Rates: Change, Growth, and Motion
Part Three: THE FLOW OF A RIVER

What does speed have to do with climate? If you are talking about the speed of a tortoise, speed and climate might not be related. Then again, maybe tortoises can move faster in warm climates than they can in the cold. Maybe it's the other way around. That could be an interesting subject of research for some scientist, maybe you, but not today.

If you are talking about the speed of the wind or the flow of a river, the speed could have a great deal to do with the climate. When do rivers run the fastest? What contributes to a high river or a low one? Could a change in the flow of a river actually create a change in climate somewhere? Can you think of other things that move with rates of motion that influence or are influenced by the climate?

If this course is going according to plan, you and/or your classmates have either just made measurements at a local stream and river or you will do that soon. You may not have understood the importance of the measurements. In this unit we will look through our data to see how much information we can get out of it.

What's data? What's information? Take a look below.

**Data:** a bunch of stuff that is informative to somebody but might not be understood by ordinary people without special training. The following is data:

(0, 1., .126, .992, .249, .968, .369, .929, .483, .876, .589, .808, .686, .728, .773, .634, .841, .540, .904, .427, .952, .306, .982, .190, .998, .608e-1, .998, -.592e-1, .982, -.188, .949, -.314, .905, -.425, .842, -.539, .772, -.636, .683, -.731, .582, -.813, .481, -.877, .363, -.932, .249, -.969, .121, -.993, -.841e-2, -.100, -.128, -.992, -.256, -.967, -.369, -.929, -.487, -.874, -.596, -.803, -.688, -.726, -.776, -.631, -.846, -.533, -.908, -.419, -.955, -.298, -.983, -.181, -.999, -.524e-1, -.998, .676e-1, -.981, .196, -.947, .322, -.901, .433, -.838, .546, -.766, .642, -.677, .736, -.575, .818, -.473, .881, -.355, .935, -.241, .971, -.113, .994, 0.00, 1.00)

**Information:** a bunch of stuff that actually means something. Sometimes data only becomes information after patterns have been recognized and presented. If we laboriously group the data above into pairs and plot the pairs as points on an “xy” graph, they look like this:

![Circle Diagram](image)

We can all recognize a circle. One image of a circle conveys more information (to most people) than all of the data that went before.

Our job is to find information in our creek and river data.

**POSITION AND TIME DATA**
Whether you are using measurements that you made yourself, measurements taken by a classmate, or data copied from the Internet, you should have a bunch of position and time data for objects floating on the surface of the water. Before you start working with the data, you should take a moment to think about the difference between the ways that the tortoise data and the river data were taken. For the gedanken-tortoise we “watched” the tortoise move and at specified times we recorded its position (one second, three seconds, five seconds, etc.). Our measurements of time were fixed in advance, and we waited to see where the tortoise would be at those times. For objects floating on the river, we probably had observers at specified positions that recorded the time when the object floated past.

1. Why do you suppose the experimenters chose different methods?

   a) In an Olympic foot race, such as the 100-meter sprint, which method is used?

   b) Can you think of competitions in which the other method is used?

2. A student who noticed the difference between the tortoise data and the river data made the following observation:

   For the tortoise data, time was the independent variable, position was dependent on the time, and so we found the speed of the tortoise by dividing “change in position” by “change in time.” For the river data, position is chosen in advance, dependent and independent variables are reversed, and so we find the speed by dividing “change in time” by “change in position.”

   Do you agree or disagree? Explain your reasoning.
You can use your own data (or the data from the Internet) in a moment. First consider the data in the table below. It describes the position of an imaginary object floating down an imaginary river.

<table>
<thead>
<tr>
<th>Position</th>
<th>Time</th>
</tr>
</thead>
<tbody>
<tr>
<td>0 m</td>
<td>0 s</td>
</tr>
<tr>
<td>10 m</td>
<td>6 s</td>
</tr>
<tr>
<td>20 m</td>
<td>15 s</td>
</tr>
<tr>
<td>30 m</td>
<td>24 s</td>
</tr>
</tbody>
</table>

1. If you look only at the data over the first ten meters and then look only at the data over the last ten meters, do the two sets of data give you the same speed of the river? *Briefly* explain your answer.

2. In the case of the tortoise, we interpreted data like this by saying that the tortoise was moving with *different speeds at different times*. Do you think that is what is going on for this river? Does it seem reasonable to guess that the “speed of the river” changed substantially during the 24 seconds in which this data was taken?

3. Aside from assuming that the flow of the river dramatically changed during these 24 seconds, what other explanation could there be for the data?
4. Can you think of a situation where the water in a river would have to move faster in one area than it would at areas slightly upstream and downstream? How many different causes of this kind of flow can you think of? (List some here.)

5. Of the causes above, can you think of any reasons why a river would flow more quickly in one area than it does upstream and downstream even if there is no change in the slope of the land? Don’t panic if you can’t (we’ll deal with it later), but try to draw a picture of what such a river might look like from above.

We almost always like to use time as an independent variable. If we are doing an experiment, it is easy to change the place of an object forward and back, but it is hard to move the time forward and back (without the help of daylight savings time).

**GRAPHING:**

In the space below, make a graph of the data of the position of the imaginary object on the imaginary river.

```
0 5 10 15 20 25
0 5 10 15 20 25
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1. How do we find speed from the graph? What does your graph tell you about the speed of this object as it floated downstream?
2. Imagine (think hard) that you only have time data from the first and the last position (TWO positions) of an object floating down a river. What information can you get? (There is a name for this, remember?)

3. What information could you get for our imaginary object (graph at the top of the page) that you cannot get for an object if you only have those two pieces of time data?

4. Now imagine (keep thinking) that you have lots of time data from several positions for an object floating down one river but only time data for two positions of an object floating down another. Is there anything you could do to compare the data?
Before we go on, a thought question: Imagine a marshmallow (we’ll call him Bob) floats 100 feet in ten seconds along the surface of the Green River. Another marshmallow (we’ll call her Mary) floats 100 feet in ten seconds along the surface of Soos Creek.

1. What is the same for the two rivers? Be specific. If you were to measure this quantity that is the same, what units might you use?

2. What is different about the two rivers? Is the same amount of water flowing through each river every second? How could this be different if the marshmallow data is the same?

You should have come to the conclusion that the speed of a river is not the same as the flow rate or discharge of the river (“flow rate” and “discharge” are essentially two ways of saying the same thing). Question 1 above refers to speed, much like the speed of the tortoise. Question 2 refers to discharge. One of our goals is to be able to correlate discharge (which is hard to measure) with speed (which is easy to measure).

1. Do you suppose that speed and discharge are related in any way? How might they be related? (Take a guess.)

2. What factors other than speed might enter into discharge?

We will come back to discharge soon. In the meantime, you have an assignment…
AND NOW THE REAL DATA…

In groups of three or four, gather together the “real” position and time data. Your data may come from your own experiments, measurements made by your classmates, or (if you don’t have either of those) the Internet. If you haven’t done so already, review the last section with the other members of your group to see if you can all agree on the way that the imaginary data was handled.

Now, staying in your small groups, look at the "position and time" data that your class collected. You should have one set of data from Soos Creek and another from the Green River. Both sets of data should describe the position of objects (sticks? marshmallows?) floating on the surface.

Your job is to study this data, see what information you can discover, and present the results in a way that you and your group-mates feel conveys the most information.

Another way of saying that is that your group needs to produce a lab report, although "field report" may be a better description. There is no single best way in which to produce a report, although a good one will include the following characteristics:

1. A very short summary or abstract at the beginning of the report that explains what the report is about. An abstract should be only a few sentences long and should summarize what was done and what was learned. Hint: Since the abstract is one of the hardest parts of a report to create, it is often easiest if it is written last, even though it comes at the beginning of the report. Write the rest of the report first, then go back and write an abstract.

2. A description of what was done to produce the research. This might be a description of an experiment or a description of how and where field observation was done (or both). There should be enough description to allow a reader to know what to do to repeat the research if necessary.

3. A report of the data collected. Remember, data alone is boring and hard to read. Do your best to organize it (as in tables) and present it (as in graphs) in ways that are quick and easy to read. The better the presentation of the data, the easier it is to write and read the report.

4. Conclusions from the data. There are almost always some inferences that can be drawn from the data. Inferences should be suggested along with an idea of the author's degree of confidence in the inferences. Sometimes the reasons for a lack of confidence in the inferences can suggest further research.

Think of the questions that your data might be able to answer. Is the river moving faster in some areas than in others? Is the river faster than the creek or vice versa? Is there any way to tell from the data which is the creek and which is the river? Keep your questions in mind as you study your data. See what information emerges, and write a brief report (one per group) summarizing your results.
End of Module Questions:

1. The graph below shows the position of a toy car as a function of time during a four second period. (Note: the toy car can move forwards or backwards in a straight line but cannot turn left or right.)

   ![Position as a function of time graph]

   a) In your own words describe the motion of the toy car during those four seconds.

   b) Consider the motion at the times labeled 0.5 s, 1.5 s, 2.5 s, and 3.5 s.

   i) Of those four times, when was the car moving the fastest? You don’t need to do any calculations yet unless you want to, but explain your reasoning.

   ii) Now calculate the speed of the toy car at the time when you think it was moving the fastest. Show your work.
2. A group of students used two marshmallows ("marsh 1" and "marsh 2") to determine the characteristics of a local stream. Students were stationed along the bank of the stream with stopwatches and recorded the times as the marshmallows floated by.

<table>
<thead>
<tr>
<th>Marsh 1</th>
<th>Marsh 2</th>
<th>Distance in feet</th>
</tr>
</thead>
<tbody>
<tr>
<td>Time in sec</td>
<td>Time in sec</td>
<td></td>
</tr>
<tr>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>10</td>
<td>5</td>
<td>5</td>
</tr>
<tr>
<td>25</td>
<td>15</td>
<td>20</td>
</tr>
<tr>
<td>40</td>
<td>26</td>
<td>35</td>
</tr>
<tr>
<td>60</td>
<td>41</td>
<td>55</td>
</tr>
<tr>
<td>70</td>
<td>49</td>
<td>65</td>
</tr>
<tr>
<td>90</td>
<td>60</td>
<td>80</td>
</tr>
<tr>
<td>92</td>
<td>71</td>
<td>95</td>
</tr>
<tr>
<td>100</td>
<td>75</td>
<td>100</td>
</tr>
</tbody>
</table>

a. Graph each set of data in a graph of the distance as a function of the time on the graph paper provided.

![Graph of Marsh 1 vs Marsh 2](image)

b. Which marshmallow had the highest average speed, marshmallow 1 or 2? What is your reasoning for your answer?

c. Is there any time at which marshmallow 1 is going faster than marshmallow 2? Explain your answer.
d. Is there any time at which marshmallow 2 is going faster than marshmallow 1? Explain your answer.

<table>
<thead>
<tr>
<th>Time in sec</th>
<th>Distance in feet</th>
<th>Marsh 1 vel/ft/sec</th>
<th>Marsh 2 vel/ft/sec</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>10</td>
<td>5</td>
<td>0.5</td>
<td>1.0</td>
</tr>
<tr>
<td>25</td>
<td>20</td>
<td>1.0</td>
<td>1.5</td>
</tr>
<tr>
<td>40</td>
<td>35</td>
<td>1.0</td>
<td>1.36</td>
</tr>
<tr>
<td>60</td>
<td>55</td>
<td>1.0</td>
<td>1.33</td>
</tr>
<tr>
<td>70</td>
<td>65</td>
<td>1.0</td>
<td>1.25</td>
</tr>
<tr>
<td>90</td>
<td>80</td>
<td>0.75</td>
<td>1.36</td>
</tr>
<tr>
<td>92</td>
<td>95</td>
<td>7.5</td>
<td>1.36</td>
</tr>
<tr>
<td>100</td>
<td>100</td>
<td>0.625</td>
<td>1.25</td>
</tr>
</tbody>
</table>

e. On our field trip we will probably find that marshmallows are faster in the middle of the stream. Which of the marshmallows was in the middle? Explain your answer.