Activity 5:
Volume Measurements with a Graduated Cylinder

OBJECTIVE:

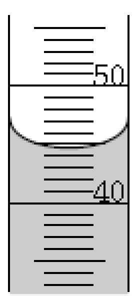
The purpose of this activity is to learn how make volume measurements with a graduated cylinder.

THEORY:

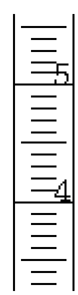
Volume is the amount of space an object takes up. It is measured in liters (L), milliliters (mL) or cubic centimeters (cm^3 or cc). A cc is exactly the same volume as an mL and a liter is exactly the same volume as 1,000 mL.

Graduated cylinders are the tools commonly used to make measurements of volumes in the laboratory. The cylinders come in a variety of sizes. Common sense and availability dictate which size to use.

The graduation (i.e., divisions) on different sized cylinders have different values. Here are drawings of segments of two cylinders. The larger one (shown with liquid in it) has 1 ml divisions, the smaller one has 0.1 ml divisions.



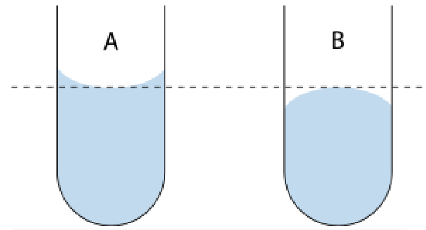
100 ml cylinder; each division is 1 ml



10 ml cylinder; each division is 0.1 ml

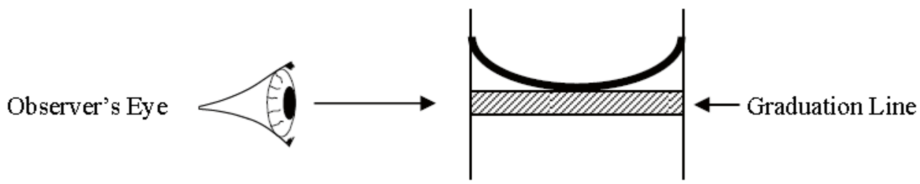
Reading the volume measurements with a graduated cylinder is essentially the same as reading length measurements with a meter stick: the reading will always be comprised of digits that can be read with certainty (because of the graduations) plus an estimated digit based on the fractional part of the smallest division.

However, unlike meter stick, reading graduated cylinder can be tricky. This is because the liquid in the graduated cylinder may be attracted to the walls of the cylinder by molecular forces which results into the formation of what is known as the ***meniscus***. The meniscus is the curve in the upper surface of the liquid close to the surface of the cylinder. The curvature of a meniscus is related to the surface tension of the liquid and inversely related to the diameter of the tubing in which it is formed. It can be either concave (shown in Fig. A on the right) or convex (shown in Fig. B on the right), depending on the liquid and the material used for the cylinder.

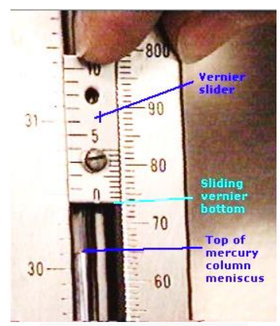


A: The *bottom* of a concave **meniscus**.
B: The *top* of a convex **meniscus.**

The meniscus of most liquids is concave-up, with the lowest point in the center that is used to determine the meniscus reading. Your eye must be on the same level as the bottom of the meniscus to read the volume correctly.

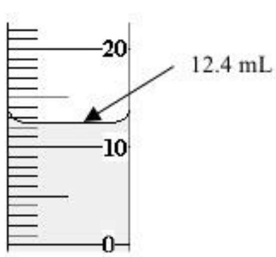


The meniscus formed by a non-wetting liquid, such as mercury (Hg), is convex with the highest point in the center. In the case of a convex meniscus, the highest point is used to make the reading. The reading of a mercury barometer or thermometer is a classic example of this kind.



Reading a mercury barometer

When reading any meniscus, it is important to ascertain that it is in an equilibrium position. Tapping of sight glasses and/or small motions of containers may be used to induce slight displacements of the meniscus. Return to the same reading is evidence of a stable meniscus.



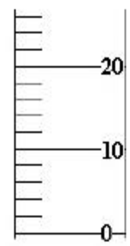
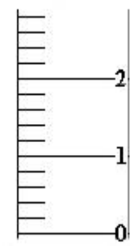
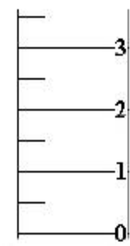
Example of a volume measurement using a graduated cylinder which has the proper number of significant figures

Keep in mind that when reading the measurement, you need to keep the graduated cylinder on a level desk, lower your eyes to the level of the meniscus, and you read the volume accordingly. Be sure to include one point of estimation in your reading (see sample reading shown on the left).

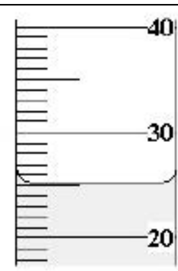
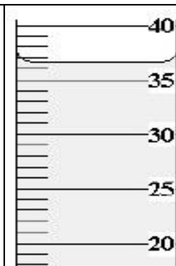
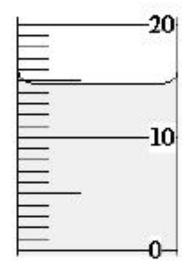
Volume measurement with a graduated cylinder is practically used to get the volume of irregularly shaped objects where the volume is found by water displacement. Volume measurement with a graduated cylinder is likewise used in measuring the amount of liquid precipitation over a set period of time using a rain gauge.

PROCEDURE:

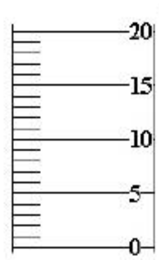
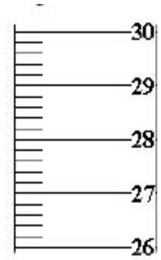
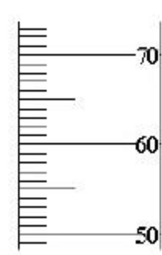
1. Given the following graduated cylinders (calibrated in mL), determine the smallest scale division (that is, the value for the minor grids) and the smallest fractional part of the scale division that can be reasonably estimated.

Volume Measurement				
Smallest scale division				
Smallest fractional part of the scale division that can be reasonably estimated				

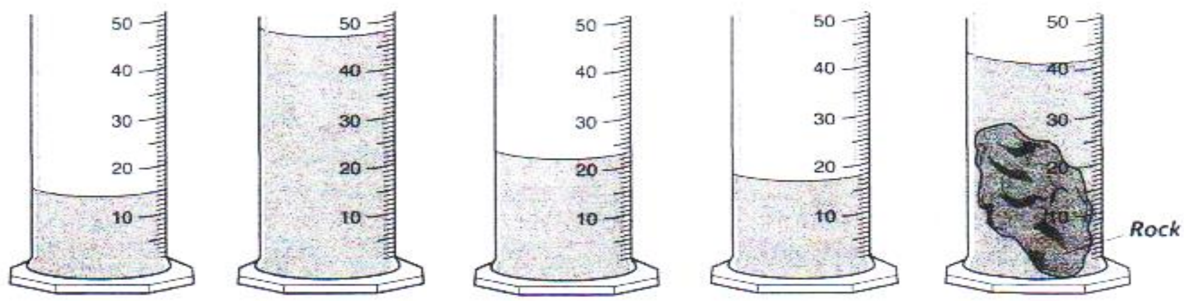
2. Measure the volume of each liquid sample shown in the figures below. The graduated cylinders is calibrated in mL. Don't forget to use significant figures.

Volume Measurement				
Reading (with proper number of significant figures)				

3. Draw in the meniscus for the following readings.

Reading	49.21 mL	18.2 mL	27.7 mL	63.8 mL
Volume Measurement				

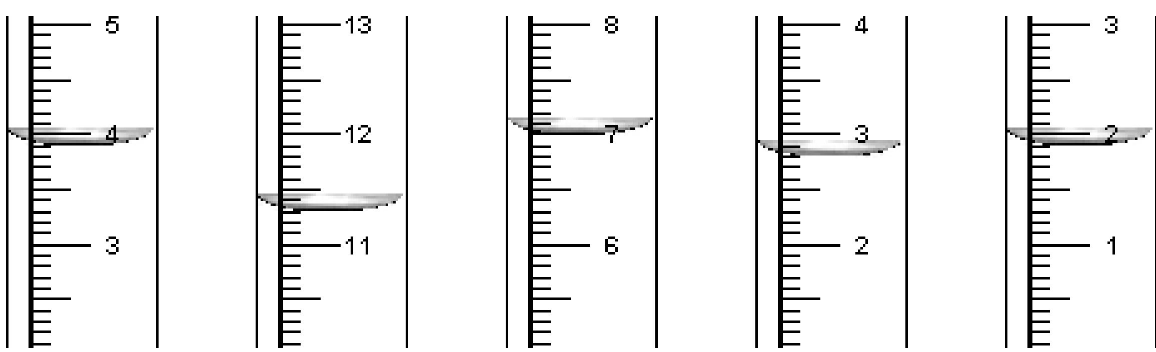
4. Pictured below are volume measurements using graduated cylinders. What is the volume of liquid shown in graduated cylinders A-D? What is the total volume in graduated cylinder E? Write your answers in the spaces provided.



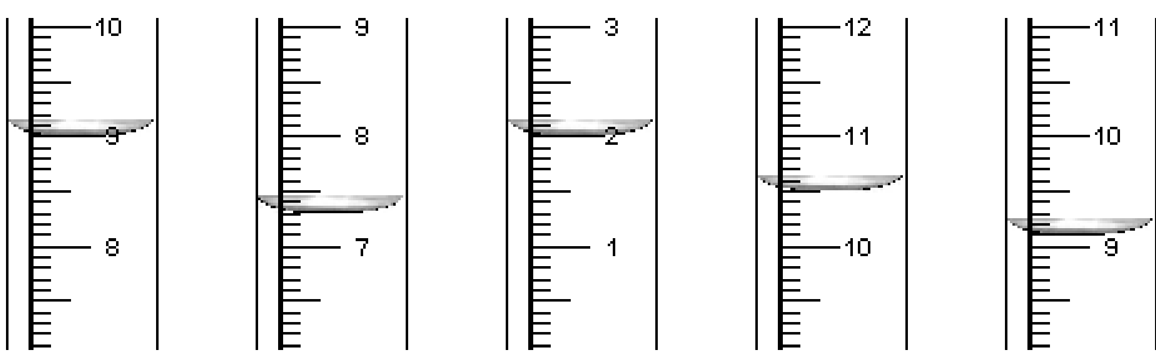
(**A**) ______ mL (**B**) ______ mL (**C**) ______ mL (**D**) ______ mL (**E**) ______ mL

5. If the graduated cylinders **D** and **E** show the same cylinder before and after the rock was added, what is the volume of the rock? ____________ mL

6. Given below are the data of liquid precipitation collected overnight in 4-cm-diameter rain gauges at different locations. The rain gauges are calibrated in cm. Determine the height of the liquid precipitation then compute for the collected volume. Use significant figures. (Hint: volume of a cylinder = $\pi r^2 h$)



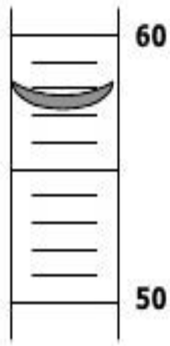
(**A**) *h*=________ *V*=________
(**B**) *h*=________ *V*=________
(**C**) *h*=________ *V*=________
(**D**) *h*=________ *V*=________
(**E**) *h*=_______ *V*=_______

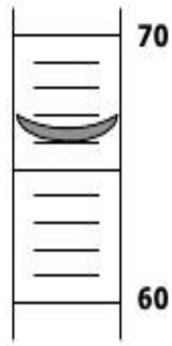


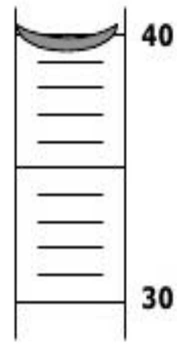
(**F**) *h*=________ *V*=________
(**G**) *h*=________ *V*=________
(**H**) *h*=________ *V*=________
(**I**) *h*=________ *V*=________
(**J**) *h*=_______ *V*=_______

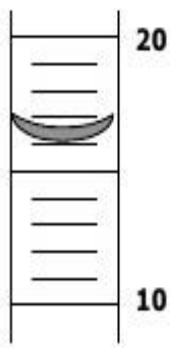
EXERCISES:

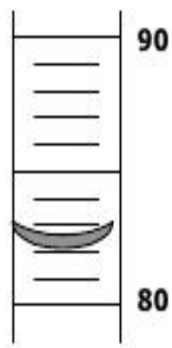
1. Measure the amount of liquid in each graduated cylinder below, using the bottom of the meniscus. Record the measurements on the line below each graduated cylinder, making sure use one decimal place and label your units in mL.

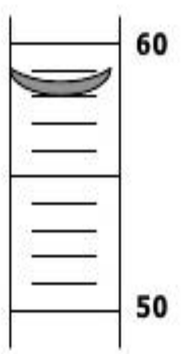


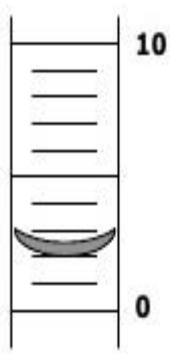


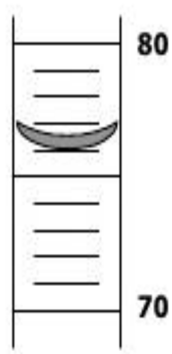


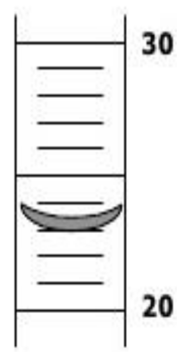




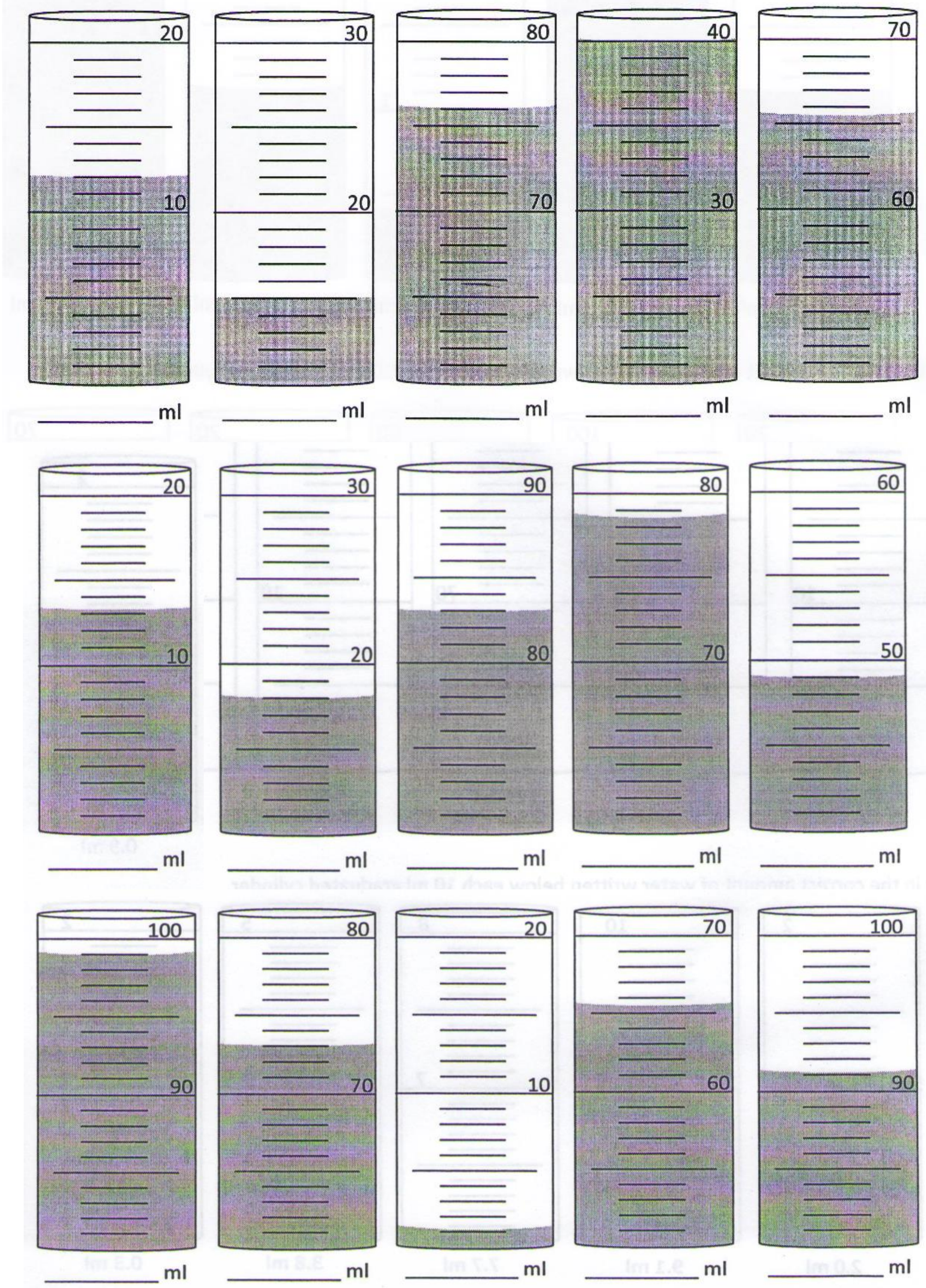




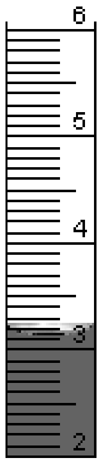


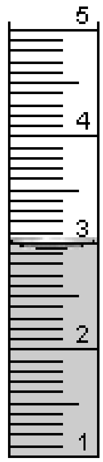


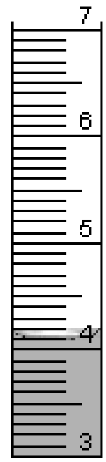
2. What is the reading in milliliters for each graduated cylinder?

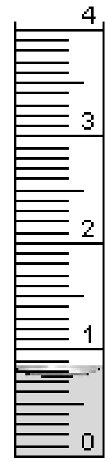


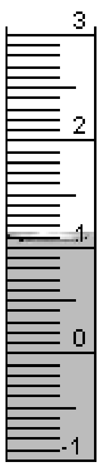
3. What is the height of liquid precipitation in centimeters for each rain gauge below?

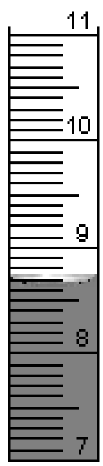


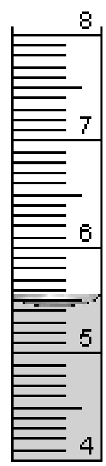


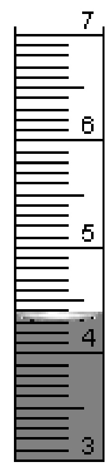


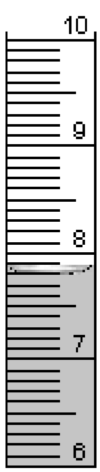


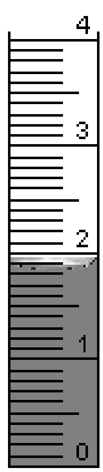


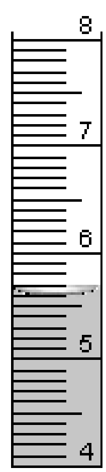


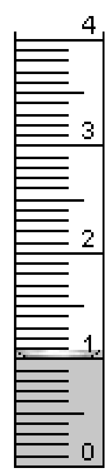












GUIDE QUESTIONS FOR ANALYSIS:

1. Explain the steps that you would use to determine estimated digit in your volume measurement using a graduated cylinder.

2. How can you say that your volume measurements with a graduated cylinder is precise?

3. How can you say that your volume measurements with a graduated cylinder is accurate?

4. In this activity, graduated cylinders were used as opposed to a meter stick. When a meter stick is used, parallax influences the precision. Other than taking into account the meniscus, what techniques were necessary to optimize the precision of the measurement?