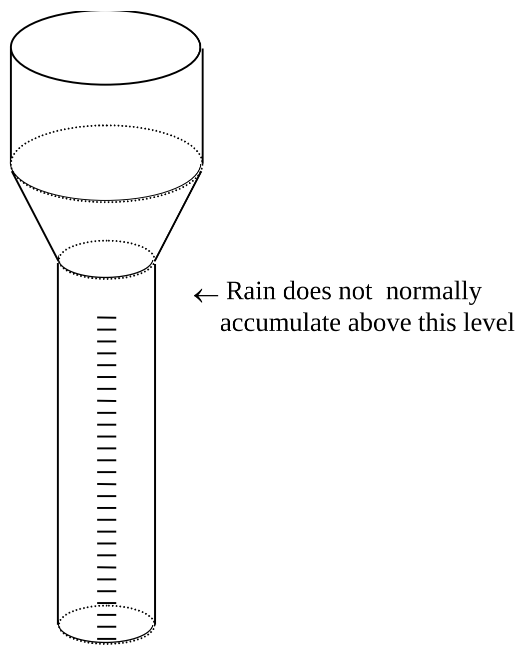
# Measuring Rain Part V: Rain Gages

## AND NOW FOR REAL RAIN GAUGES!!!

Most real rain gauges have another complication that we haven't looked at yet. This complication makes it a little harder to understand how rain gauges work, but it makes them oh-so-much easier to use. We often hear that someplace had 0.03 inches of rain in July. How do you measure rain every day for a month, add up all of your measurements, and get a height as small as 0.03 inches? That means on some days the rain must have been less than 0.001 inches – a thousandth of an inch! Could you pour a thousandth of an inch of water into a soup can? Could you measure a thousandth of an inch with a ruler? No. Something else is going on.

The feature of most rain gauges that makes it possible to measure tiny amounts of rain is that they are *wider at the top than they are at the bottom.* A common design for a fancy rain gauge looks something like the picture below. You should find an example in the classroom.




Why make a fancy rain gauge look like this? It actually works better. Let's think about it.

First of all, you need to know that we only use a gauge like this when the water level is below the "funnel-shaped" part of the gauge. The exact shape (and volume) of the funnel-shaped part never enters into our measurement of the rain. (So don't worry about the funnel-shaped part! You only need to think about the parts above and below it.)

Second, think back to the rectangular blocks you made out of little cubes. You made many boxes that had the same volume but different shapes. Remember? Something similar would happen to water if you poured it from a soup can shaped like the top of this rain gauge into one shaped like the bottom.

With that in mind, you should be able to figure out how this rain gauge works and why.

The "real" rain gauge…

1) **Think about water sitting in a rain gauge**. (Note: it might not be rainwater; maybe somebody just poured this water into the gauge.) The volume of water in the gauge is proportional to the height of the column of water times the area, but what area? The area of what part *of the rain gauge* (times height) determines the volume of water?

2) **Now think about water collected by a rain gauge** (left out in the rain). With our rain machines we determined that the amount of water that falls into the rain gauge during that time is directly proportional to the area, but what area? The area of what part *of the rain gauge* determines how much rain falls into the rain gauge?

3) **Again, think about water sitting in a rain gauge**. The column of water in the rain gauge has a certain height. Assume you have a soup-can ***holding*** a column of water of the same height as the column of water in your rain gauge. Based on your answer to question 1, what size (and shape) of a soup-can would you need to hold the same *volume* of rain as this rain gauge (*assuming the columns are the same height and that the soup-can has straight sides with no funnel at the top*)?

4) **Now think about water collected by your soup-can.** Again, assume your soup-can has straight sides (no funnel at the top). What size (and shape) of a soup-can would you need to ***collect*** the same *volume* of rain as this rain gauge (in the same rainstorm for the same amount of time)? What would have to be the same about the soup can and the fancy rain gauge (assuming the fancy rain gauge has a funnel at the top but that the soup-can has the same area at the bottom and the top)?

Your answers to questions 3 and 4 are probably different, which may lead you to wonder how they could both be correct. Try an experiment to find out. Place a soup or sauce can next to a real rain gauge and run the rain machine over all three for a few seconds.

5) ***Using a ruler***, measure the height of the column of water in the rain gauge and the height of the column of water in one of the cans. Are the heights the same?

6) ***Reading the numbers off of the side of the rain gauge,*** and comparing those numbers to the height of the column of water in the can, are those measurements the same?

7) ***Using a graduated cylinder,*** is the volume of water in the rain gauge and the can the same?

8) One more time: During a rainstorm, the volume of rain that falls into the rain gauge is one centimeter times *what area*?

9) One more time: When the rain is in the bottom of the rain gauge, the volume of the column of water is determined by the height of the column times *what area*?

10) Imagine a column of water that starts at the top of the rain gauge (the wide part) and moves down into the bottom of the rain gauge (the narrow part). When rain moves from the top of the gauge to the bottom, does the volume of the water change, does the ("cross-sectional") area change, or does the height change? What changes and what stays the same?

| | | |
|---|---|---|
| Volume? | Changes | Stays the same |
| Area? | Changes | Stays the same |
| Height? | Changes | Stays the same |

11) Look at your answer to question 10. If all of those quantities are related, and one stays the same while the other two quantities change, they must change in a very special way. For each quantity, indicate whether it increases, decreases, or stays the same:

| | | | |
|---|---|---|---|
| Volume: | Increases | Decreases | Stays the same |
| Area: | Increases | Decreases | Stays the same |
| Height: | Increases | Decreases | Stays the same |

Explain your reasoning:

12) You should be able to tell by looking at the rain gauge that the cross-sectional area decreases. Let's imagine that the area at the bottom is only a fifth of what it is at the top. *Remind yourself about the relationship between Volume, Area, and Height,* and then fill in the blanks below *as accurately as you can*.

Volume: ________________________________________

Area: One fifth of what it is at the top.

Height:________________________________________

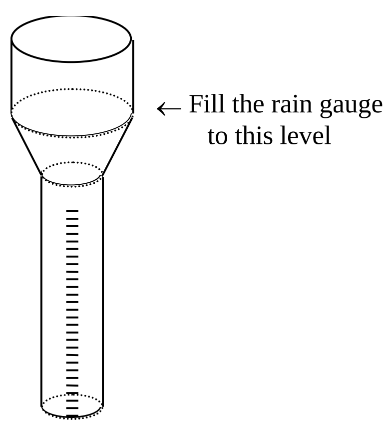
Explain your reasoning:

13) Take an actual rain gauge and fill it to the level marked "one centimeter" of rain. (If you have a rain gauge that is "calibrated" in units other than centimeters you may use 10 mm or half of an inch.) Measure the height of the column of water with a ruler.

a) How tall is it?

b) What does this tell you about the areas of the top and bottom of the rain gauge?

Pour your "one centimeter" of water into a cup. Save this for later. Now get some more water and fill the rain gauge up to the bottom of the part where it is widest. The rain gauge doesn't have marks to indicate rainfall at this level since we would normally empty the gauge before it fills this far, but for now fill it just to that level.



14) Now look back at the water that you poured into a cup. *Without actually doing anything*, discuss what would happen if you poured that water back into the rain gauge with the water level starting at the wide part of the gauge. Think about it and talk it over. Make a prediction. Be as detailed (quantitative) as you can. Write your prediction below.

15) Try it. Pour the water from the cup into the rain gauge. What happened? Do you still have that ruler lying around? Check your prediction. Write your observations below.

16) Now play. Scientists always save time for play. The way you do this depends on the kind of rain gauge you have.

a) **If you have a rain gauge that you can fill to the top without leaking:** Pour water into the rain gauge and fill it up to the one cm (or half of an inch) level. Pour that water out into a cup to save it for later. Then fill the rain gauge to the top of the "funnel part" of the rain gauge (so that the only part left unfilled has straight sides the same size as the opening at the top). What would you expect to see if you then emptied the cup into the gauge? Try it! How much did the water level in the rain gauge change?

b) **If you have a rain gauge with a top that comes off (leaving behind a narrower tube inside of a cylinder the same size as the opening):** Pour water into the rain gauge until it reads one cm (or half of an inch). Then take the rain gauge apart and pour this water into a cup for use a little later. Now take the bottom part of the rain gauge (it should be a cylinder with the same diameter as the opening at the top). What would you expect to see if you then emptied the cup into this part of the gauge? Try it! What is the water level in this part of the rain gauge?

c) **With whatever kind of rain gauge you have:** Try holding a rain machine over the rain gauge and a soup can at the same time. What do you expect to see? What do you see? Record some observations.

17) Now try to figure out *why* they make the rain gauge this way. Imagine 2 cm of rain falls. If it falls into a soup can, how do you measure it? Could you be sure it isn't 2.1 cm of rain? 2.05 cm? Fill a rain gauge up to the mark *labeled* 2.0 cm. Can you tell the difference between 2.0 cm and 2.1 cm? Could you tell the difference from 2.05 cm? What about the design of this rain gauge makes it easier to make precise measurements? Explain your answer in words as completely as you can. (If you get stuck, there are some hints below. Talk to your classmates and discuss your ideas with an instructor.)