Classic Circular Force

Directions and Suggestions for Teacher

Purpose:

This lab is designed to give students an understanding of the relationship between the force required to keep an object moving in a circle and the speed of the object moving in that circle. This lab uses the string in the tube apparatus that has been used for this type of lab for many decades. 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/ClassicCircularForceWithPredictionLab/)

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 # of Washers:

This number will be given directly to the students. They will change this number for each new trial.

Measuring Speed:

When students start the motion of the stopper in its circular path, a timer will also begin. I suggest that you have the students count off ten full revolutions of the stopper and then record the time. They use that time along with the radius of the circle to get the speed of the stopper.

$$v = \frac{\theta r}{t}$$

Where the angle will be equal to 20π since they did 10 revolutions. If they do a different number of revs, make sure they use the proper angle in radians.

Working Through the Lab:

Although there are about thirty different washer numbers that are possible in 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 radius 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:

Radius of circle: 1.06 m

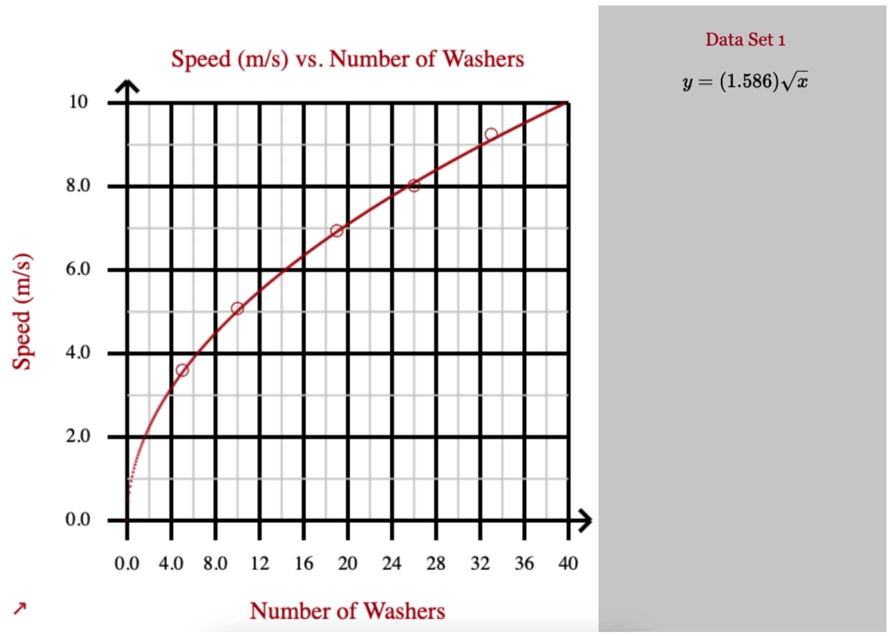
Number of Washers	Time (s)	Speed (m/s)
5	18.5	3.60
10	13.1	5.08
19	9.6	6.94
26	8.3	8.02
33	7.2	9.25

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 number of washers is the independent variable and should be placed on the x-axis and the speed (m/s) should be on the y-axis. This graph should come out to be a square root 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 square root relationship between the variables. This indicates to them that a larger number of washers will cause greater speed, but in a non-proportional way. Some of the students will pick linear for their graph type and although that may fit some of their data points rather well, if they did a nice range of washer numbers, including some very small number of washers, they will see that linear is not the best curve fit to pick. Make sure they realize that zero washers would have zero speed and that their linear graph doesn't go through the origin and therefore cannot possibly be correct for this relationship.

The equation for a square root relationship is given below.

$$y = (\text{graph constant})(x)^{0.5}$$

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 speed of the stopper in m/s and the x is the number of washers. So the equation becomes:

$$\text{speed} = (\text{graph constant})(\text{\# of washers})^{0.5}$$

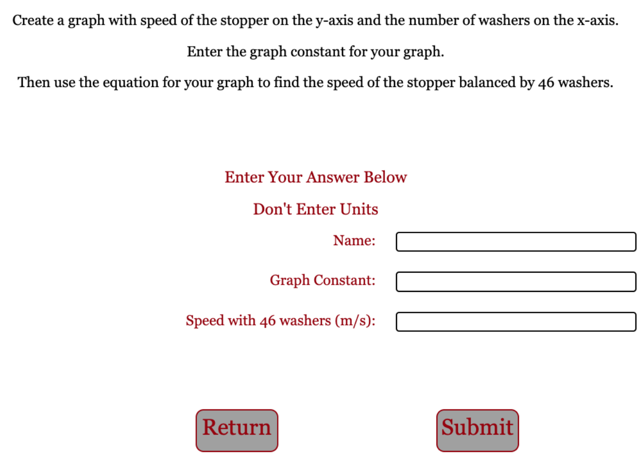
We then want students to think about the significance of the graph constant. We can prompt them to tell us what could have changed other than the number of washers that would have made the speed of the stopper different from what they measured in the lab. Hopefully, some students will come up with the radius of the circle and the mass of the stopper. Maybe, someone might mention the gravitational field of the planet.

Either at the end of the lab or in a subsequent class, this lab results should be tied into the formula for force needed to keep an object moving in a circle at a constant speed. The gravitational force on the washers was responsible for keeping the object moving in a circle.

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 their graph constant when they curve fit their data with a square root relationship. They will then use their equation to make a prediction on how much speed would be required to keep the stopper in a circular path of the same radius they used in the lab but for a number of washers for which they didn’t collect data.


Create a graph with speed of the stopper on the y-axis and the number of washers on the x-axis.

Enter the graph constant for your graph.

Then use the equation for your graph to find the speed of the stopper balanced by 46 washers.

Enter Your Answer Below

Don't Enter Units

Name:

Graph Constant:

Speed with 46 washers (m/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. I found that doing a live lab just like the virtual lab was the best option. Students always had a good time collecting data and trying to master the swinging of the stopper in a circular path. Goggles should be worn when doing the live part of this lab.

1. **The Setup:**
    a. I found the glass tubes worked the best and when necessary I would make new glass tubes using a bunsen burner to make sure the ends of the tube were as smooth as possible.
    b. Putting a few layers of masking tape on the tube or putting shrink tubing around the glass made the glass much less likely to break when the students put it down too roughly.
    c. I would often pre-tie the stopper onto the string and make sure the string was the right length. By doing this myself, I felt more secure about them whirling the stopper in a circle.
    d. At the end of the lab I would have them put the tube and the string in a zip-lock bag to keep it from getting tangled with the strings from other groups.
    e. Next year, things are ready to go with little effort and I might only have to fix one or two of the setups.
2. **Tips for Good Data:**
    a. The most important thing was to have the students practice keeping the masking tape marker at the right location before starting to collect data.
    b. I would have the students start with 15 washers and then go to 20, 25, 30, 10, 5. The 10 and 5 washer trials are the hardest to do and that is why I save them until the end.

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 equation we got only applies if the object is moving in a perfect circle at a constant speed. When we use this formula for calculating orbits, it will give us only an approximate answer because planets, moons, and satellites often are in elliptical orbits with changing speeds..

Going Further

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

1. You could have students keep the number of washers constant and try changing the radius of the circle.

2. You could have students change the mass of the stopper and see how that affects necessary stopper speed needed to maintain a perfect circle.