

Flow Rates

Name _____

This activity will challenge you to question your assumptions about fluid flow through a system. You will consider different explanations for flow characteristics you observe in a demonstration system made of laboratory apparatus. You will collect data about outflow from the system, simulate that flow by making a computer model of the system, and analyze graphical displays of relationships in the system.

Part A: Thinking about flow

Many biological systems include some part, acting as a container, that gains and loses fluid. The fluid usually is water or an aqueous solution (water is the solvent).

Knowing how fast fluid flows into and out of the “container” helps you understand the system you are studying. The rate of fluid flow in a system is characteristic of that system. For example, an organism’s overall fluid balance can indicate its health. Doctors may monitor a hospitalized patient’s fluid intake and outflow over time, to make sure the patient’s body is not retaining too much fluid or losing fluid too fast.

1. What are some other examples of biological systems with “containers”?

2. Flow through a “container” characterizes many kinds of systems besides biological systems. What are some examples of other flow-through systems?

Systems like the examples you’ve thought of can be hard to study. They often have different flow rates under different conditions, so their flow rates change over time. In this activity you will analyze flow in a system made of pieces of laboratory equipment, and you will use a computer and the STELLA® application to construct a model of flow through the system and to determine outflow behavior over time.

The demonstration apparatus is a simple flow-through system, graduated in milliliters. You are going to observe fluid passing through the system and calculate average outflow rates in milliliters per minute.

Part B. Calculating a flow rate

You are first going to calculate the system's outflow rate. The inflow (funnel) and outflow (burette) valves are closed, and the burette contains 20 ml of fluid. The outflow valve is opened to release fluid slowly.

3. In how many seconds do 5 ml of fluid flow out of the burette?

4. What is the average outflow rate in ml/min?

5. At the rate you calculated in question 4, in how many minutes should the burette empty?

You are next going to calculate the system's inflow rate. Suppose the system is in its original state, with 20 ml of fluid in the burette and both valves closed. The inflow valve is opened to allow fluid to enter at a slightly faster rate than the outflow valve was previously set to allow fluid to escape.

6. In how many seconds should 5 ml of fluid flow into the burette?

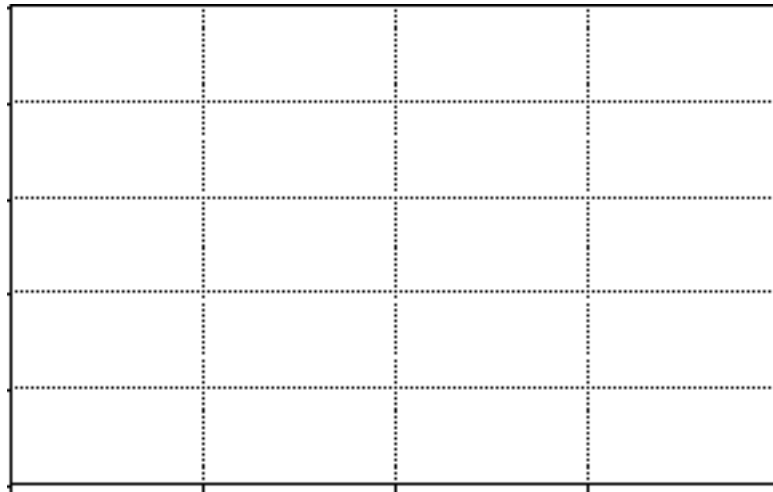
7. What is the average inflow rate in ml/min?

8. At the rate you calculated in question 7, in how many minutes will the burette fill to 50 ml if it contains 20 ml when filling starts?

Suppose that the system is in its original state, holding 20 ml of fluid with both valves closed. The inflow valve and outflow valve are opened at the same time and set at enough drops per second to deliver 4.0 ml/min into the burette and 1.5 ml/min out of the burette.

9. How many minutes do you think it will take to fill the burette to 50 ml?



10. What would a graph of burette volume versus time look like? Use the blank graph below to sketch your prediction. Label the x-axis TIME in min and mark the scale from 0 to 12; time is the independent variable. Label the y-axis BURETTE VOLUME in ml and mark the scale from 0 to 50 ml; volume is the dependent variable.



Part C. Constructing the model



To make a computer model of the laboratory apparatus flow-through system, you are going to combine STELLA® elements and assign values to them.

- Double-click the STELLA® icon to open the application.

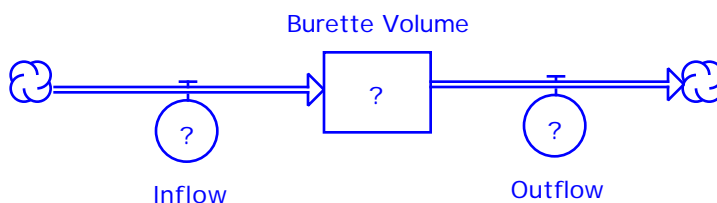
- Click the icon of the world . It changes to , so you can enter values.

The tool bar across the top of the screen looks like this:



- Click the stock icon . Slide the icon into the upper part of the blank window and click again. A stock called Noname 1 should appear. Type Burette Volume to rename the stock, which represents the fluid in the burette.
- To represent flow into the container, click the flow icon , place it to the left of the burette volume stock and drag its arrow into the stock. Name the icon Inflow.
- For flow out of the container, position a flow icon inside the stock and drag its arrow out of the stock to the right. Name the icon Outflow.


Your model should look like this:

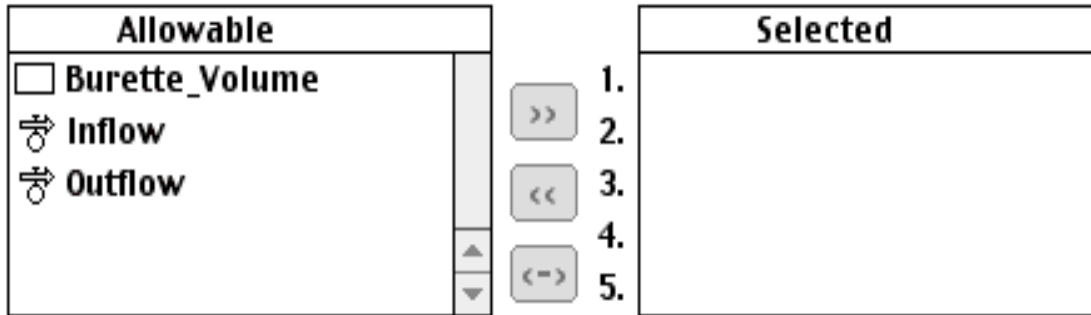


Question marks in the three icons indicate that no values have been entered.

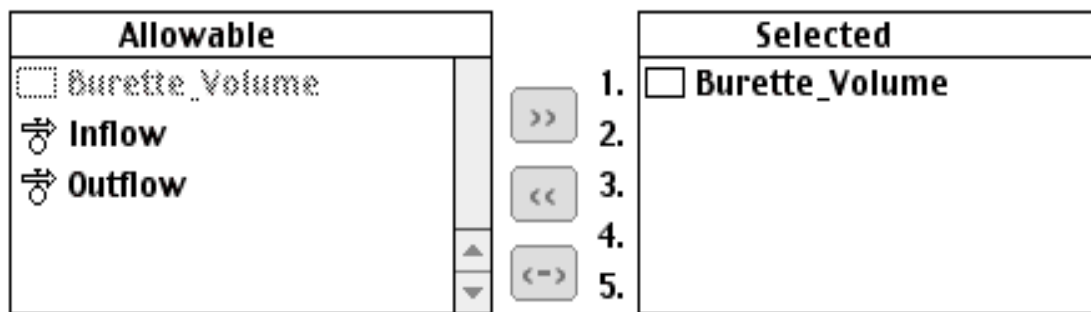
- Double-click each question mark and enter in the equation box of the window that opens the values for the system you are studying. For Burette Volume, enter 20 {ml} under Initial. For Inflow and Outflow, enter the appropriate rates and put the measuring unit in braces. Inflow = 4 {ml/min}, Outflow = 1.5 {ml/min}. When you use STELLA®, you must always place the unit of measure in braces, {}.
- Click OK after you enter each value.

To see how the burette volume responds to the inflow and the outflow, you can use STELLA® to generate a graph of burette volume as a function of time.

- Click the graph icon , place it below the model, and click again. A large blank graph should appear.
- To prevent the graph from disappearing every time you run the model, pin the graph to the window. Move your pointer to the horizontal title bar at the top of the graph and click-and-drag the graph so it fits in the space below the model. Click the black circle (looks like a push pin) in the upper left corner of the graph. The pin's point and graph's title bar disappear, and the graph stays in place until you unpin it (click the pin).
- Double-click the blank graph. A new window will open. You will see two boxes, which look like the ones on the next page.



- To select burette volume as the dependent variable, click Burette_Volume in the Allowable box, then click the >> symbol (or double-click Burette_Volume). STELLA® will move the Allowable input you have chosen into the Selected box. The boxes now look like this:



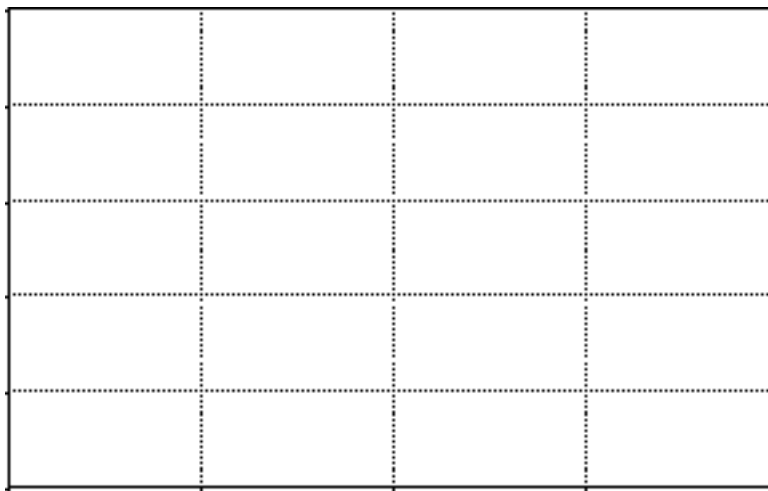
- To compare the STELLA® graph to your prediction in question 12, you need to make sure the STELLA® graph scale for Burette_Volume is the same as the scale of your prediction graph. Click once on Burette_Volume in the Selected box. Then, click once on the double-headed arrow to the right of Burette_Volume. Look for the Scale: boxes in the window. Set Min to 0.000 and Max to 50.00.
- Click OK.

Part D. Running the model

To run the model,

- Open the Run menu. Slide down to Run on the pull-down menu and release the mouse button. A line will form on the graph.

11. On the blank graph below, sketch the line that your model creates. Label the x-axis TIME in min and the y-axis BURETTE VOLUME in ml.



12. How does the model result compare to your prediction?

Part E. Comparing the data

While you were making your STELLA® model, fluid has been flowing through the burette. You are going to test your model by comparing its results to the behavior of the demonstration system.

13. How does the volume change indicated by the graph generated by your model compare with the real change in burette volume?

14. Why do you think the burette has not filled? Write down all the possibilities that you can think of.

15. What assumptions about the apparatus and the flow through it could you check?

16. What part of the system will you measure to see if the flow rates are constant?

17. How will you use the demonstration apparatus to make your measurements?

Part F. Checking the system

To check the assumption that outflow is constant, you are going to measure the outflow and calculate the flow rate. During the experiment you will record data as you observe fluid passing through the apparatus. From these data you will calculate the average outflow rate and graph outflow rate versus burette volume.

For the experiment your teacher is going to fill the burette above 50 ml, close the inflow valve, and open the outflow valve slightly. Fluid will begin flowing out of the burette.

Start counting seconds when the fluid level passes the 50-ml mark. At that moment, the elapsed time, volume change and outflow all equal zero.

18. Record your observations in the blank table below.

OBSERVE 1	OBSERVE 2	CALCULATE 1	CALCULATE 2	CALCULATE 3	CALCULATE 4
Burette Volume (ml)	Elapsed Time (sec)	Volume Change (ml)	Seconds per 5 ml	Average Outflow (ml/min)	Corresponding Burette Vol ml
50	0	NA	NA	NA	NA
45					
40					
35					
30					
25					
20					
15					
10					
5					

You have recorded your observations as the burette emptied. You will use these data to calculate the change in burette volume, the change in time, and the outflow rate.

19. In the CALCULATE 1 column, write the volume change in milliliters for each observation point.

20. In the CALCULATE 2 column, write the time interval in seconds between each observation point.

21. In the CALCULATE 3 column, write the outflow rate in ml/min. In the space below, write the formula you will use to calculate the outflow rate.

22. Each outflow rate you have calculated is an average for a particular 5-ml interval. What value in a volume interval would an average outflow rate correspond to—the first, the middle, or the last value?

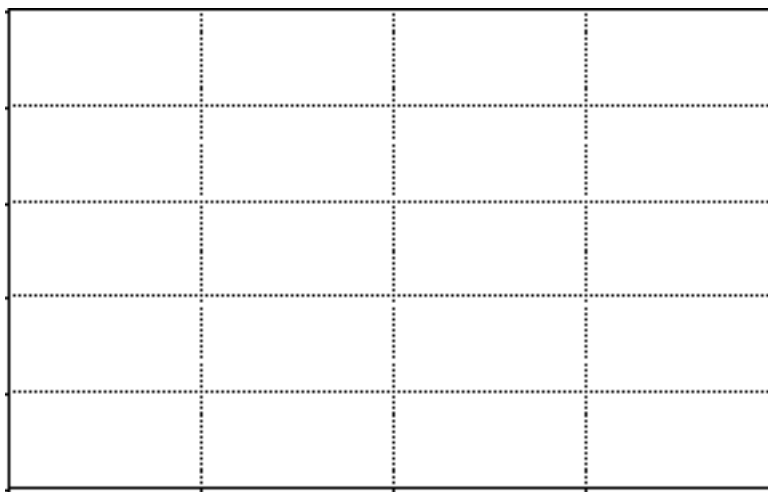
23. In the CALCULATE 4 column, write the specific burette volume to which each average outflow rate corresponds.

24. Describe what happens to the outflow rate.

Part G. Graphing the data

You are going to show your experimental observations on graphs.

25. On the blank graph below, label the y-axis OUTFLOW RATE in ml/min and the x-axis BURETTE VOLUME in ml. Mark the axes. Enter your data points and sketch the curve that you think represents the outflow data in your table.



Part H. Writing the equation

The line on the graph that shows the change in outflow with respect to burette volume represents the outflow rate. The line can be expressed by an algebraic equation.

26. What equation expresses the experiment's apparent average outflow rate (dependent variable) as a function of burette volume (independent variable)?

27. You have disproved the initial assumption that the outflow rate from the burette remained constant. Why do you think the outflow decreased during the experiment instead of remaining constant?


28. Do you think the inflow rate will also vary during the experiment? Defend your answer.

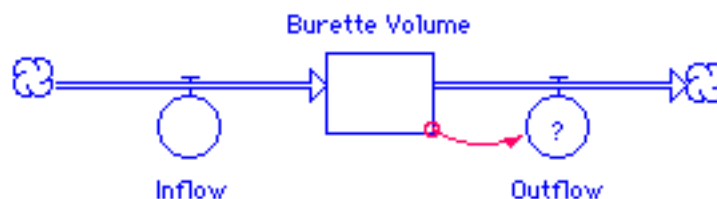
29. Design an experiment to test your hypothesis.

At this time, your teacher may ask you to conduct the experiment designed in question 29. Or, he/she may direct you to go on to Part I based on the assumption that the inflow rate remains constant.

Part I. Modifying the model

Modifying a model to better simulate a real system is part of the scientific process. You are going to change your model design to reflect the relationship between outflow rate and burette volume by adding a connector from the burette volume stock to the outflow flow. The connector sets up the feedback between outflow rate and burette volume that you described in questions 26 and 27. The model's outflow rate will now depend on the volume of fluid in the burette.

- Click the Connector icon . Position the connector's arrow tip inside the burette volume stock and drag the arrow to the outflow flow. A question mark appears in Outflow indicating that a new value must be entered. Your model now looks like this:



30. How will you change the Outflow value?

- In the model, double-click the Outflow question mark. In the Outflow dialog window, replace the constant 1.5 {ml/min} with the equation you obtained from your data. You can click the window's keypad and Required Inputs to enter the equation or you can type the equation using your keyboard. Click OK.

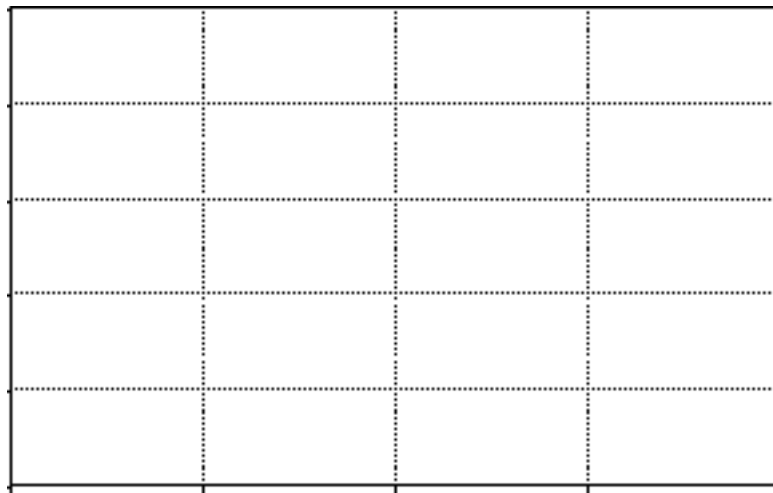
While you work on your model, your teacher will run the demonstration again, with 20 ml of fluid in the burette and inflow greater than outflow.

- To allow the model to run for a longer time period, use Time Specs... under the Run menu. Set Length of Simulation: from 0 to 60. For Unit of Time: type Minutes in the Other category. Click OK.
- Run the model.

Part J. Validating the model

You can compare your model results with the actual behavior of the demonstration system.

31. On the blank graph below sketch the curve the model generates. Label and mark the axes and title the graph.



32. What does the shape of the curve tell you about the change in burette volume?

33. How does the model output compare to the result from the demonstration system?

34. In questions 1 and 2, you selected real world problems for which the burette experiment might serve as a model. Now that you recognize that the burette apparatus has an inflow rate which is constant, but an outflow rate which is dependent on the burette volume, write a paragraph explaining how well the burette apparatus fits your real world problem.