Flow Rate from a Dispenser

Directions and Suggestions for Teacher

Purpose:

This lab is designed to show students the connection between the height of a fluid in a large dispenser and the velocity at which the fluid flows out of the faucet. Students will be able to change the height of the fluid in the dispenser and then measure the rate at which the fluid fills a beaker placed below the faucet. Once they have their graph they will it to create a mathematical model and then use the model to make predictions.

Virtual Part:

(https://thephysicsaviary.com/Physics/Programs/Labs/FlowRateFromBeverageDispenserPredictionsLab/)

This lab can easily be supplemented with a live part using dispensers that you can get at Target or even a dollar store.

Measuring Height in Dispenser:

Students should record the height of the fluid before they open the faucet. The height will change very slightly during the time students are collecting data and this should be noted as a source of error for this experiment.

Measuring Time:

When students click on the faucet, water will start to flow into the collection beaker and the timer will also begin to record the time to the nearest tenth of a second. Students can fill the collection beaker to any height, but the greater the height they use, the less significant any errors in judgment that they make will be.

Determining Volume:

Students should fill the beaker to at least a depth of 0.5 meters. The greater the depth, the better their accuracy. Then they can use the radius of the collection beaker and the depth of fluid to calculate the volume in cubic meters using Volume = $\pi r^2 h$

Calculating Volume Flow Rate:

Students will get the volume flow rate for each trial by dividing the Volume they calculate by the time that they measured.

Calculating Velocity:

Students will get the velocity of the water leaving the faucet by dividing the flow rate they calculated by the area of the opening of the faucet.

Working Through the Lab:

Although there are twelve different heights that students can start with in their beverage dispenser, 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 gravitational field where this dispenser is being used so that 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 Collection Beaker = 0.0564 m
Radius of the Faucet = 0.007 m
Area of Faucet = 1.54e-4 m^2

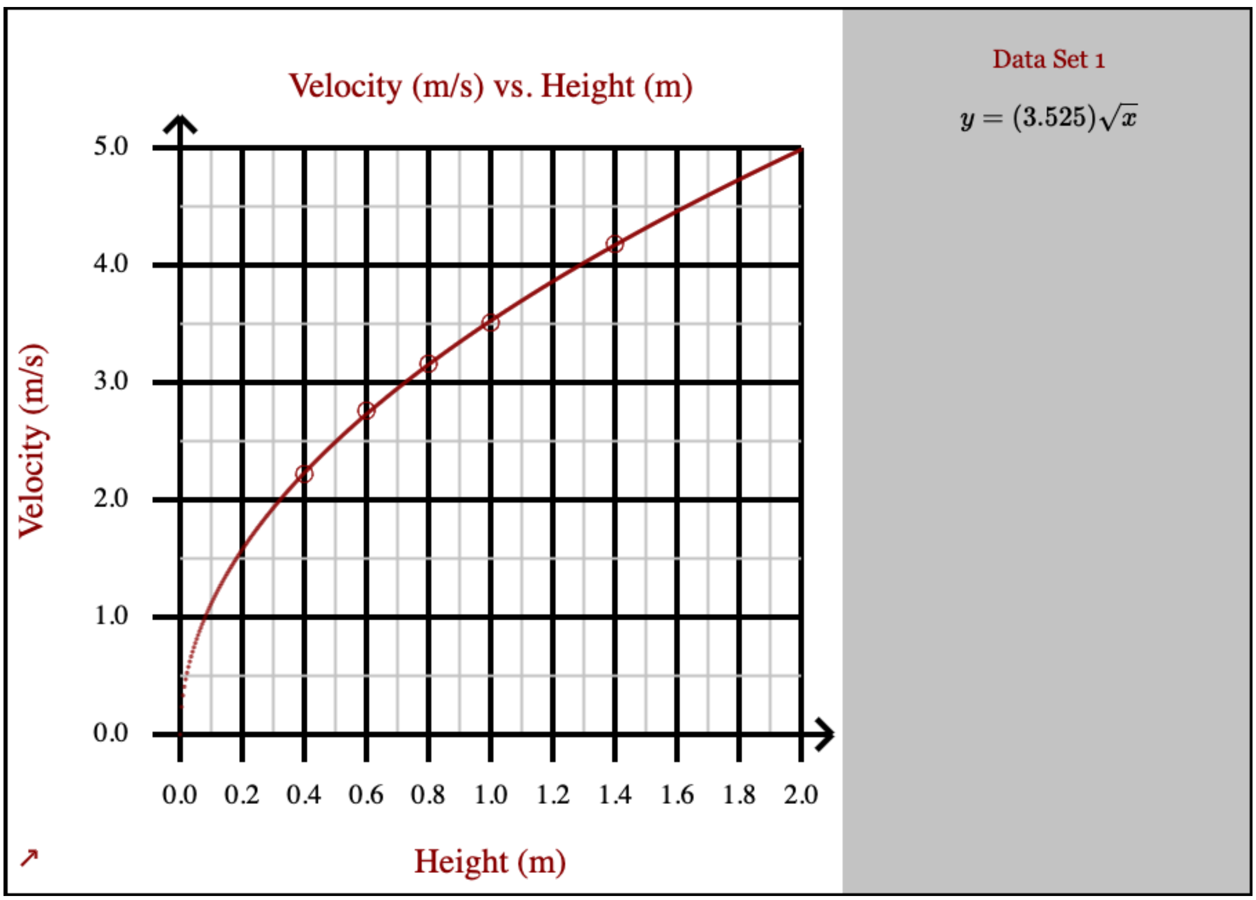
Height in Dispenser (m)	Fill Time (s)	Fill Depth (m)	Volume Collected (m^3)	Flow Rate (m^3/s)	Velocity (m/s)
1	11.1	0.60	0.0060	5.40e-4	3.51
0.8	14.4	0.70	0.0070	4.86e-4	3.16
0.6	12.0	0.51	0.0051	4.25e-4	2.76
1.4	15.4	0.99	0.0099	6.43e-4	4.18
0.4	14.6	0.50	0.0050	3.42e-4	2.22

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 height of the fluid in the dispenser is the independent variable and should be placed on the x-axis and the velocity (m/s) of the fluid coming out of the faucet 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 greater height of fluid in the dispenser will correspond to a larger velocity for the fluid flowing from the faucet. Since it is a square root relationship, it will take four times the height to double the velocity.

The equation for a square root relationship is given below.

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

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 velocity in m/s and the x is the height of the fluid in the dispenser. So the equation becomes:

$$\text{velocity} = (\text{graph constant})(\sqrt{height})$$

We then want students to think about the significance of the graph constant. We can prompt them what could have changed about the situation that would have given us different results. Hopefully there will be some students that mention the gravitational field of the planet. Some students might mention the radius of the faucet and for now you can say that we will see in a bit if that is a factor. The final thing they might suggest is the type of fluid. Higher viscosity fluids will have much slower velocities and the equation will not match what we got with this ideal fluid.

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 their graph constants for their square root graph. They will then use their equation to make predictions for information for which they didn’t collect data.

Create a graph with Height (m) of fluid on the x-axis and the velocity (m/s) of the water on the y-axis.

Enter the graph constant for your graph.

Then use the equation for your graph to find the velocity for a water height of 2.18 m.

Finally, find the flow rate of the water for that same height.

Enter Your Answer Below

Don't Enter Units

Name:

Graph Constant:

Velocity for height of 2.18 m (m/s):

Flow Rate for height of 2.18 m (m^3/s):

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:

It is always a good idea to pair a simulation with a live lab that looks at the same principles as the simulation. For this I get a beverage dispenser from Target or a dollar store and have students collect water in a large graduated cylinder to measure flow rate and velocity.

I will use a permanent marker to put 5 to 10 different height lines on the beverage dispenser. I will have the students work in groups of 4. One student has the job of pouring water into the dispenser to keep the water level at the height line they are testing. If this is not done, the change in height for the water will be significant during each trial. A second student is in charge of timing the flow of water. A third student is the one who will open and close the faucet and the final student will be holding the collection vessel and let everyone else know when to do their jobs.

The bores on the dispensers are not going to give a perfect flow of water and all fluids are going to experience losses due to viscosity. Because of this the results will not be as good as the results are for the simulation, but students will get to see the increase in speed with height and they will get hands-on experience working in a group where all the members must be working as a team.

If you don't have enough time or enough dispensers, just have each team do one trial. By giving each team a different height to work with, you can have the class pool their data and see the trends emerge.

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 biggest error is probably the viscosity of the fluid and the energy loss that takes place as it moves through the faucet. There are other minor errors like measuring heights and times, but the systematic error of viscosity cannot be eliminated

Going Further

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

1. You could ask the students to think about how the results would differ if we had a lid on the dispenser and how the “air tightness” of the lid would change the results.

2. You could ask the students how the results would change if the fluid was ketchup (real ketchup, not the stuff from the cafeteria)