Rolling Distance Lab

Directions and Suggestions for Teacher

Purpose:

This lab is designed to give students experience with circular motion ideas. Mainly, the connection between the angular changes and the linear changes. Students will roll objects with varying radii through a set number of revolutions and measure the linear distance the objects travel. 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/RollingDistanceWithPredictionLab/)

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 Radius:

The radius of the wheels will be given to the students directly. Although I don't normally just give them measurements, in this lab that radius will be directly displayed to the students. Students should record their radii in meters.

Determining Rolling Distance:

Students will be rolling the wheel through exactly one revolution. The spikes on the wheel are different colors to help them track the object as it rolls. If they stop the wheel too soon or too late, they will be able to move it frame by frame to position it just right. Students will then read the distance off the two-meter stick that is placed on the table. Make sure you remind the students that the wheel doesn't start at the zero on the stick. Students should convert their distance measurement to meters before recording it.

Working Through the Lab:

There are over ten different radii that the students could use in the virtual program. I would suggest students do at least five very different radii. It is a good practice to collect more data to have greater confidence in your results. The program will randomize the available radii, so all students will get different results. Below is a sample of what potential data might look like.

Data:

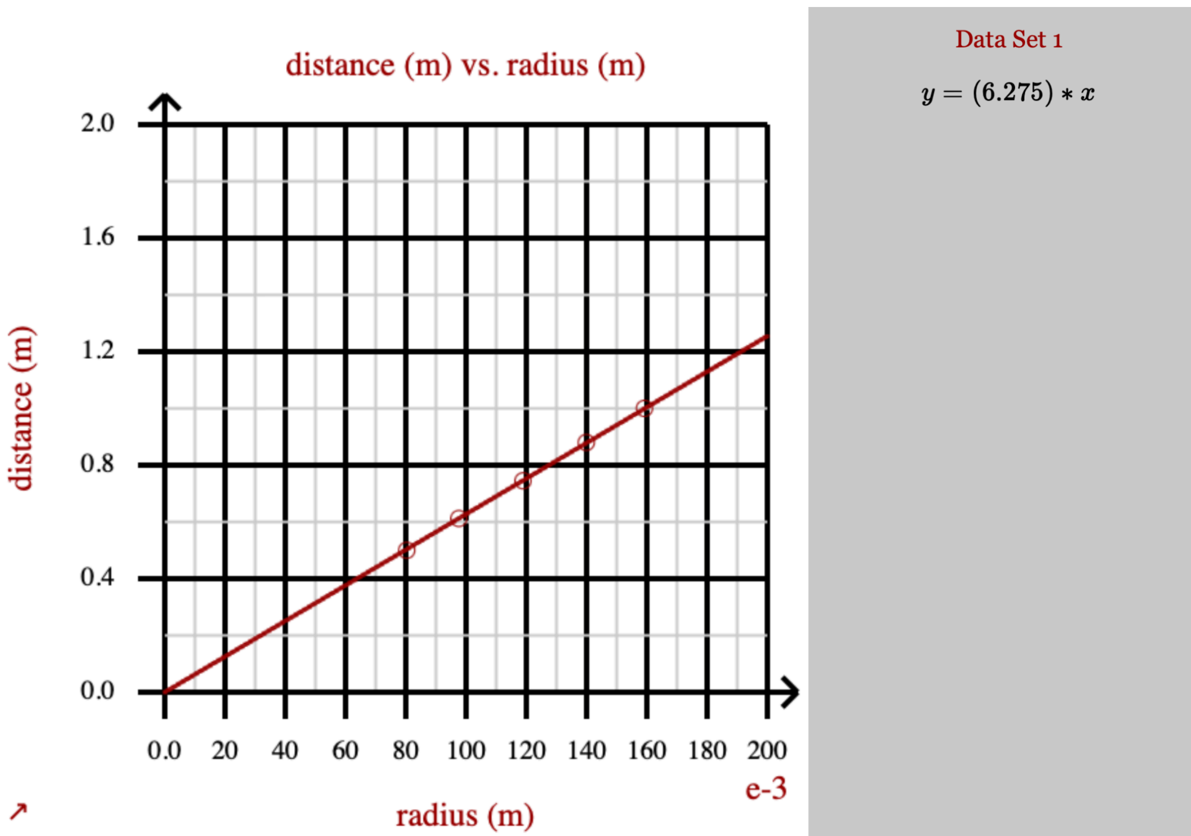
Radius (m)	Distance (m)
0.0803	**0.500**
0.0976	**0.612**
0.1189	**0.745**
0.1399	**0.880**
0.1592	**1.000**

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 radius of the disk (m) is the independent variable and should be placed on the x-axis and the rolling distance (m) should be on the y-axis. This graph should come out to be a proportional graph.

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



Equation:

For this graph students get a proportional relationship between the variables. This indicates to them that a larger radius disk will travel a farther distance when traveling through one full revolution.

The equation for a proportional relationship is given below.

$$y = (\text{slope})*x$$

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 rolling distance in meters and the x is the radius of the disk in meters. So the equation becomes:

$$\text{Rolling distance} = (\text{slope})*(\text{radius of disk})$$

The slope of the graph should be 6.28 or 2π since we had the wheel turn through one complete revolution. A more general formula would be

$$\text{Rolling distance} = (\text{angle of rotation})*(\text{radius of disk})$$

or

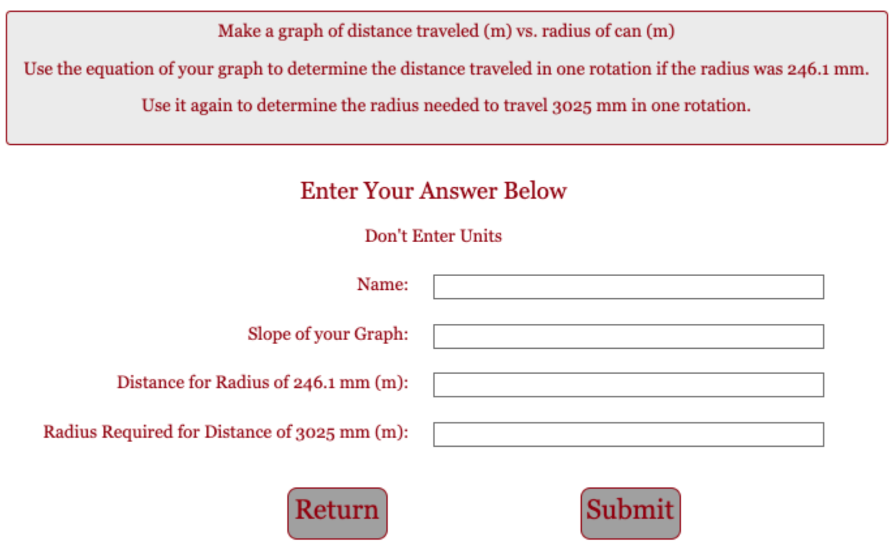
$$d = \vartheta r$$

Where the ϑ is the angle through which the disk turned in radians.

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 slope that they found when graphing their data with a proportional relationship. They will then be told a disk radius that they didn’t collect data for and they are to use their mathematical equation to predict the rolling distance for that radius. They will then be told a rolling distance that they didn’t measure and they will have to figure out the disk radius that would produce that distance for a single revolution.


Make a graph of distance traveled (m) vs. radius of can (m)

Use the equation of your graph to determine the distance traveled in one rotation if the radius was 246.1 mm.

Use it again to determine the radius needed to travel 3025 mm in one rotation.

Enter Your Answer Below

Don't Enter Units

Name:

Slope of your Graph:

Distance for Radius of 246.1 mm (m):

Radius Required for Distance of 3025 mm (m):

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 bring in can goods a various radius and have the students roll them across the ground and measure the distance the cans traveled over a set number of revolutions. I would usually do more than just a single revolution and I would often have different lab groups assigned a different number of revolutions.

1. **The disks:**
    a. Most years I would have students use can goods of various radii as their objects. I would have maybe eight different cans and have the students take turns with the different cans.
    b. A hockey puck or other size disks or wheels can be used if you don't have a kitchen full of expired can goods.

2. **Measuring Revolutions.**
    a. Putting a tiny piece of blue painter's tape on the can can help students track how many revolutions it has gone through.
    b. I have had students tape a PocketLab onto the flat top or bottom of cans to measure the exact angle it rotates through as they push it across the floor.

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. If we are using this equation when dealing with orbital motion and the orbit is not a perfect circle, our accuracy will be compromised.

Going Further

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

1. Extend the formula that we developed for linear and angular distance to also include velocity and acceleration.

$$d = \vartheta r$$

becomes

$$v = \omega r$$

becomes

$$a = \alpha r$$

2. Either bring in or show pictures of the tools that they can buy that will mark off linear distance by rolling a wheel along the ground you want to measure.

3. Ask the students to draw a line on their graph for how things would have been different if they had used a greater number of revolutions than the number that we used in this lab.

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