Stopping Distance Lab

Directions and Suggestions for Teacher

Purpose:

This lab is designed to give students experience with the connection between speed and stopping distance. Of all the labs we do this year, this is one I always focus on how this could save their life. At the end of this lab, I want them to understand how rapidly the stopping distance increases when they try driving their car at higher and higher speeds.. Students will adjust the starting speed and then see how that affects the amount of distance required for the object to slide to rest. 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/SneakerStoppingDistanceLab/)

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:

There will be a speed bar above the sneaker that will give students the ability to get nearly any speed they want between 0 m/s and 4.5 m/s. The speed displayed on the bar at the exact moment they click on the sneaker will be the initial speed of the sneaker.

Determining Stopping Distance:

They will be measuring the distance to the front edge of the sneaker. There is a floating arrow that will help them get the distance that the sneaker has moved when sliding.

Working Through the Lab:

There are technically an infinite number of different starting speeds that the students could use in the virtual program. I would suggest students do at least five very different speeds. It is a good practice to collect more data to have greater confidence in your results. The program will randomize the coefficient of friction between the sneaker and the floor, so all students will get different results. Students should not refresh the website while working or it will generate new values and thus make all the old data irrelevant. Below is a sample of what potential data might look like.

Data:

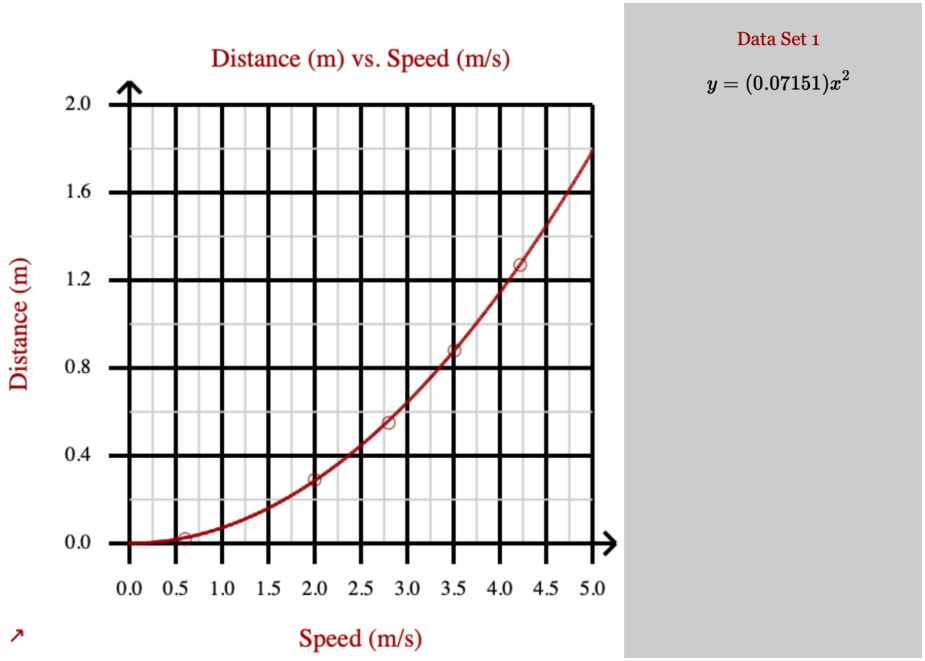
Speed (m/s)	Distance (m)
4.22	**1.27**
3.51	**0.88**
2.8	**0.55**
2.0	**0.29**
0.6	**0.02**

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 starting speed of the sneaker (m/s) is the independent variable and should be placed on the x-axis and the stopping distance (m) should be on the y-axis. This graph should come out to be an inverse graph.

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



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Equation:

For this graph students get a squared relationship between the variables. This indicates to them that a larger starting speed will cause a larger stopping distance, but not 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 stopping distance in meters and the x is the starting speed in m/s. So the equation becomes:

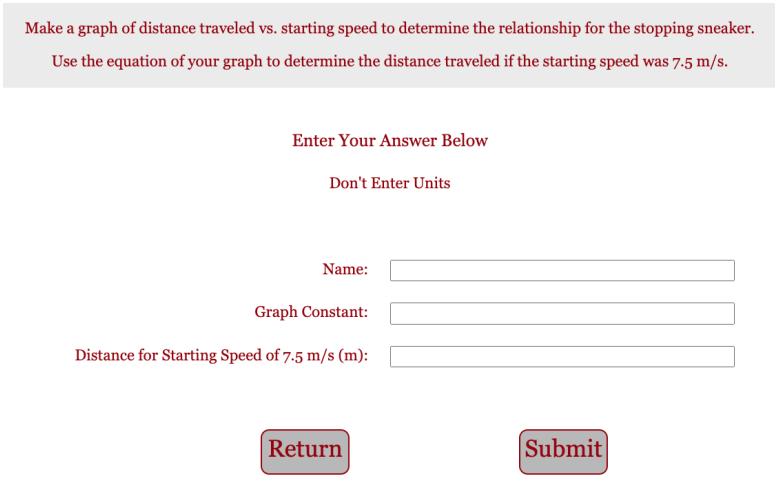
$$\text{Stopping distance} = (\text{graph constant})*(\text{starting speed})^2$$

Based on this squared relationship, a doubling of the starting speed would cause the stopping distance to quadruple.

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 found when graphing their data with a squared relationship. They will then be told a speed that they didn’t collect data for and they are to use their mathematical equation to predict the stopping distance for that speed.

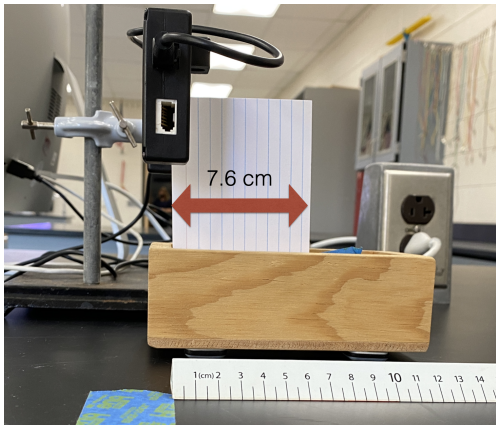


I would normally offer a small amount of extra credit added to the lab grade if they get all their answers correct. I would have them show me their completion certificate so I could record that they earned the extra credit. If a student doesn’t get everything correct, you can have them redo the lab by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

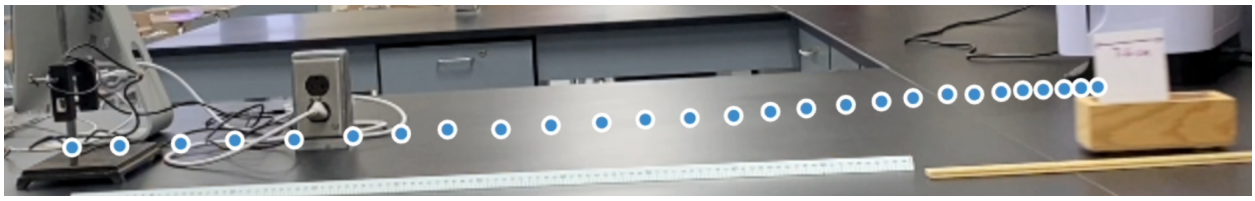
Live Part:

I always suggest a live lab counterpart to any virtual lab that you do with your students. This lab gives a few options that will allow you to collect live data similar to the data collected in the virtual lab.

1. **Photogate:**
    a. If you have access to photogates, they will give you the best data for determining the initial speed of the sliding object.
    b. You can see my setup in the picture to the right. Students would give the box a push and let go before the box reaches the photogate.
    c. The index card will break the beam on the photogate and allow you to get the time it took the card to move by the gate.



    d. The size of the card and the time to pass the gate will get you an approximate starting speed for the box.
    e. When the box slides to rest, measure the distance covered from the photogate to the center of the index card when it has stopped moving.
    f. Students should try to give the box different speeds for different trials.
    g. My students get really good graphs from this method.
2. **SuperSlow Motion**
    a. If you don't have access to a photogate, you can have the students record the motion of the box past the starting line at a very high frame rate.
    b. Using the size of the box and the number of frames it takes for the box to move past the start line, students should be able to get a pretty decent starting speed.



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 coefficient of friction will remain constant during the entire stopping process. Oftentimes, surfaces will have some spots with greater or lesser amounts of friction. This is usually not going to make much difference, but I have seen hockey pucks unexpectedly come to a dead stop on a spot of ice that has a much higher friction than the surrounding ice.

Going Further

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

1. Have them change the mass of the box by a significant amount to see how (or if) the mass of the object affects the stopping distance for a given speed.

2. Have them put the box on a “magic slider” furniture mover to see how the stopping distance will change. You could also put a strip of carpet or other material down to see how this affects stopping distance.