Constant Speed Lab

Directions and Suggestions for Teacher

Purpose:

This lab is designed to give students their first taste of modeling the motion of an object. They will collect data for an object moving with a constant speed and then use the data to create a graph, use the graph 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.

Virtual Part:

(http://thephysicsaviary.com/Physics/Programs/Labs/FatherBrownConstantSpeedLab/)

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 of the Electric Bike:

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 speed setting of the electric bike being ridden by Father Brown.

Measuring Time of Travel:

After students hit “Start Motion” they should be ready to then start their timer. The timer should be started when the front wheel of the bike first reaches the initial umbrella. They will then monitor the motion of the bike and they should stop the timer when the front wheel of the bike first reaches the second umbrella. If they feel they messed up the timing, they should reset the system and try it again.

Although there are ten different levels on the virtual program, students need not do all ten 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 between the umbrellas, 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.

The program has time slowed down a bit so that it is easier to collect data on the higher speed settings. I suggest telling students to start with settings between 4 and 6 so that the bike will not be traveling too fast or too slow as they are learning to work the controls. I also recommend the slowest settings be saved for near the end of the lab. They can be a bit tedious. Have them read the speedometer while the bike is moving between umbrellas.

Below is a sample of what potential data might look like.

Data:

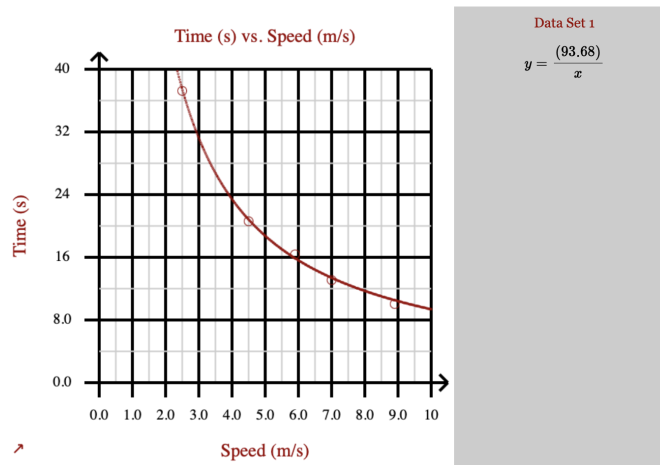
Setting #	Speed (m/s)	Time (s)
4	**4.5**	**20.6**
6	**5.9**	**16.37**
8	**7.0**	**13.09**
10	**8.9**	**10.04**
1	**2.5**	**37.24**

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 bike is the independent variable and should be placed on the x-axis and the time of travel should be on the y-axis.

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



Equation:

For this graph students get an inverse relationship between the variables. This indicates to them that a higher speed will cause the time of travel to decrease. Although this might be an obvious relationship, it is good to have something so obvious as one of the first labs during the year. This will allow them to make connections between the mathematical relationship and their common sense. The equation for an inverse relationship is given below.

$$y = A/x$$

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 speed of the bike. So the equation becomes:

$$\text{time} = \text{graph constant/speed}$$

We then want students to think about the meaning of the graph constant. We can prompt them by asking what other factor determines the time of travel beside the speed of the vehicle. Hopefully, most will realize that it is the distance between the umbrellas. Hence, the equation becomes:

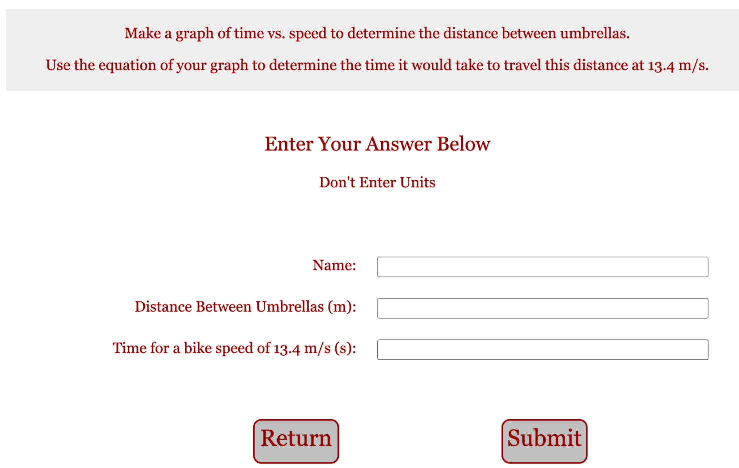
$$\text{time} = \text{distance/speed}$$

We then want students to realize that this is the same equation we taught them in class (speed = distance/time), but rearranged algebraically. This is a great time to introduce them to the notion that physics equations are not handed down to us from on high, but they are discovered through the collection of data and the graphing of said data.

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.

They will be entering in the distance between their umbrellas (that is the graph constant they found when plotting out the inverse graph). They will then use their equation to make a prediction on how much time is required to travel from umbrella to umbrella at a speed for which they didn’t collect data.


Make a graph of time vs. speed to determine the distance between umbrellas.

Use the equation of your graph to determine the time it would take to travel this distance at 13.4 m/s.

Enter Your Answer Below

Don't Enter Units

Name:

Distance Between Umbrellas (m):

Time for a bike speed of 13.4 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.

This lab was created by Frank McCulley for thephysicsaviary.com.

Live Part:

I always suggest a live lab counterpart to any virtual lab that you do with your students. It is not going to be easy to replicate this experiment in a live setting unless you have access to toy cars with multiple speed settings. Because that is not something that is easy to find, my suggestions will be related to this virtual lab but they will not be getting the same relationship they got in the virtual lab. Anyway here are some suggestions for things you can do with the live part of your lab.

1. **Finding Speed:**
    a. Have the students set up a start and finish line on the floor of the classroom. Use blue painter's tape so that the tape comes off the floor with ease..
    b. Allow the students access to a few toy cars that they can choose from and have them run the cars through the "race track" that they set up with painters tape. I had a few cars I picked up through the years including "Shake and Go" cars, pull-back cars, and other battery powered vehicles. Oftentimes students will have said cars at home from younger siblings and they will bring them in for the class to use.
    c. Have the students use stop watches on their phones or laptops to time the cars.
    d. Have them do multiple trials for each car to see how consistent their timing is or how consistent the speed of the car is.
    e. If you have zero access to powered cars, have the student roll a tennis ball or other object through their race course. Maybe you can challenge them to see how close to a certain speed they can obtain.
2. **Distance and Time**
    a. If you have battery operated cars that give a consistent speed, try having them change the size of the "race course" multiple times. For each race course have them determine the distance and the time it takes the car to run that distance.
    b. This will allow them to graph a different set of variables compared to the ones that were done in the virtual lab. They will obtain a different relationship but it will still be related to the speed = distance/time equation.
    c. If you have the time and the facilities available to you, let the students be the object and have them move as best they can along the school's athletic track. Have different students time them for different distances and then make the graph of time vs. distance.

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 that are moving at a constant speed. If our bike was human powered, the speed would probably not stay constant for the entire trip and therefore predictions of travel time would not be accurate based on a single reading of the speedometer.

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 a different distance between the umbrellas? 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 distance between the umbrellas was farther apart.

2. Have the students envision a car moving down a highway (like the Jersey Turnpike) at a constant speed. Set a certain distance for everyone in the class to use (i.e. 40 miles). Then have different people figure out how many minutes it would take to go that distance at a certain speed. Every student in the class should do a different speed. Then have them share the data and create a graph of time in minutes on the y-axis vs. speed in mph on the x-axis. They can then develop an equation that will give them time as a function of speed in a set of what would be normally incompatible units. You could then have them try to figure out where the graph constant for this graph comes from and how the equation would be changed for a different distance.

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