Thermal Speed

Directions and Suggestions for Teacher

Purpose:

This lab is designed to give students an understanding of the connection between the temperature of an ideal gas and the speed of the particles that make up the gas. In this lab students will be examining the connection between the average speed of the particles and the temperature of the sample.

Virtual Part:

(https://www.thephysicsaviary.com/Physics/Programs/Labs/ThermalSpeedWithPredictionLab/)

This lab doesn't have a real good live part to go with it, but it should be coupled with a complete discussion of the connection between temperature, speed and energy of the average gas particle.

Measuring Temperature:

Students will be estimating the temperature of the sample as best they can using the gauge provided below the container of gas particles.

Measuring Speed:

Students will be estimating the speed of the average particle as best they can using the gauge provided below the container of gas particles. Students should notice the particles are moving in random directions and that not all particles are moving at the same speed.

Working Through the Lab:

Although there are ten different temperature 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 type of gas used in the container, 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:

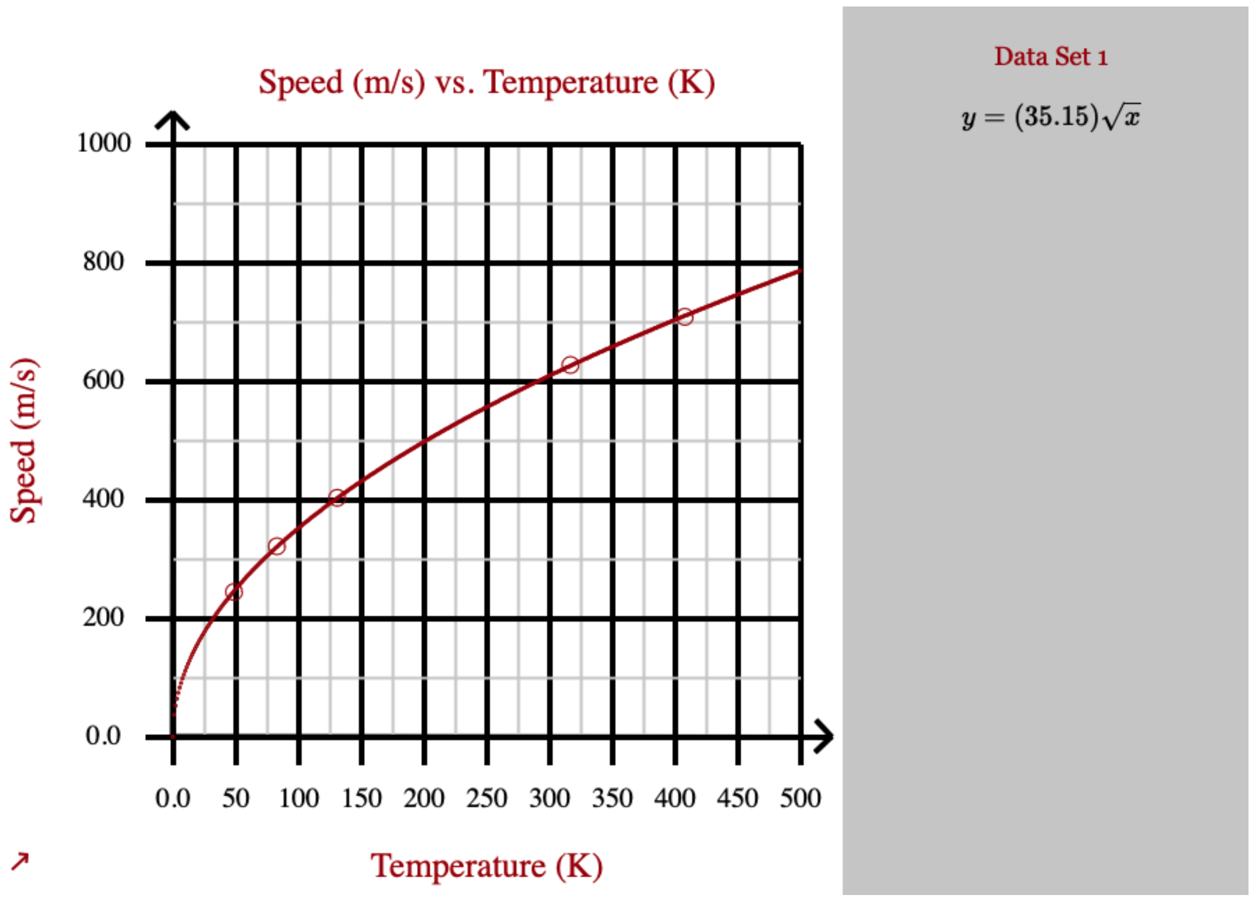
Temperature (K)	Speed (m/s)
49	244
83	321
131	403
317	627
408	708

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 temperature of the sample in Kelvin is the independent variable and should be placed on the x-axis and the average speed of the particles in m/s should be on the y-axis. Some students are going to be tempted to fit this graph with a linear relationship but a linear graph will not pass through the origin and cannot be correct. Be on the lookout for this and make sure they pick square root.

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



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

Equation:

For this graph students get a square root relationship between the variables. This indicates to them that a larger temperature will cause a larger average speed. This is something the students probably already knew, but they would have guessed that doubling the temperature would double the speed and that is not how square root graphs work. It would take a four fold increase in temperature to cause a doubling of the speed.

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 average speed in m/s and the x is the temperature in K. So the equation becomes:

$$\text{Average speed} = (\text{graph constant})(\text{Temperature})^{0.5}$$

We then want students to think about the significance of the graph constants. Prompt them by asking what over thing about the gas particles could be changed that might affect the speed of the particle besides the temperature of the system. Hopefully at least one student will realize it is the mass of the particles.

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 graph constant of their graph. Next they will use their equation to calculate the average speed for a system temperature that they didn’t collect. Finally, they will use their equation again to find the temperature required to produce a speed that they didn’t measure in their experiment.

Make a graph of temperature in Kelvin on the x-axis and average speed in m/s on the y-axis.

Use the equation of your graph to answer the questions below.

Enter Your Answer Below
Don't Enter Units

Name:	
Graph Constant:	
Speed at 675 K (m/s):	
Temperature Required for 1907 m/s (K):	

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:

Although I usually suggest a live lab counterpart to any virtual lab that you do with your students, the difficulty in getting live data similar to what we did in the virtual program makes this unfeasible for this lab.

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 with the gas particles tested in the lab. If you had a different mass gas, the graph constant would be different.

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 would happen to the graph constant if the mass of the particles were more than those tested in the lab. Have them think through an explanation on why they think this change would take place.

2. Ask the students to create another curve on their graph for a system with high mass particles.