

MEASUREMENTS AND ERROR ANALYSIS

Objective

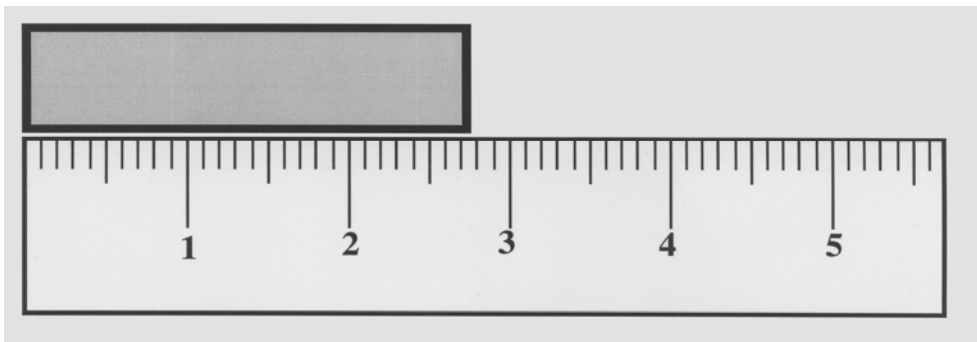
1. To learn how to use the following measuring devices and understand the uncertainties associated with them.
 - a) meter stick
 - b) metric ruler
 - c) triple-beam balance
 - d) digital balance
 - e) vernier calipers
2. Calculate the area and uncertainty of the table-top by measuring the dimensions with a meter stick
3. Calculate the density and its uncertainty of an aluminum metal block by measuring its dimensions with the metric ruler and the mass with the triple-beam balance.
4. Calculate the density and its uncertainty of an aluminum block by measuring its dimensions with the vernier calipers and digital balance.

Theory

Refer to lab handout on **Error Propagation**.

Using the Metric Ruler

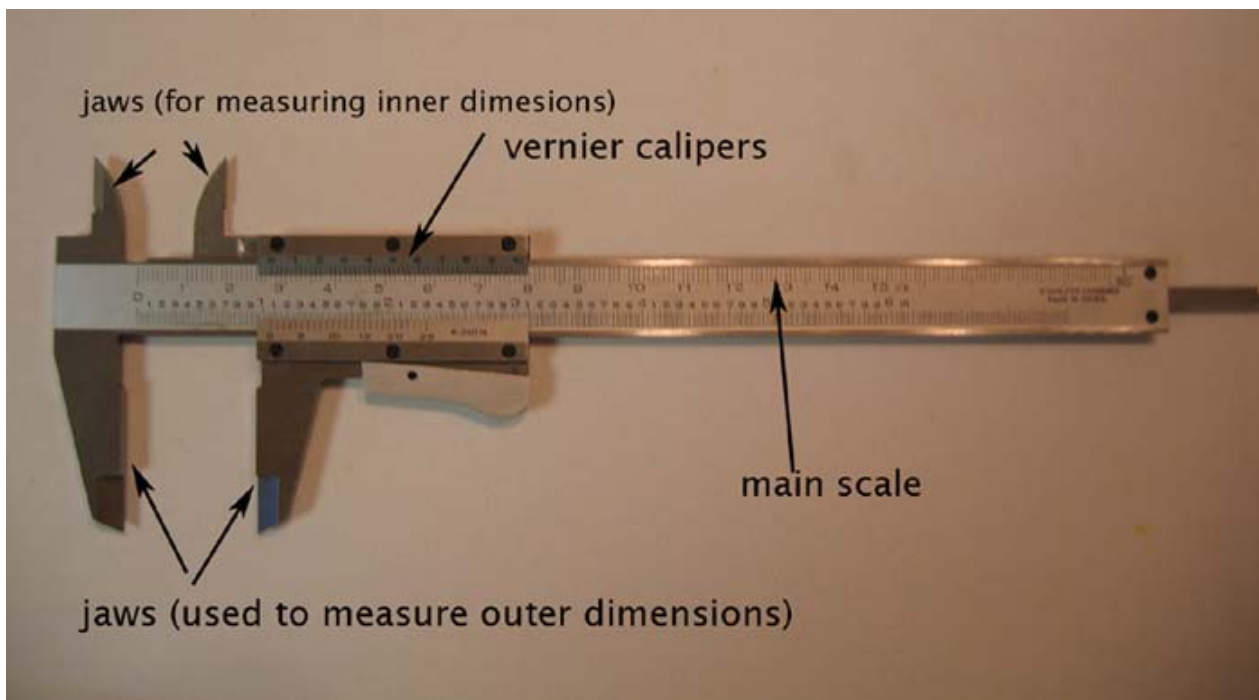
Consider the following standard metric ruler.



The ruler is incremented in units of centimeters (cm). The smallest scale division is a tenth of a centimeter or 1 mm. Therefore, the uncertainty $\Delta x = \text{smallest increment}/2 = 1\text{mm}/2 = 0.5\text{mm} = 0.05\text{cm}$. Note that a measurement made with this ruler must be stated to a tenth of a centimeter since the uncertainty is stated to a tenth of a centimeter. In the example above, the length of the object would be stated as $x = 2.77 \text{ cm} \pm 0.05 \text{ cm}$.

Using the Vernier Calipers

The Vernier caliper is an instrument that allows you measure lengths much more accurate than the metric ruler. The smallest increment in the vernier caliper you will be using is $(1/50)\text{mm} = 0.02\text{mm} = 0.002\text{cm}$. Thus, the uncertainty is $\Delta x = (1/2)0.002 \text{ cm} = 0.001 \text{ cm}$.



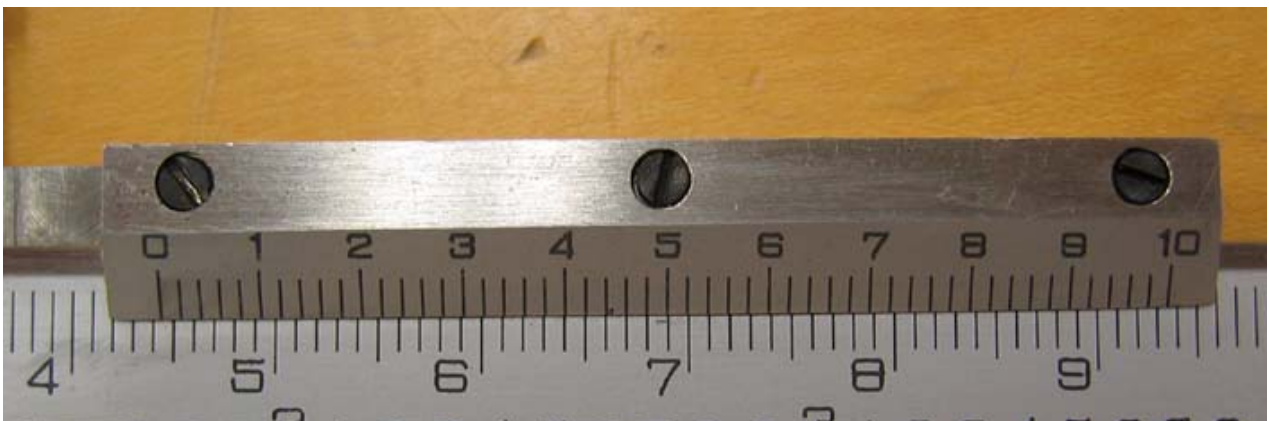
The vernier scale consists of a fixed metric scale and a sliding vernier scale. The fixed scale is divided into centimeters and millimeters, while the vernier scale is divided so that 50 divisions on it cover the same interval as 49 divisions on the main scale. Thus, the length of each scale vernier division is $49/50$ the length of a main scale division. Close the jaws completely and note that the first line at the far left on the vernier scale (called the “zero” or “index” line) coincides with the zero line on the main scale. Carefully compare and see that the first vernier division is 0.02 mm short of the first main scale division, the second vernier division is 0.04 mm away from the second main scale division, and so on. If the jaws are slightly opened it is easy to tell what fraction of the main scale division the vernier index has moved by noting which vernier division best coincides with a main scale division.

A measurement is made with a vernier caliper by closing the jaws on the object to be measured and then reading the position where the zero line on the vernier falls on the main scale. The measurement is incomplete until an additional fraction of a main scale division is determined. This is obtained by noting which line on the vernier scale (0,2,4,6,8) coincides best with a line on the main scale.

As an example, let's consider measuring the length of the aluminum block below.



Note that the zero line on the vernier scale falls between the 4.4 cm and 4.5 cm mark on the main scale. Thus, the first significant digits are 4.4 cm. The remaining two digits are obtained by noting which line on the vernier scale (0,2,4,6,8) coincides best with a line on the main scale. Looking closely at the picture below indicates that the 46 line lines up the closest. Therefore, the reading is 4.446 cm. Or in standard form $4.446 \text{ cm} \pm 0.001 \text{ cm}$.



Equipment

1. one aluminum block
2. meter stick
3. metric ruler
4. triple-beam balance
5. digital balance
6. vernier calipers

Procedure

(for this lab any measurements and calculations should be stated in the standard form of:

measurement = $x_{\text{best}} \pm \Delta x$)

Part I (Using Measuring Devices)

1. Learn to use all the measuring devices listed above.
2. Calculate the uncertainties of all measuring devices you will be using.

Part II (Area of Table-Top)

1. Measure the length of the table-top with the meter stick and calculate the uncertainty.
2. Measure the width of the table top.
3. Calculate the area and uncertainty of the table-top.

Part III (Density of Aluminum block Using Metric Ruler and Triple-Beam Balance)

1. Measure the dimensions of the aluminum block with the metric ruler.
2. Calculate the volume and uncertainty.
3. Measure the mass with the triple-beam balance.
4. Calculate the density ($\rho = M/V$) and uncertainty.
5. Calculate the % error between your calculate value of density and the expected value of 2.699 g/cm^3 .

Part IV(Density of Aluminum block Using Vernier Calipers and Digital Balance)

1. Calculate the volume and uncertainty of the aluminum block by measuring its dimensions with the vernier calipers.
2. Measure the mass of the aluminum block with the digital balance.
3. Calculate the density ($\rho = M/V$) and uncertainty.
4. Calculate the % error between your calculate value of density and the expected value of 2.699 g/cm^3 .

