

Doppler Effect

Directions and Suggestions for Teacher

Purpose:

This lab is designed to give students a hands-on experience with the phenomenon known as the Doppler Effect. In this lab students will be examining the connection between the speed of an object producing sound and the wavelength of the sound in front of the object.

Virtual Part:

(<https://www.thephysicsaviary.com/Physics/Programs/Labs/DopplerWithPredictions/>)

This lab doesn't have a real good live part to go with it, but it should be coupled with demonstrations, both live and videos, of the Doppler effect for sound.

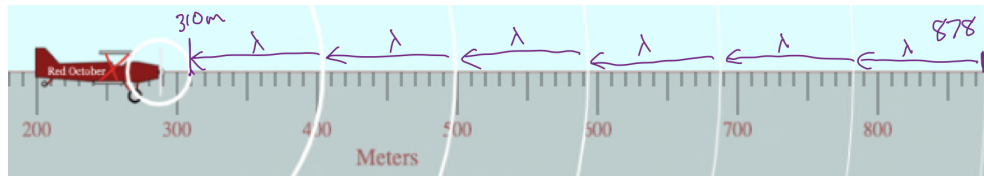
Measuring Speed:

The plane that is equipped with a low frequency sound machine will fly passed two poles that are placed 700 meters apart. The plane will be automatically timed as it moves from pole to pole. Students will then estimate the amount of time that was required and then they will calculate the speed based on the 700 meters of distance and the time of passage.

Sound:

There is an optional feature in this program for students to hear the sound of the airplane's engine. This sound is not the same as the low frequency sound waves that are visible using the program, but it will give students an idea of the change in frequency that occurs as the plane approaches and then passes the observer standing near the finish line. If you are doing this in a class setting, I recommend headphones or requesting students disable the sound before starting the experiment.

Measuring Wavelength:



$$\begin{aligned}6\lambda &= (878 - 310) \\6\lambda &= 568 \\ \lambda &= 94.7 \text{ m}\end{aligned}$$

Switch the program from “Measuring Speed” to “Measuring Waves” to see the waves being produced by the wavemachine on the plane. Pause the plane so that many wavelengths of sound are visible at once. Use the ruler to determine the wavelength of the waves in front of the plane. The more wavelengths included in the measurement, the better the results will be.

Although there are ten different speed levels on 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 the frequency of the sound wave that is being displayed and the temperature of the air, 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:

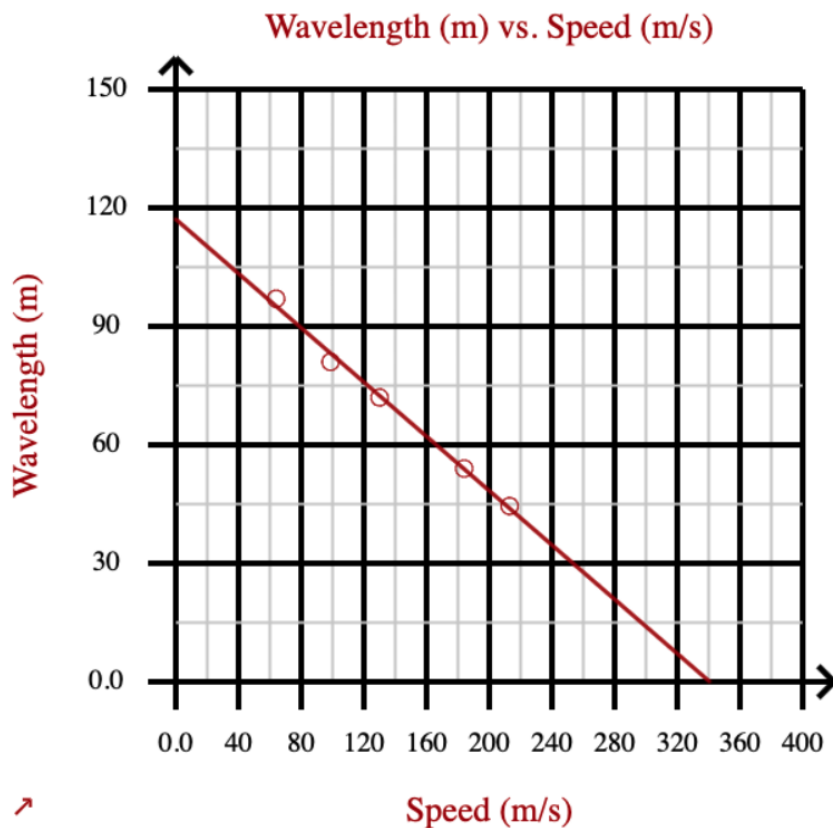
Speed Level #	Time (s)	Speed (m/s)	Wavelength (m)
1	10.90	64.0	97.1
3	7.09	98.7	80.9
5	5.39	129.9	72.2
7	3.81	184.2	54.0
9	3.29	212.8	44.5

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 plane is the independent variable and should be placed on the x-axis and the wavelength in front of the plane in m should be on the y-axis. Some students are going to be tempted to fit this graph with an inverse relationship. Be on the lookout for this and make sure they pick linear.

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



Data Set 1

$$y = (-0.3437) * x + (117.1)$$

Correlation: 0.99747

Equation:

For this graph students get a linear relationship between the variables. This indicates to them that a larger speed will cause a smaller wavelength in front of the plane.

The equation for an inverse relationship is given below.

$$y = (\text{slope})(x) + (\text{y-intercept})$$

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 wavelength in m and the x is the speed in m/s. So the equation becomes:

$$\text{wavelength in front of plane} = (\text{slope})(\text{speed of plane}) + (\text{y-intercept})$$

We then want students to think about the significance of the graph constants. Have them think about what would be the physical meaning of the y-intercept. Hopefully, many of the students will realize that it is the wavelength of the waves when the plane has no speed or is at rest.

The slope of the graph is going to be the period for the oscillator making the waves we were measuring. The period of the oscillator multiplied by the speed of the plane gives the amount of distance the plane moved between production of waves.

So the final equation becomes:

$$\text{wavelength in front of plane} = -(\text{period})(\text{speed of plane}) + (\text{original wavelength})$$

$$\lambda = -Tv_p + \lambda_o$$

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.

The first thing they will be entering is the slope of their graph. They should enter this as a positive number. This number will be the period of the oscillator that was making the low frequency sound waves they were looking at. Then they will enter the y-intercept. This is the wavelength of the sound if the plane was at rest. Next they will use their equation to calculate the speed required to get the wavelength in front of the plane to equal zero. This should be the speed of sound on the day the experiment was conducted. Finally, they will use their equation again to find the wavelength at a speed that they didn't test in their experiment.

Make a graph with the speed (m/s) of the plane on the x-axis and the wavelength (m) in front of the plane on the y-axis.

Record the absolute value slope of your graph as a positive number as well as the y-intercept of the graph.

Calculate the plane speed needed to create a wavelength of zero meters and the wavelength at a speed of 265.0 m/s.

Enter Your Answer Below

Don't Enter Units and Make all Answers Positive

Name:

Slope of Graph:

y-intercept of Graph:

Speed Causing $\lambda = 0$:

Wavelength at a speed of 265.0 m/s (m):

[Return](#)

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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; however, the difficulty in getting live data similar to what we did in the virtual program makes this unfeasible for this lab. Instead, I would do some live demos of the Doppler effect or I would show videos of objects creating the Doppler effect. Plenty of examples can be found online.

Conclusion:

I personally like to have students write out a conclusion by hand after they are done with the entire lab.. 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.
- 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, this model only works for plane speeds less than the speed of sound. Once the plane exceeds the speed of sound, our equation no longer works. Also, this formula only works if the source of the sound is moving directly towards you.

Going Further

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

1. Ask the students what they think the equation would look like if we were studying the wavelength behind the plane instead of in front of the plane?
2. Ask the students to create another line on their graph for an object that was producing a higher frequency sound compared to the one we were studying in the lab.