around this turn if the car had a speed of 28.26 m/s.

Enter Your Answer Below

Don't Enter Units

Name:

Graph Constant:

Acceleration for a speed of 28.26 m/s (m/s/s):

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 I would have the students use a wireless accelerometer on a spinning lazy susan or record player to measure the acceleration as the accelerometer moves in a circular path at a constant speed. You could have them vary the radius or the speed of the turning platform between trials.

1. **The Accelerometer:**
   a. I have used Vernier Accelerometers for this experiment. If the accelerometer is not wireless, you will need to put the data collection device on the rotating platform as well as the accelerometer.
   b. I have also used a Pocket Lab as the wireless accelerometer in this lab.
   c. Finally, if you have none of these devices, you can use the accelerometers on your phone to collect data. I have a program I wrote that might help you collect acceleration data using your phone. It is found here (https://thephysicsaviary.com/Physics/Programs/Labs/AccelerationinCircleLiveLab/)
   d. Make sure whichever device you use that students keep the speed of the rotation slow enough that the accelerometers don't slide or fly off the rotating platform.

2. **Measuring Radius.**
   a. If your live lab requires you to know the radius from the point of rotation to the accelerometer, you will need to make a rough estimate. Most times you will not know exactly where the acceleration sensor is placed inside the accelerometer.

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, our model assumes that the object that we are rolling is a perfect circle at a constant speed. Let them know that things will be more complicated when trying to measure acceleration if the speed of the car is also changing or if the roadway is not flat.

Going Further

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

1. Based on what we have learned, ask students why they cannot detect the acceleration of the Earth as it moves around the sun.

2. Ask the students to draw a curve on their graph for how things would have been different if they had used a curve with a greater radius. Have the students create their new curve in a different color.