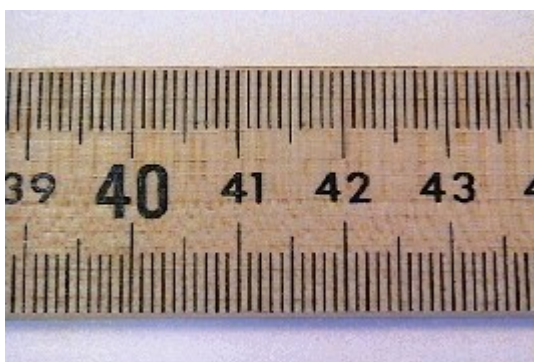


# EXPERIMENT 1

## Precision of Measurements Density of a Metal Cylinder

Physics is a quantitative science, relying on accurate measurements of fundamental properties such as time, length, mass and temperature. To ensure measurements of these properties are accurate and precise, instruments such as a meter sticks, a tape measure, triple-beam balances, analytical balance, and laboratory thermometers are often used. It is important to understand how to properly use these devices. With any measurement tool, the student should always try to achieve the greatest accuracy the apparatus will allow.

**Meter stick.** The simplest way to measure length is to use an ordinary meter stick. In the laboratory, our meter sticks are carefully calibrated in centimeters with a millimeter least count. That is, the millimeter is the smallest subdivision on the meter stick, which can be seen in Figure 1. This means the millimeter is the unit of the smallest reading that can be made without estimating.



**Figure 1.** This meter stick is calibrated in centimeters (shown as the numbered major divisions) with a least count of millimeters.

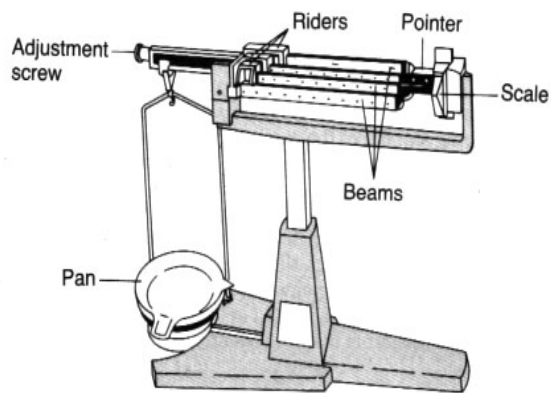


**Figure 2.** An example of a meter sticks reading. The object's length is measured to be 41.64 cm. (See text for description.)

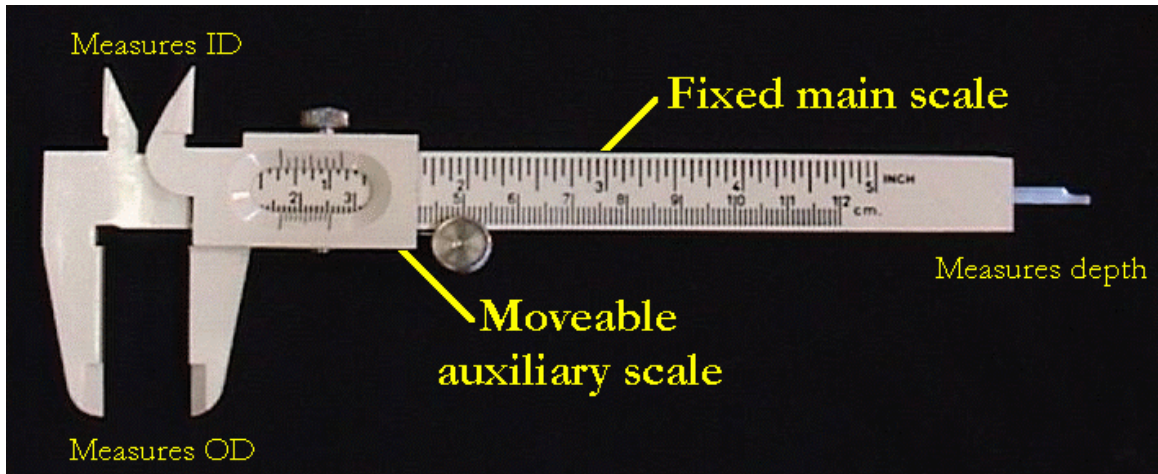
A measurement reading usually has one more significant figure than the least count reading of the scale. The least count of our laboratory meter sticks is 0.1cm and therefore a reading can be made to 0.01cm. Figure 2 above shows a meter stick being used to measure the length of a plastic strip. The meter stick is calibrated in centimeters, so we know that the strip is between 41 and 42 cm. The least count of this meter stick is one millimeter, so we know with absolute certainty that the object is between 41.6 cm and 41.7 cm. We then estimate the object's length to the fractional part (doubtful figure) of the least count subdivision. In Figure 2, it we may estimate that the strip is closer to 41.6 cm than it is to 41.7 cm and report the length to be 41.64 cm or 0.4164 m.

**Triple-beam balance.** The triple-beam balance, or laboratory balance, measures the mass of an object by balancing the unknown mass with sliding masses of known values. The triple-beam balance is usually calibrated in grams with a least count of 0.1g. A measurement, then, can be made to 0.01g. It is important to note that laboratory balances are used to make measurements of an object's mass, not weight. (The weight of an object, as you will learn, is the product of the object's mass,  $m$ , and the acceleration due to gravity,  $g$ , or  $W = mg$ .)

Before the triple-beam balance is used to make a measurement, verify that the balance is properly zeroed. Fine adjustments may be made by turning the knob under the balance pan.

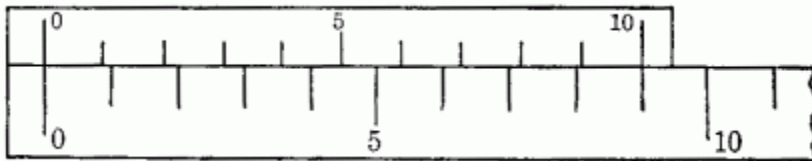


**Vernier Caliper.** A vernier caliper (or vernier) is a common tool used in laboratories and industries to accurately determine the fraction part of the least count division. The vernier is a convenient tool to use when measuring the length of an object, the outer diameter (OD) of a round or cylindrical object, the inner diameter (ID) of a pipe, and the depth of a hole.



Their spacing is not the same as that of the marks on the main scale. If you look at these closely you will see that ten divisions of the Vernier scale occupy a length interval equal to *nine* of the smallest main scale divisions (millimeters). Obviously, in this case, the Vernier scale markings are engraved 9/10 millimeter apart.

A *metric* Vernier scale usually has ten divisions, requiring 11 engraved marks (ten plus the index mark). In general, a Vernier scale will have at least one more mark than it has divisions. Sometimes they have a few more marks at one or both ends, just for convenience. An *English* metric length scale, with the main scale marked in 1/16 inch intervals, may use a Vernier scale with 8 divisions, capable of measuring to  $(1/8)(1/16) = 1/128$  inch.



**Micrometer Caliper.** Fig. 1 shows a typical micrometer caliper. The object to be measured is placed between the fixed jaw (A) and the movable jaw (R) and the jaw is gently closed on the object. The movable jaw (R) of the micrometer caliper is driven by a precise and uniform screw. A typical metric instrument has the main scale marked to 1/2 millimeter. The circumference of the rotating handle (the thimble, T) is subdivided into 50 equal subdivisions. One rotation of the handle carries the screw a distance of 1/2 mm along the main scale (S). Therefore the markings on the thimble allow one to read hundredths of millimeters.

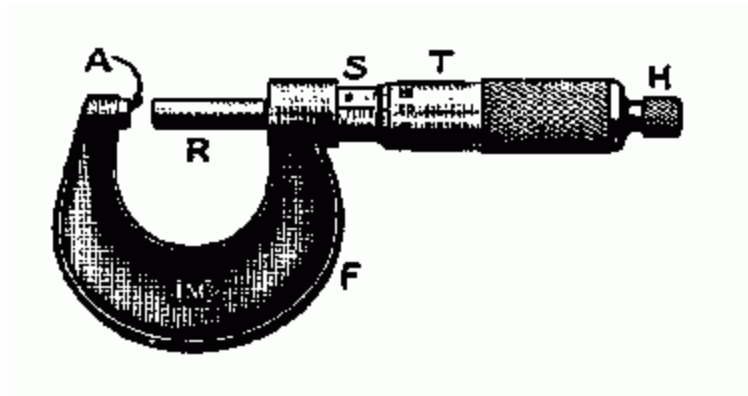


Figure 1

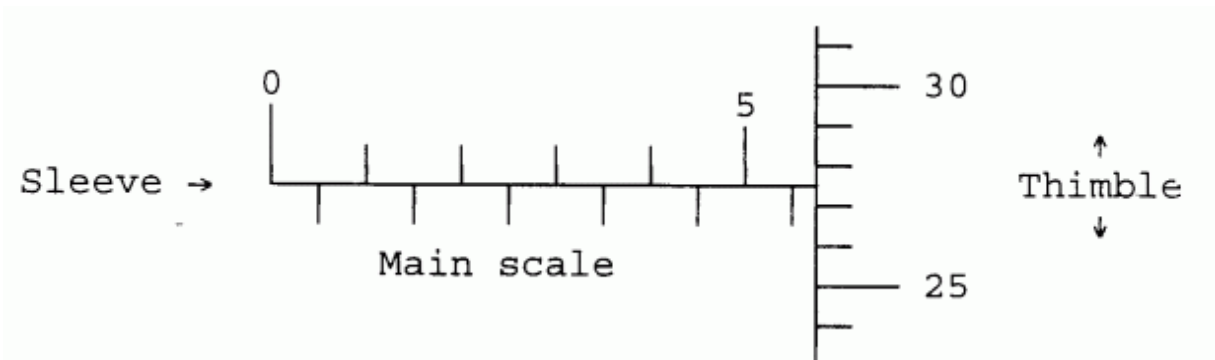


Fig. 2. Principle of the micrometer.

In Fig. 2 the reading on the main scale is more than 5.5 mm but less than 5.6 mm. The thimble reading is 27.5, so the instrument's length reading is  $5.5 + 0.275 = 5.775$  mm.

You must practice so that you are *sure* whether the reading lies in the lower or upper half of a millimeter. If it is in the upper half, be sure to include the extra half millimeter in the final value.

**Density.** All matter has mass and volume. Mass is a measure of the amount of matter an object has. Its measure is usually given in grams (g) or kilograms (kg). Volume is the amount of space an object occupies. There are numerous units for volume including liters (l), meters cubed ( $m^3$ ), and gallons (gal).

Mass and volume are physical properties of matter and may vary with different objects. For example, it is possible for two pieces of metal to be made out of the same material yet for one piece to be bigger than the other. If the first piece of metal is twice as large as the second, then you would expect that this piece is also twice as heavy (or have twice the mass) as the first. If both pieces of metal are made of the same material the ratio of the mass and volume will be the same. We define density ( $\rho$ ) as the ratio of the mass of an object to the volume it occupies. The equation is given by:

$$\rho = \frac{M}{V} \quad (1.1)$$

here the symbol M stands for the mass of the object, and V the volume. Density has the units of mass divided by volume such as grams per centimeters cube ( $g/cm^3$ ) or kilograms per liter (kg/l).

**Objective:** To study the proper handling of data and the concept of significant figures. Application will be made to the measurement of length, diameter and mass of three metal cylinders and the determination of their volume and density.

*Note: Volume of a Cylinder =  $\Pi * R^2 * H$   
Aluminum density 2.70 g/cm<sup>3</sup>  
Copper density 8.96 g/cm<sup>3</sup>  
Brass density 8.57 g/cm<sup>3</sup>*

**Procedure:**

1. Measure the mass of the cylinders on the balance.

**MASS**

<b>Metals</b>	<b>MASS</b>
Aluminum	
Copper	
Brass	

2. Measure the height and diameter of the cylinders with the ruler.

**RULER**

<b>Metals</b>	<b>HEIGHT</b>	<b>DIAMETER</b>
Aluminum		
Copper		
Brass		

3. Measure the height and diameter of the metal cylinders with the vernier caliper.

**VERNIER CALIPER**

<b>Metals</b>	<b>HEIGHT</b>	<b>DIAMETER</b>
Aluminum		
Copper		
Brass		

4. Measure the height and diameter of the cylinders with the micrometer caliper.

**Micrometer**

Metals	HEIGHT	DIAMETER
Aluminum		
Copper		
Brass		

**Calculations:**

1. Divide the mass of the cylinders as determined in step # 4 by the **more accurate volume** to get the density of the cylinder. Give the probable error and report this with the proper number of significant figures.

*Calculate the Density*

Metals	Volume (cm <sup>3</sup> )	Mass (grams)	Density (gm/cm <sup>3</sup> )
Aluminum			
Copper			
Brass			

**Questions:**

1. Define percent error, accuracy, and precision.
2. The measuring devices used above which is most precise?
3. To improve on the accuracy of the density determination what measurement will have to be made with much better precision?