

Background information:

Water is a substance unlike any other. If not for its unique properties, life as we know it could not possibly exist. Water is one of only a handful of substances which are less dense as solids than as liquids. The lower density of ice as opposed to water accounts for the fact that ice floats on water. Imagine what would happen to ocean and pond life if ice sank instead of floating.

Water molecules are made up of an oxygen atom, which has a partial negative charge, and two hydrogen atoms, which have partial positive charges. Water is thus said to be polar because it has a positive end and a negative end. Since unlike charges attract, the oxygen atom on one water molecule is attracted to the hydrogen atom of another molecule. Therefore, water molecules are attracted to one another. In addition to the attraction caused by the polarity of the molecule, water also exhibits hydrogen bonding. A hydrogen bond is a special type of relatively weak bond between a partially positive hydrogen atom of one molecule and a partially negative atom of another molecule.

Water is especially cohesive because of its polarity and hydrogen bonding. Cohesion is the attraction between molecules of a substance. The cohesiveness of water causes it to have a high surface tension. Surface tension results from molecules on the surface of a liquid being attracted only to molecules on the sides or underneath, whereas the molecules not on the surface are attracted to molecules on all sides. This difference in attractive forces causes a liquid to assume a shape with minimum surface area – a sphere. In other words, water drops are spherically shaped because of surface tension.

Water also exhibits adhesion to certain substances. Adhesion is the attraction between a molecule of one substance and a molecule of another substance. The adhesive and cohesive forces of water lead to capillary action. Capillary action is the movement of a liquid up a narrow tube. For example, water in a narrow glass tube will be attracted to the glass because of adhesive forces. These forces cause the water to move up the walls of the tube. The water molecules which cling to the glass due to adhesion will pull up additional water molecules because of cohesion.

Materials such as a paper towels absorb water through capillary action. Paper is composed mostly of fibers made of cellulose. Cellulose molecules are long molecules which form tiny tubes within a substance like paper. When a substance such as paper absorbs water, the process is facilitated by the capillary action of the water in these tubes.

Objective: To develop a model for the rate of growth of a straw wrapper as a result of capillary action

Materials: Straws with wrappers
metric ruler
Digital camera capable of taking a mini-movie
Graphing calculator
jumbo paper clips
chalkboard erasers
water
paper towels

Procedure:

1. Remove straw from wrapper by “scrunching” it down to one end.
2. “Unbend” and straighten the paper clip as much as possible. Stick the straightened paper clip through the straw wrapper.
3. Arrange the ruler and straw wrapper as shown in the diagram. Make sure that you can clearly see the straw wrapper and ruler markings on the camera LCD panel.



4. Place the straw into the water at a depth of one inch. Place your finger over the other end of the straw so that the water will not spill out when you remove the straw from the water.
5. Hold the straw with the water in it over the middle of the straw wrapper.
6. Start recording the movie just before you release the water from the straw onto the straw wrapper.
7. View the movie you recorded. If you did not get good results, dry your workspace and repeat the procedure until you get a good movie. It may take several attempts.
8. Advance through the movie frame by frame and record the beginning and ending positions in the table below. Look in the camera’s manual to determine the time between frames. Record the total elapsed time in the table.

5. Enter these values into your calculator.
6. Create a new list made up of the Right Endpoint minus the Left Endpoint. This list contains the length of the wrapper at any specific time.
7. Graph length versus time.
8. Use the statistical capabilities of your calculator to determine what type of function best models this data.

Questions

1. What type of function best fit your data? Write the equation for the function.
2. What was the second best function? Write this function?
3. Why did you pick the function in Question 1 as being better than the function in Question 2?
4. Can you give any physical reason why your function is a good mathematical model?
5. Estimate the volume of the straw wrapper. Explain how you came up with your estimate.
6. Estimate the volume of water that you placed on the wrapper. Explain how you came up with this estimate.
7. How much of the water did the wrapper absorb?

Extensions

1. Repeat the experiment a number of times using a dropper to release the water onto the straw wrapper. Each time you repeat the process, use one more drop of water. Graph the total growth of the wrapper versus number of drops. What kind of function is this?
2. Repeat the experiment a number of times, dropping the water over a different portion of the wrapper each time. That is, on the first trial, drop the water on the very end of the wrapper. On the next trial, drop the water a little closer to the center, and so on. Record the total growth and the growth as a function of time. Does placing the water in a different spot change the results? Explain.
3. Try crumpling up the straw wrappers in different ways before dropping the water on it. Do the wrappers seem to expand as much? Report your results and explain.

TEACHER NOTES: The questions have no easy answers. As a matter of fact, the author of this lesson does not know the *right* answers. It is the process of thinking, hypothesizing, and justifying answers that is really being tested.