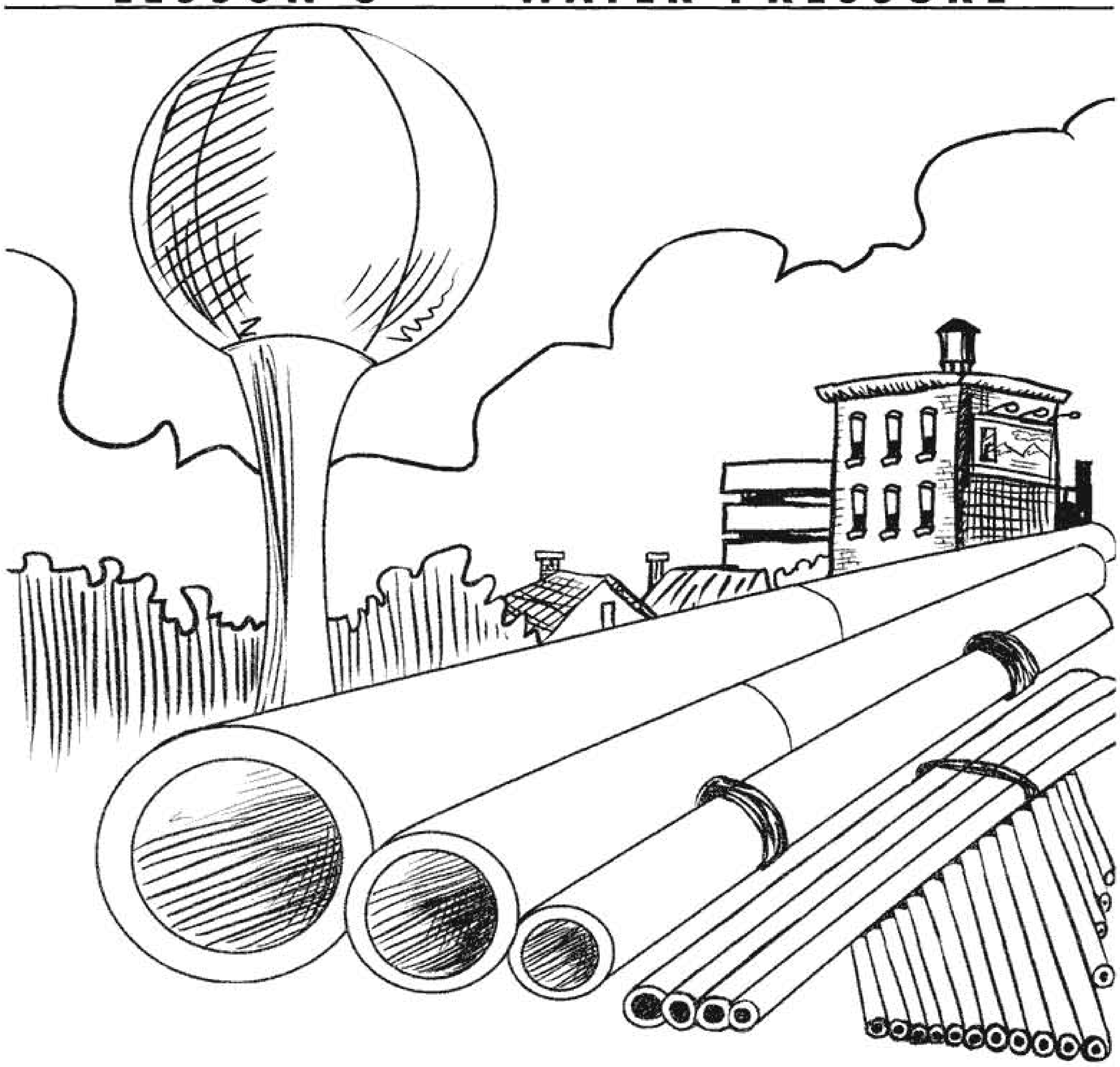
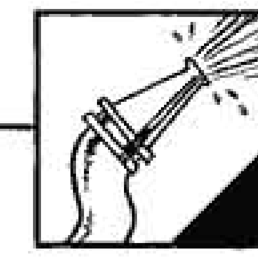
LESSON 3 WATER PRESSURE



LESSON 3 WATER PRESSURE

Water flows freely in our bathrooms and kitchens at the turn of a faucet. Students know it arrives through pipes, and they will tell you that "water pressure" pushes it out. This lesson leads students to explore two variables in water flow: the diameter of pipes and the elevation difference between water's storage and its users.

Both activities use variations of the same apparatus. In the first, students measure flows through two different diameter tubes. In the second, they construct a system much like the one they use every day: elevated storage, delivery at ground level into buildings, and flow in upper stories. In both cases they are working in teams to manipulate an apparatus, collect data, answer questions, and draw conclusions. These activities will bring some basic laws of fluid mechanics to bear on their daily water use and the model will help them visualize aspects of water systems that are usually hidden from view.



ACTIVITY 3-1 Hydraulics - Size of Pipes

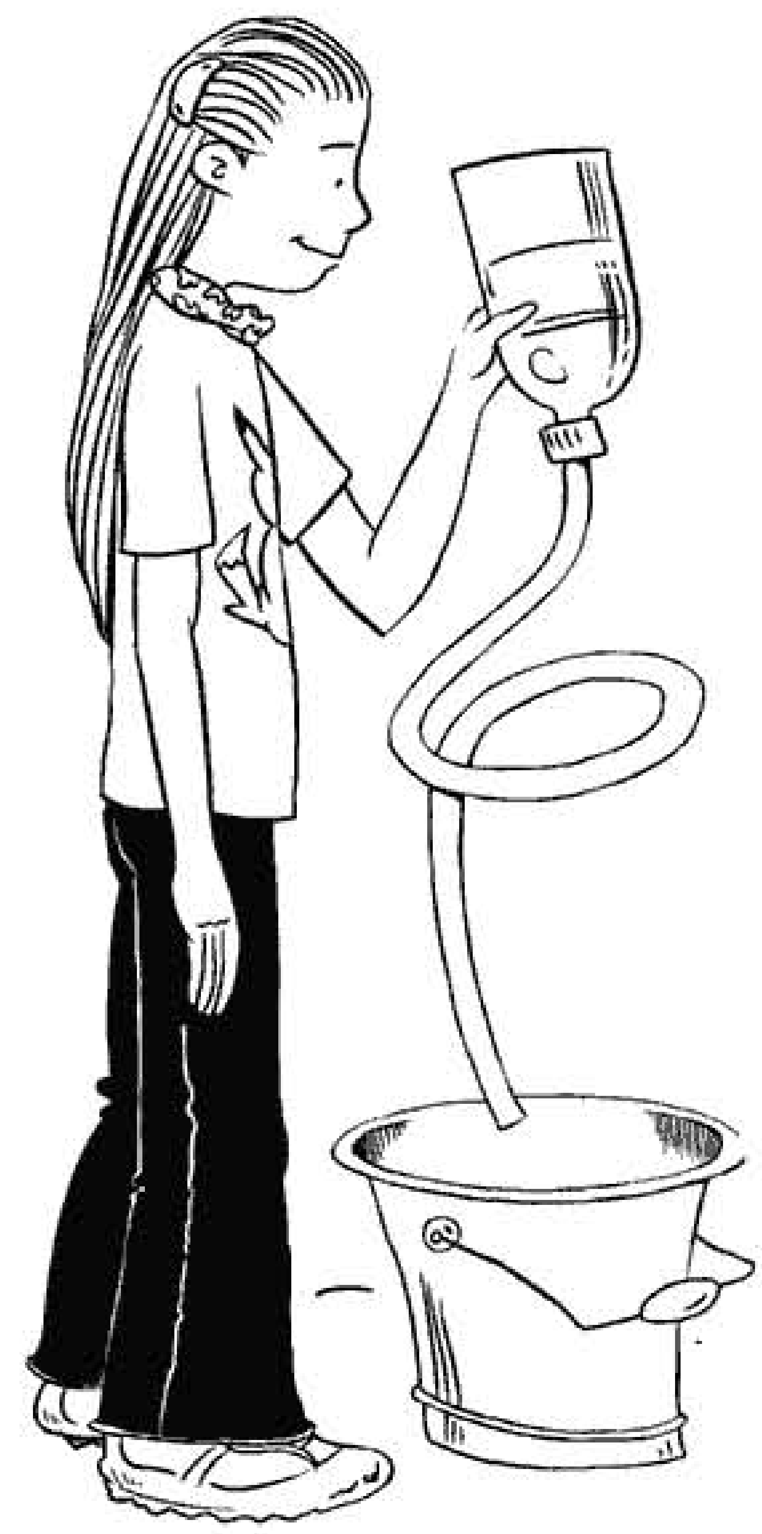
Summary Students collect and analyze data on the time required for water to move through two different diameter tubes.

Content Areas physical science, math

Goal to demonstrate the difference that pipe diameter makes to the amount of water delivered

Time one session

Materials For each group:
-water, paper towels
-a hydraulics apparatus (see construction procedure below)
-a bucket
-a .5 liter measuring cup
-a watch that can read seconds, or a wall clock with second hand
-student pages
-optional: calculators

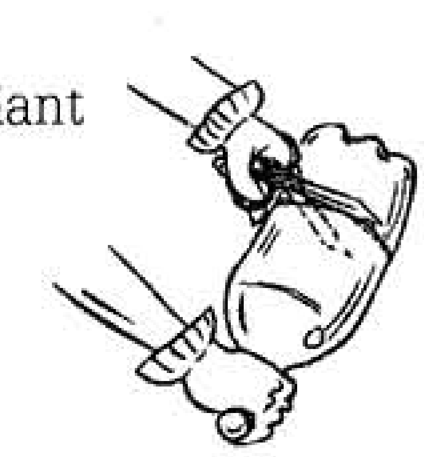


Advance Preparation

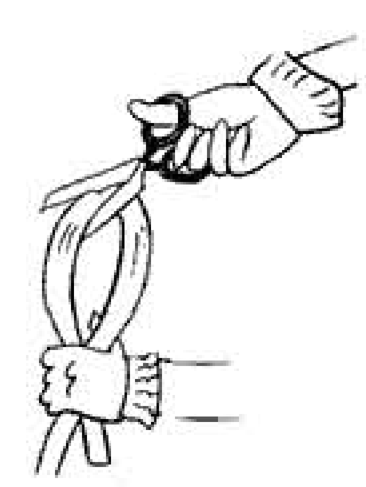
- Create student working groups.
- Copy student pages.
- To construct the student hydraulics apparatus, you will need:
  - plastic bottles; 1 liter bottles are best; bottles with wider caps are preferable but not necessary
  - 2 caps for each bottle
  - 3-foot lengths of vinyl tubing in two sizes:
    a. 3/16" inside diameter (5/16" outside diameter)
    b. 3/8" inside diameter (1/2" outside diameter)
  - electric drill
  - optional: plumber's adhesive sealant

Construction Procedure

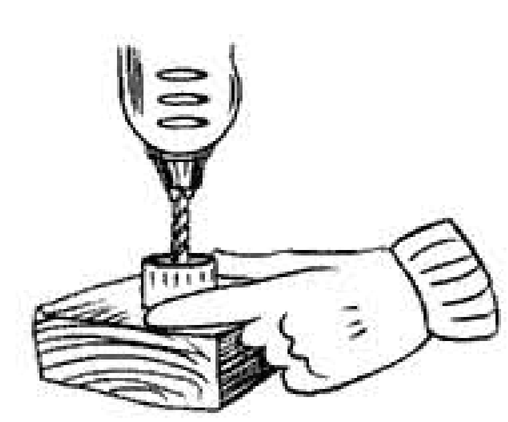
1. Cut off the bottom of each bottle.

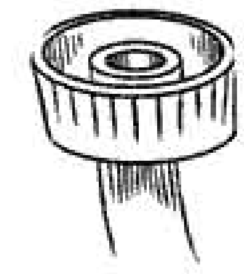


2. Cut 2 3-foot lengths of vinyl tubing, one 3/16" and one 3/8"

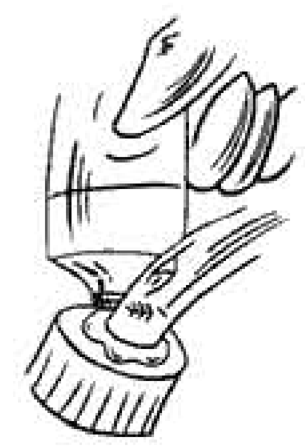


3. Remove any inside gasket from the inside of the cap and carefully drill either a 5/16" or 1/2" hole through it. Wear gloves, and place cap on a surface, such as a block of wood, to protect the work surface. Suggestion: hold cap right-side up, set drill to reverse, and apply pressure. You will effectively melt your way through, leaving a better hole in the cap.





4. Insert one end of each tube through the cap about 1/2". It should fit snugly.



5. Optional: Apply sealant to the tube on both sides of the cap, work the tube back and forth once or twice, and allow to dry.

6. When screwing the cap back onto the bottle until it seals tightly, hold the cap steady and turn the bottle to minimize strain on the sealant.

Background Information

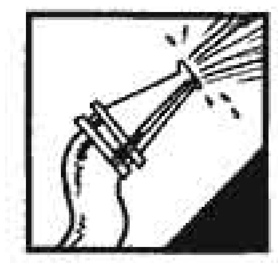
This activity allows students to demonstrate for themselves the difference that pipe diameter makes to the amount of water delivered.

Municipal water systems and household plumbing use many different sizes of pipes. The pipes in the streets are larger than those leading into buildings, and those inside buildings are smaller still. Most students will recognize that larger pipes can carry more water, and that the pipe from the town well or reservoir must transport water for many people, while the pipe to a bathroom sink supplies just one user at a time.

By choosing two tube sizes, one exactly twice as large as the other, we also introduce an interesting geometric concept: that doubling the diameter of a cylinder quadruples its cross-sectional area. If students perform the experiment carefully and look at data from the whole group, they may discover that when tube diameter doubles, water moves four times as fast. Allow them to discover this relationship themselves; if they don't, simply accept "faster and slower." Hands-on guided learning gives students the opportunity to discover relationships for themselves when they are ready to see them. The teacher's job is to prompt them when they are close but not to supply them with answers too soon.

The size of the tube is only one variable that determines rate of flow; the other is the difference in elevation, which is the subject of the next activity, 3.2. For the purposes of this activity, be certain that the tables or desks from which students work are all the same height, or distance from the floor.

If data is inconsistent from one group to another, observe whether students are holding the end of the tube at the bottom of the bucket, as directed, or within the bucket but higher from the floor. You may suggest that students try keeping the bottle and bucket at the same elevations but raising the



end of the tube to see what effect that has on the time (flow rate).

TEACHER PROCEDURE

1. Ask students how water reaches their faucets. When they mention pipes, ask them where the pipes are and how big they are. Pipes are sized according to "inside diameter," or the distance from one inside wall to the other. After brief discussion, tell them they will be doing an activity with water moving through pipes.

2. Divide students into working groups. Groups of at least three students are recommended: one to hold the bottle, another to hold the tube in the bucket, and a third to act as timer and recorder. Students should trade responsibilities as they collect data.

3. Distribute student pages, hydraulics apparatus, paper towels and a measuring cup to each group.

4. Instruct students to familiarize themselves with the materials by following the instructions (steps 1-8) for a practice run. Remind them that when they attach tubes to bottles to hold the cap still and turn the bottle.

5. Instruct students to begin data collection by completing steps 1 through 4 on the **Data Collection Pages**. (Hint: Data will be more consistent if the end of the tube is very near the bottom of the bucket.)

6. Once they have completed step 4, instruct them to change to the larger tube and collect data as directed in Steps 5 through 8.

7. Construct a **Class Data Table** on the board (see below) and ask students to record their average times (from Steps 2 and 7).

8. Discuss the **Class Data Table.** Then instruct students to complete questions 9 through 13 of the **Analysis and Conclusion** section.

9. You may want to treat Questions 14 and 15 as optional.

CLASS DATA TABLE

GROUP #	3/16" TUBE TIME	3/8" TUBE TIME
1		
2		
3		
ETC.		

ANSWERS TO STUDENT QUESTIONS

Question 11: Most homes use 1/2" copper tubing for hot and cold water. The service pipe between the street and the building are probably 1" for single family, and larger for apartment buildings.

Question 12: Distribution pipes may be 4" to 6" on residential streets, but under main streets pipes are often 12" or larger.

Question 13: These aqueducts carry water for nearly two million people in more than 40 communities.

Question 14: Answers will vary. Suppose the average in Question 2 was 26 seconds. Then,

$$\frac{.5 \text{ ltrs}}{26 \text{ sec}} \times \frac{60 \text{ sec}}{1 \text{ min}} = \frac{30}{26}\ \frac{\text{ltrs}}{\text{min}} = 1.2 \text{ ltrs/min}$$

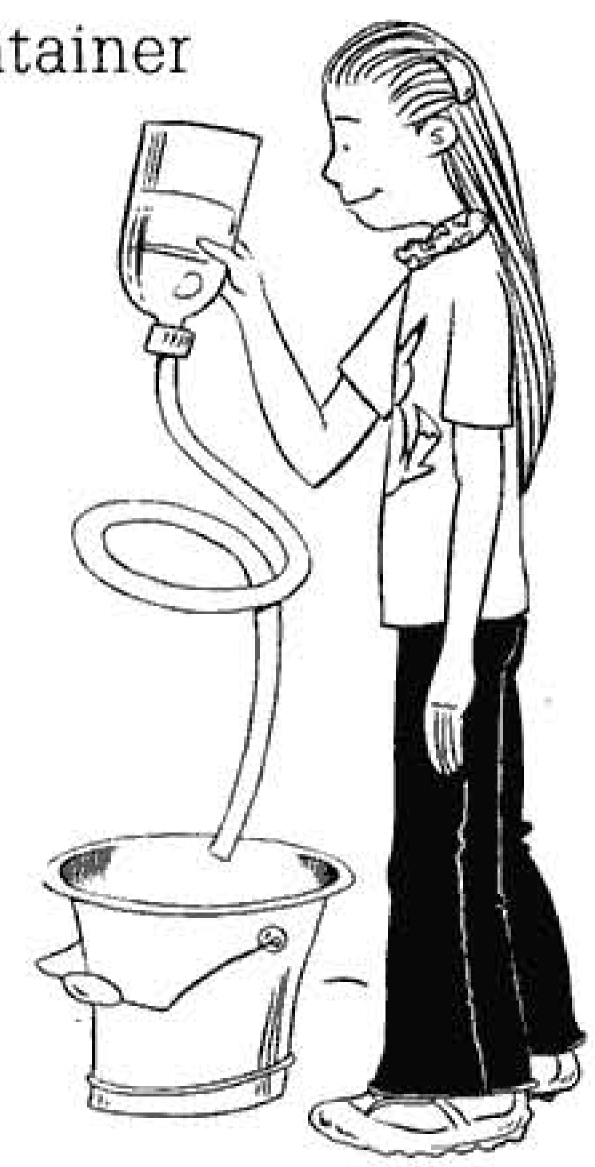
Question 15: Answers will vary. Suppose the average in Question 7 was 7 seconds. Then,

$$\frac{.5 \text{ ltrs}}{7 \text{ sec}} \times \frac{60 \text{ sec}}{1 \text{ min}} = \frac{30}{7}\ \frac{\text{ltrs}}{\text{min}} = 4.3 \text{ ltrs/min}$$

ACTIVITY 3-1 HYDRAULICS - SIZE OF PIPES

INTRODUCTION

Does the diameter of a pipe or tube affect how fast water can move through it? You will experiment with two different size tubes, a smaller one (3/16" inside diameter) and a larger one (3/8" inside diameter). You will use the same volume of water with each tube and observe how long it takes the water to empty from one container to another.



MATERIALS

Your teacher will give each group the following items:

-a plastic bottle with its bottom cut off

-a measuring cup with markings to .5 liters

-a plastic cap with a smaller tube through it

-a plastic cap with a larger tube through it

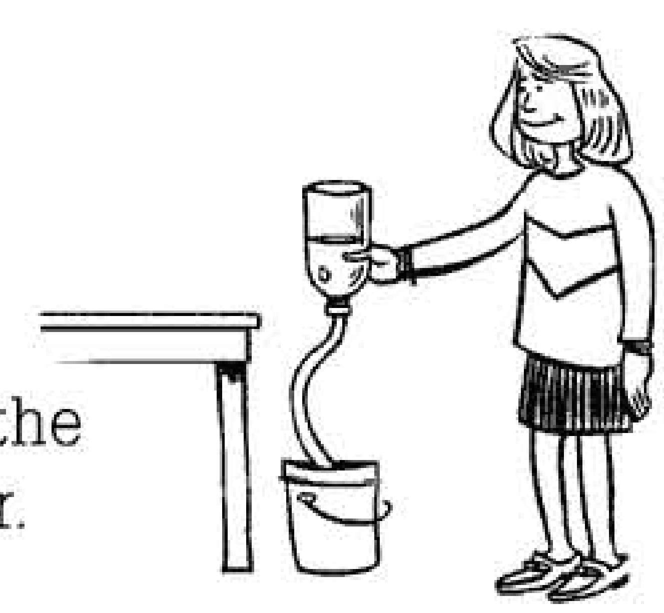
-a bucket to collect the water

-student pages, including **Data Collection Pages**

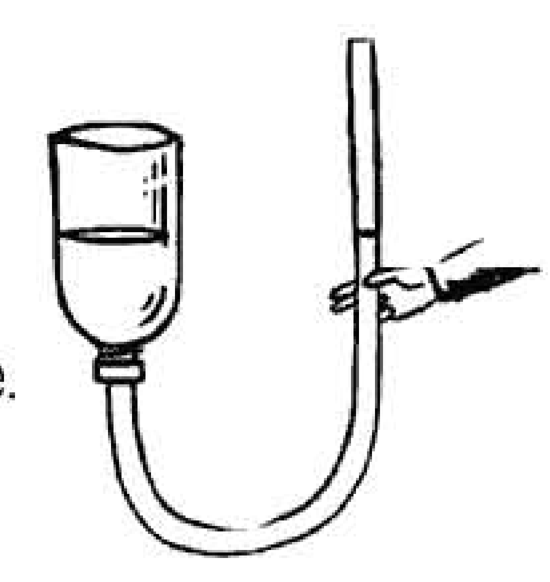
PRACTICE RUN

First, make the following practice run with the apparatus.

1. Attach the cap and smaller tube to the bottle. To protect the seal, it is best to hold the cap in place and turn the bottle until it is securely in place.

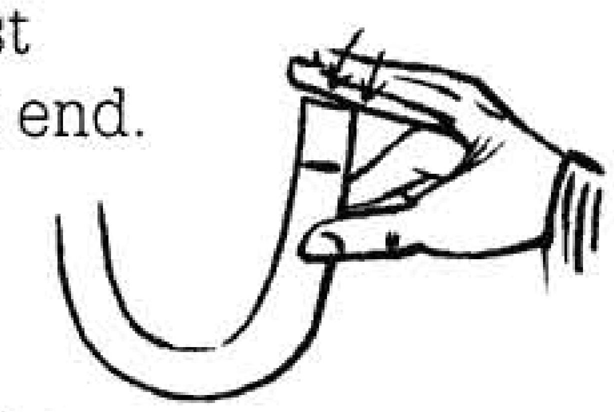


2. One student should hold the bottle so that the cap is at the edge of the table. Place the collecting bucket on the floor.



3. A second student should hold the end of the tube above the top of the bottle. Slowly pour .5 liters of water into the bottle.

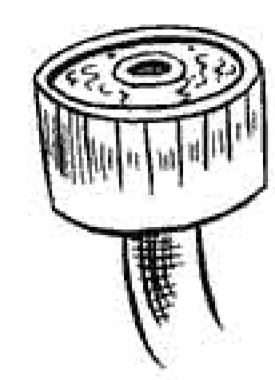
4. Slowly lower the end of the tube. When the water level just reaches the end of the tube, put your finger firmly over the end.



5. Keeping your finger firmly in place, lower the end of the tube to the bottom of the bucket.

6. When the timer says "go," the student holding the tube should release his/her finger and allow the water to flow. When the steady flow suddenly decreases to just a few drops, say "stop". The timer should then note the total elapsed time.

7. You will notice that a small amount of water remains in the bottle cap, beneath the top of the tube. Not all the .5 liters moved from the bottle to the bucket. Allow that water to stay in place; for subsequent trials, exactly .5 liters will pass through the tube.



Now you are ready to begin collecting data.

DATA COLLECTION PAGES

NAME ______________________________

GROUP MEMBERS ______________________

____

DATE ______________________________

1. Conduct three trials of the same experiment with the smaller (3/16") tube, recording times on the **Data Table** below. Record the elapsed time for each trial.

3/16" DATA TABLE

TRIAL #	VOLUME (LITERS)	TUBE SIZE	ELAPSED TIME (SEC)
1	.5	3/16"	
2	.5	3/16"	
3	.5	3/16"	

2. Compute the average time of your three trials. Record it below.

   Average time with smaller tube: ______________

3. How close were the three times to each other? From your three trials what do you think the time would be in a fourth or fifth trial?

4. Before conducting the same experiment with the larger (3/8") tube, predict how long you think it will take the bottle to empty through the larger tube.

   Prediction: __________ seconds

5. Now remove the small tube from the bottle (remember to hold the cap and turn the bottle) and attach the larger tube to the bottle.

6. Conduct three trials with the larger tube. Record the data.

3/8" DATA TABLE

TRIAL #	VOLUME (LITERS)	TUBE SIZE	ELAPSED TIME (SEC)
4	.5	3/8"	
5	.5	3/8"	
6	.5	3/8"	

7. Compute the average time for these three trials. Record it below.

   Average time with larger tube: ________________

8. How close were these three times to each other? Can you predict what time you would get if you ran more trials?

ANALYSIS & CONCLUSION

9. Put your data on the board with that of your classmates. Are all the averages consistent with each other? If not, what might account for the differences?

10. Do you see any patterns in the data? If so, what are they?

11. How large are the water pipes in your home? If they were larger, how would that affect the rate of flow?

12. Have you ever seen people installing water pipes in the streets? About how large do you think they were?

13. Tunnels and aqueducts from Quabbin and Wachusett Reservoirs into the Boston area are as large as 14 feet in diameter! Why do they need to be so large?

RATE OF FLOW

Sample problem:

If .5 liters of water moved through a tube in 12 seconds, what is its rate of flow in liters per minute?

You can convert your measured flow to standard units (liters per minute) in the following way:

$$\frac{.5 \text{ liters}}{12 \text{ \sout{seconds}}} \times \frac{60 \text{ \sout{seconds}}}{1 \text{ minute}} = \frac{.5 \times 60}{12} \; \frac{\text{liters}}{\text{minute}} = \frac{2.5 \text{ liters}}{1 \text{ minute}}$$

Note that because 60 seconds = 1 minute, the fraction $\frac{60 \text{ sec}}{1 \text{ min}} = 1$. Multiplying a quantity by 1 does not change its value, but by using this method we can convert from one set of units to another.

14. Convert your average from Question 2, the smaller tube, to a rate of flow in liters per minute. If necessary, round to the nearest tenth.

15. Convert your answer to Question 7 to liters per minute, rounding to the nearest tenth if necessary.

ACTIVITY 3-2 HYDRAULICS - CAN WATER FLOW UPHILL?

SUMMARY

Students experiment with water, containers and tubing to learn how water can move from the basement to an upstairs bathroom.

CONTENT AREAS

physical science, math

GOAL

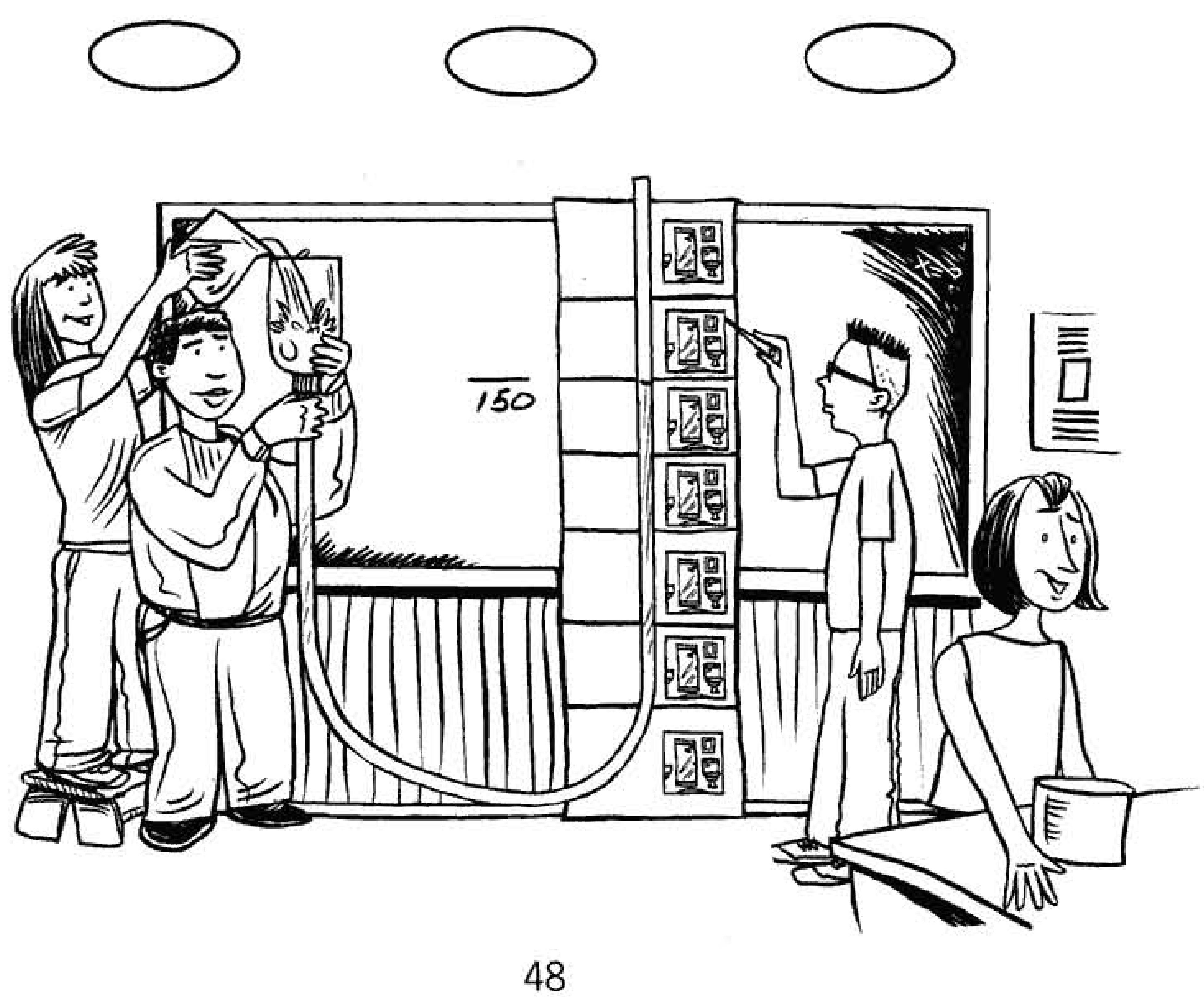
to understand the relationship between elevation and water pressure

TIME

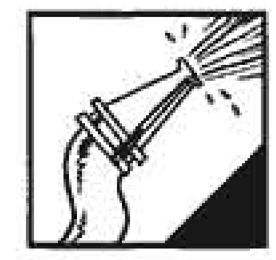
two sessions: one for the gathering data in the basic activity; a second for data analysis and discussion of problems

MATERIALS

For each group:
-water, paper towels
-a hydraulics apparatus (see construction procedure)
-a bucket
-a .5 liter measuring cup
-a meter stick
-a sheet of newsprint or other large paper, about 7 feet long
-a permanent marker
-a watch that can read seconds, or a wall clock with second hand
-copies of student pages
-optional: calculators



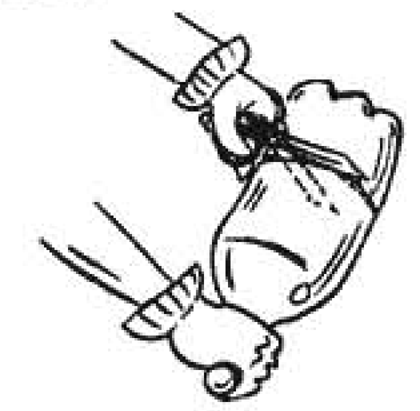
ACTIVITY 3-2 HYDRAULICS - CAN WATER FLOW UPHILL?



ADVANCE PREPARATION

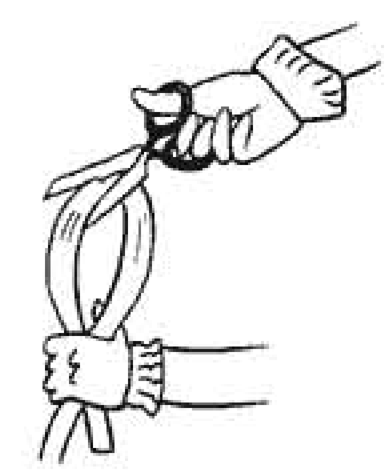
- Create student working groups.
- Copy student pages.
- Cut the necessary number of large sheets of paper.
- To construct the student apparatus, you will need:

  - plastic bottles; 1-liter bottles are best; bottles with wider caps are preferable but not necessary
  - a cap for each bottle
  - a 14-foot length of vinyl tubing 1/4" inside diameter (3/8" outside diameter)
  - electric drill
  - optional: plumber's adhesive sealant



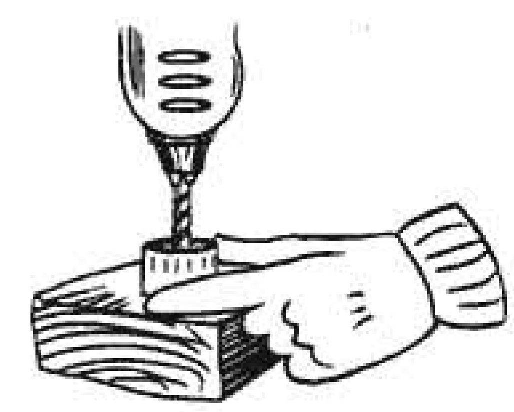
CONSTRUCTION PROCEDURE

1. Cut off the bottom of each bottle.

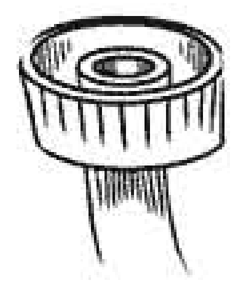


2. Cut a 14-foot length of vinyl tubing.

3. Remove any inside gasket from the inside of the cap and carefully drill a 3/8" hole through it. Wear gloves, and place cap on a surface, such as a block of wood, to protect the work surface. Suggestion: hold cap right-side up, set drill to reverse, and apply pressure. You will effectively melt your way through, leaving a better hole in the cap.



4. Insert one end of the tube through the cap about 1/2". It should fit snugly and should not leak.



5. Optional: For a better seal, apply sealant to the tube on both sides of the cap, work the tube back and forth once or twice, and allow to dry.

6. When screwing the cap back onto the bottle until it seats tightly, hold the cap steady and turn the bottle to minimize strain on the seal.

BACKGROUND INFORMATION

Students often ask how water gets from the pipes in the basement to kitchens and bathrooms on upper floors. This activity will explore that very question.

The water tower is a familiar landmark in many communities. If the terrain is naturally hilly, the tower will be located on one of the higher elevations in the area. In flat terrain, towers are constructed on long legs to stand well above the ground. The purpose in either case is to raise the elevation of the water storage (the bottle in our apparatus) in order to increase the pressure at people's faucets.

Metropolitan Boston, near sea level, is fortunate to collect its water in reservoirs west of the city at significantly higher elevations. Water collected at Quabbin Reservoir (530 feet above sea level) supplements supplies from Wachusett Reservoir (395 feet); then it's on to Norumbega Reservoir (272 feet), with gravity conveying water toward the city. The water in most of Metro Boston arrives entirely by gravity, though a few higher elevations do require pumping.

ACTIVITY 3-2 HYDRAULICS - CAN WATER FLOW UPHILL?

Another intriguing question is how water gets to the top of tall buildings. Some office towers in Boston are 700 feet high, much higher than the 272 foot elevation of Norumbega Reservoir in Weston. Such buildings must contain internal systems of pumps and storage tanks that raise water to the higher floors. Most houses, apartment buildings and schools don't require such complex systems, thanks to gravity-based water pressure.

If a community's water source is a river or well, the water must be pumped up to the water tower. If the pumps are electric, a power outage will deprive the community of not only the health and sanitation benefits of running water but of public safety as well, for without water at hydrants, fire fighters lose their primary weapon against destruction: a sufficient supply of water.

TEACHER PROCEDURE

1. Ask students how water enters their homes. Most will know that underground pipes lead into the basements of buildings. Then, how does the water reach kitchens and bathrooms on upper floors? Can water flow uphill? They will probably suggest the word "pressure," but what causes the pressure? Tell them they will be doing an activity to explore water pressure.
2. Divide students into working groups of at least three, and preferably four or five students. Encourage students to trade responsibilities as they proceed through the activity.
3. Give each group a large sheet of newsprint. Instruct the students to draw a seven-story apartment house with its ground floor at the bottom of the paper and its roof at the top. The building does not need much detail, but each floor should be 30 centimeters high and they should draw a bathroom at each level.
4. Have them tape the paper to the board or wall, with its ground floor at floor level. The top floor of the apartment should be higher than 150 cm.
5. Next tell them to tape a mark on the wall next to the apartment building at an elevation of 150 cm.
6. To fill the bottle, have one student hold the open end of the tube well above the bottle while another carefully pours .5 liters of water into the bottle. Then the student holding the tube should lower it slowly until the water level just reaches the end of the tube. That student should then place a finger firmly over the end of the tube.
7. The student holding the bottle should raise it until its cap is at the 150 cm. level.
8. Direct them to try to deliver water through the tube to all floors of the apartment house (catching the water in a bucket, of course). The tube should lie along the floor for a portion of its length, then rise to the floor in the apartment being tested. (This closely resembles the actual configuration of community water systems: a supply of water at a high elevation, pipes that carry water under ground, below the level of the buildings, and household plumbing that delivers water to kitchens and bathrooms.)
9. This activity includes the mathematical challenge of converting from one set of units to another. To explore conversion further, assign the problems on pages 55 and 56.

ANSWERS TO STUDENT QUESTIONS

Question 8: They should observe that they can deliver water to the lower floors, but not to the top floor (or floors).

Question 9: They should discover that the higher they move the tube, the more slowly the water moves. They may describe this as a difference in water pressure.

Question 10: asks students to devise their own procedure to measure rate of flow. If they have dificulty, you might suggest one of the following methods.

a. They may put a quantity of water (say, .5 liters) of water in the bottle and tube, and record the time it takes for the water to stop flowing. This method has a definite end point, the end of flow, but it will leave some water in the tube.

b. They may fill the tube and the bottom of the bottle, make a mark on the bottle at that level, then add .5 liters to the bottle. They can record the time it takes for the bottle to empty to the original line. This method requires students to judge when the line is reached, but it eliminates the issue of water remaining in the tube.

Question 11: To complete the third data column, students should report their rate of flow in the terms they measured it. For example, if they moved .6 liters of water in 21 seconds, their first rate of flow column would be .6 liters/21 seconds. No calculation is required.

Question 12: In order to compare data with others, the last column asks students to convert their data to standard units, in this case, liters per minute. Sample Problem 1 in the **Rate of Flow** section (page 56) will show them how to make the conversion.

Question 13: For class discussion, you will want to post a **Class Data Table** for students to display data. This will help them look for patterns and reach conclusions. A sample chart is included here (page 51); you may copy it as a transparency so students can enter their data onto an overhead, or you can create your own table on the board or on a flip chart.

ANSWERS TO STUDENT QUESTIONS

Question 14: Rates of flow will decrease at higher floors. Students may or may not see mathematical relationships.

Question 15: Water suppliers store water in elevated tanks to increase pressure in the distribution system. As long as the tank is higher than the highest kitchen or bathroom, water will enter the building through the basement and fill the pipes, escaping wherever anyone opens a faucet or valve.

CONVERSION PROBLEMS

1. $\frac{15\ \text{cm}}{1} \times \frac{1\ \text{in}}{2.54\ \text{cm}} = 5.9\ \text{in}$

2. $\frac{1000\ \text{ft}}{1\ \text{min}} \times \frac{1\ \text{mile}}{5280\ \text{ft}} \times \frac{60\ \text{min}}{1\ \text{hr}} = \frac{1000 \times 60}{5280}\ \frac{\text{mi}}{\text{hr}}$

$= \frac{60{,}000}{5280}\ \frac{\text{mi}}{\text{hr}}$ (or mph, miles per hour)

$= 11.4$ mph

3. a. $\frac{60\ \text{mi}}{1\ \text{hr}} \times \frac{5280\ \text{ft}}{1\ \text{mi}} \times \frac{1\ \text{hr}}{60\ \text{min}} = \frac{5280\ \text{ft}}{1\ \text{min}}$

b. $\frac{5280\ \text{ft}}{1\ \text{min}} \times \frac{1\ \text{min}}{60\ \text{sec}} = \frac{5280}{60}\ \frac{\text{ft}}{\text{sec}} = 88\ \frac{\text{ft}}{\text{sec}}$

4. $\frac{100\ \text{m}}{10\ \text{sec}} \times \frac{60\ \text{sec}}{1\ \text{min}} \times \frac{60\ \text{min}}{1\ \text{hr}} \times \frac{1\ \text{km}}{1000\ \text{m}} \times \frac{.625\ \text{mi}}{1\ \text{km}} = \frac{22.5\ \text{mi}}{1\ \text{hr}} = 22.5$ mph

CLASS DATA TABLE

GROUP (names)	FLOOR	RATE (l/m)	FLOOR	RATE (l/m)	FLOOR	RATE (l/m)	FLOOR	RATE (l/m)	FLOOR	RATE (l/m)	FLOOR	RATE (l/m)	FLOOR	RATE (l/m)
	1		2		3		4		5		6		7	
	1		2		3		4		5		6		7	
	1		2		3		4		5		6		7	
	1		2		3		4		5		6		7	
	1		2		3		4		5		6		7	
	1		2		3		4		5		6		7	
	1		2		3		4		5		6		7	
	1		2		3		4		5		6		7	

ACTIVITY 3-2 HYDRAULICS - CAN WATER FLOW UPHILL?

INTRODUCTION

How does water get to the top floor of an apartment house? In the previous activity, you experimented to learn whether the diameter of a pipe has an effect on the rate at which water moves through it. In this activity you will use only one size tube (1/4" inside diameter), but you will vary the vertical distance between the containers (bottle and bucket) to learn if that affects the rate of flow.

MATERIALS

Your teacher will give each group the following items:

- -a plastic bottle with its bottom cut off
- -a measuring cup with markings to .5 liters
- -a plastic cap with a tube through it
- -a bucket to collect the water
- -a meter stick
- -a large sheet of paper
- -a permanent marker
- -a data recording form

PROCEDURE

1. Draw a seven-story apartment house on the paper with its ground floor at the bottom and its roof at the top. Each story should be 30 cm high. Draw a bathroom at each level.

2. Tape the paper to the board or wall, with its lowest floor at ground level.

3. Tape a mark on the wall at an elevation of 150 cm. next to the apartment building. Your mark should be at the top of the 5th floor of your building.

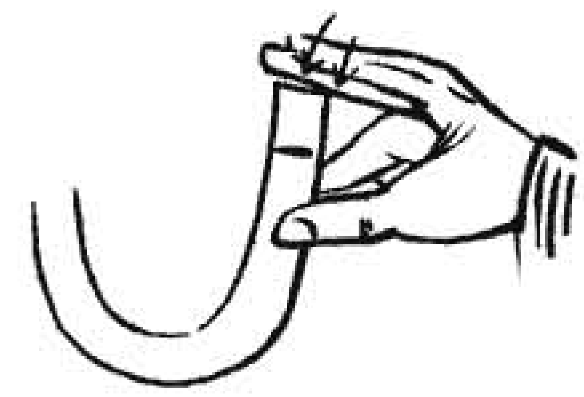
4. Holding the end of tube higher than the bottle, carefully pour .5 liters of water into the bottle.

NAME ____________________

GROUP MEMBERS ____________________

____

DATE ____________________



5. Slowly lower the tube until the water just reaches its end. Place your finger firmly over the end of the tube.

6. Hold the bottle with its cap at the 150 cm. level.

7. Try to make water come out of the tube at the first floor. (Be sure to have your bucket in place.)

8. Now move the end of the tube to the second floor, and the third, and the fourth. Does water reach all those floors? What about the top floor?

9. Can you observe any difference between how the water moves at the first floor and at the higher floors? What do you see?

10. Try to design a procedure to measure the rate of water flow at different levels of your building. Someone will need to act as timer, and you will need to work closely together to get consistent data. Try your procedure at least twice at each level, to be confident you have reliable data. Your measurement data will complete the first two columns on the **Group Data Table**.

GROUP DATA TABLE

FLOOR	Volume of Water (ltrs)	Time (sec)	Rate of Flow (Vol/Time)	Rate of Flow (Liters/min)*
1				
2				
3				
4				
5				
6				
7				

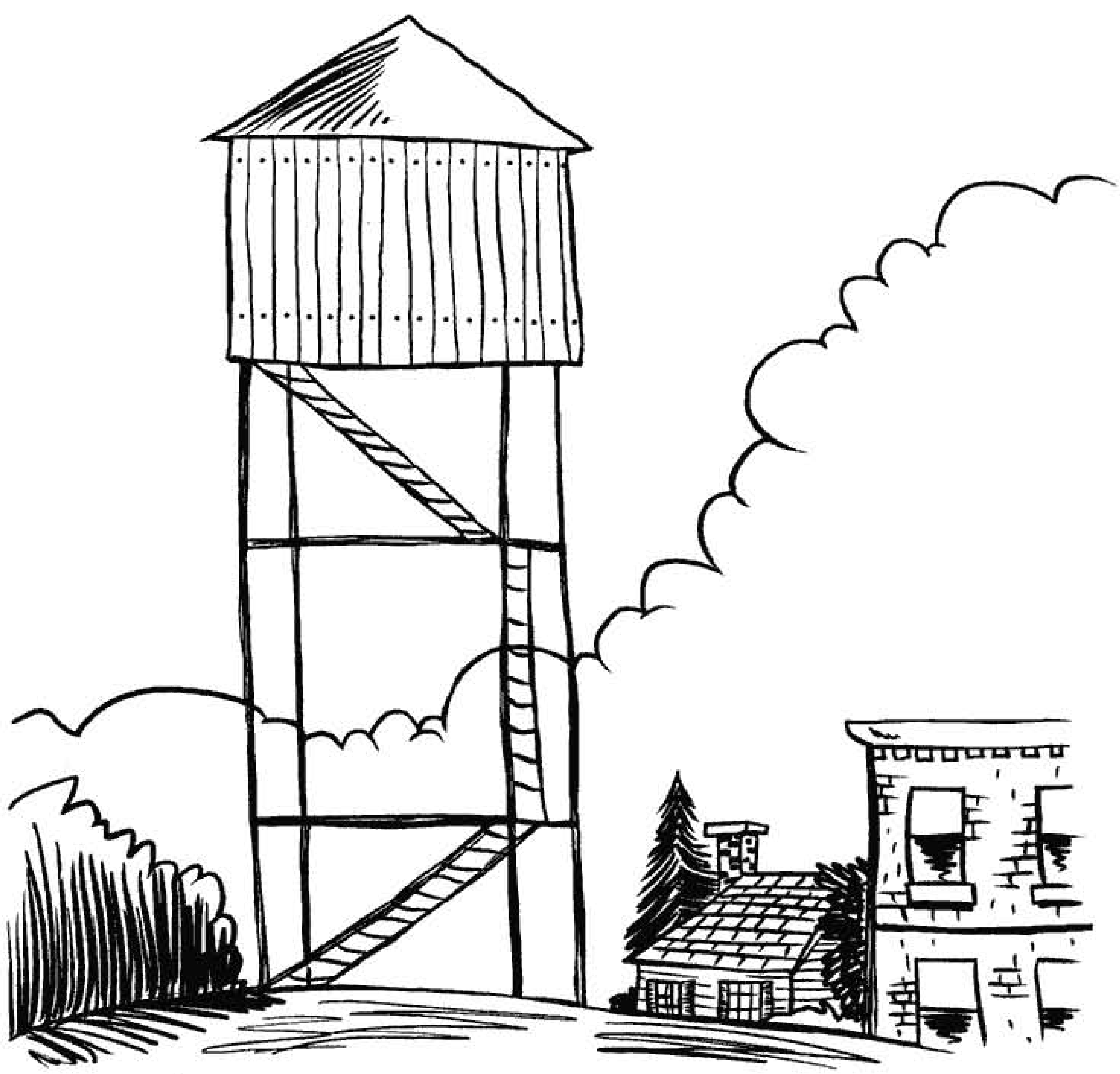
11. To complete the next column, express the rate of flow as your Volume column divided by your Time column. (Example: .6 ltrs/21 sec.)

12. To complete the last column, convert your rate of flow to standard units, liters per minute. If you don't know how to convert to liters per minute, see **Sample Problem 1** on page 56. Round your answer to the nearest tenth.

13. Compare your results with those of other groups on the **Class Data Table** that your teacher provides. Did you all use the same procedure?

14. Do you see any patterns in the data? If so, what are they?

15. How do water suppliers make use of this phenomenon to assure water pressure for their customers?



CONVERTING RATE OF FLOW

Sample Problem 1: If .5 liters flows through a tube in 16 seconds, how many liters (to the nearest tenth) would flow through in one minute?

Solution:

$$\frac{.5 \text{ liters}}{16 \cancel{\text{seconds}}} \times \frac{60 \cancel{\text{seconds}}}{1 \text{ minute}} = 1.9 \frac{\text{ltrs}}{\text{min}}$$

Note that because 1 minute = 60 seconds, the fraction $\frac{60 \text{ seconds}}{1 \text{ minute}} = 1$. Multiplying a quantity (such as $\frac{.5 \text{ liters}}{16 \text{ seconds}}$) by 1 does not change its value. It does allow us to change the units in which the value (rate of flow, in this case) is reported.

Sample Problem 2: If .5 liters of water moved through a tube in 20 seconds, how many gallons (to the nearest tenth) would flow in one minute?

Solution: You can convert liters to gallons and seconds to minutes in the following way:

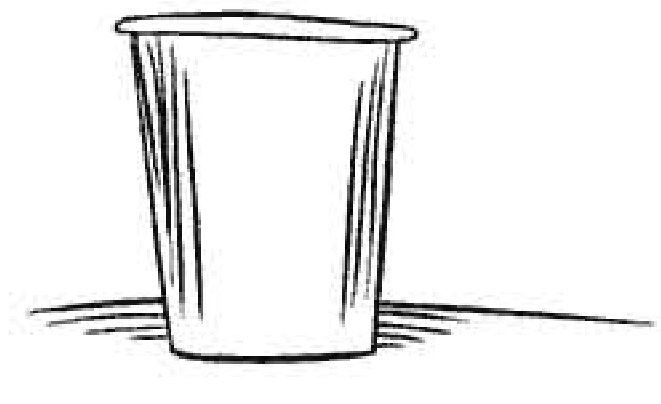
$$\frac{.5 \cancel{\text{liters}}}{20 \cancel{\text{seconds}}} \times \frac{1.06 \cancel{\text{quarts}}}{1 \cancel{\text{liter}}} \times \frac{1 \text{ gallon}}{4 \cancel{\text{quarts}}} \times \frac{60 \cancel{\text{seconds}}}{1 \text{ minute}} = \frac{.5 \times 1.06 \times 60}{20 \times 4} \frac{\text{gallons}}{\text{minute}}$$

= .4 gallons per minute

Note two things: 1) Because 1 liter = 1.06 quarts, 1 gallon = 4 quarts, and 1 minute = 60 seconds, each of those three fractions equals 1. Multiplying a quantity by 1 does not change its value.

2) Similar units on the tops and bottoms of fractions cancel each other. Thus, liters, quarts, and seconds all cancel, leaving the flow rate expressed in gallons and minutes.

Now try these conversion problems.



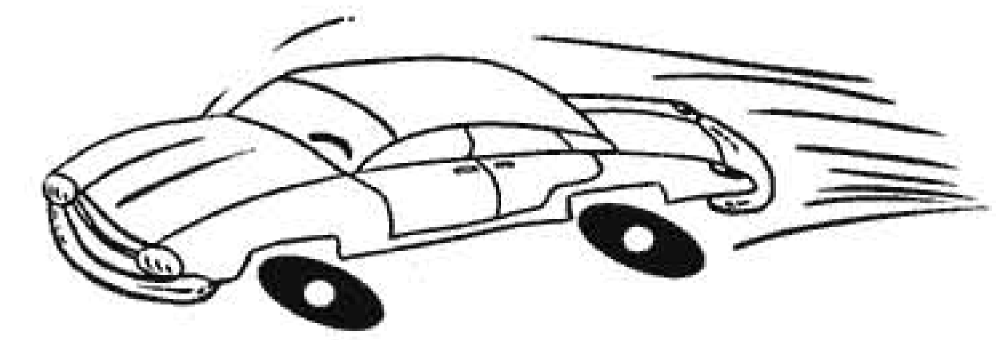
1. You know a container is 15 cm deep. How deep is that in inches?

   You need to know that 1 inch = 2.54 cm.

Hint: For this problem, remember that the fractions $\frac{2.54 \text{ cm}}{1 \text{ in}}$ and $\frac{1 \text{ in}}{2.54 \text{ cm}}$ both equal 1. Which way will you use the fraction? (Round your answer to the nearest tenth of an inch.)

2. Can you run 1000 feet in one minute? If you can, you traveled at the rate of $\frac{1000 \text{ feet}}{1 \text{ minute}}$.

   But how fast is that in miles per hour(to the nearest tenth)? You know that 1 hr = 60 minutes, and 1 mile = 5280 feet.



3. a. A car is traveling 60 mph. How far does it move (in feet) in 1 minute?

   b. How far does the same car travel in 1 second?

4. Optional: (And harder.) World class sprinters run 100 meters in about 10 seconds. What is their average speed in miles per hour?

   Facts: 1000 meters = 1 kilometer
   1 kilometer = .625 miles (= 5/8 mile)