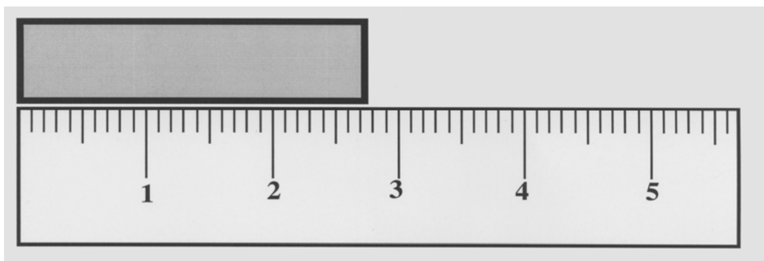
Lab Skills: Using Rulers, Vernier Calipers, and Micrometers*

1 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 is clearly longer than 2.7 cm and less than 2.8 cm. It looks closer to 2.8 cm, so the value would be stated as $x = 2.77$ cm $\pm$ 0.05 cm.

(You might think it looks more like $x = 2.78$ cm $\pm$ 0.05 cm, that would also be fine, it is still inside the uncertainty range. Make the best estimate you can.)

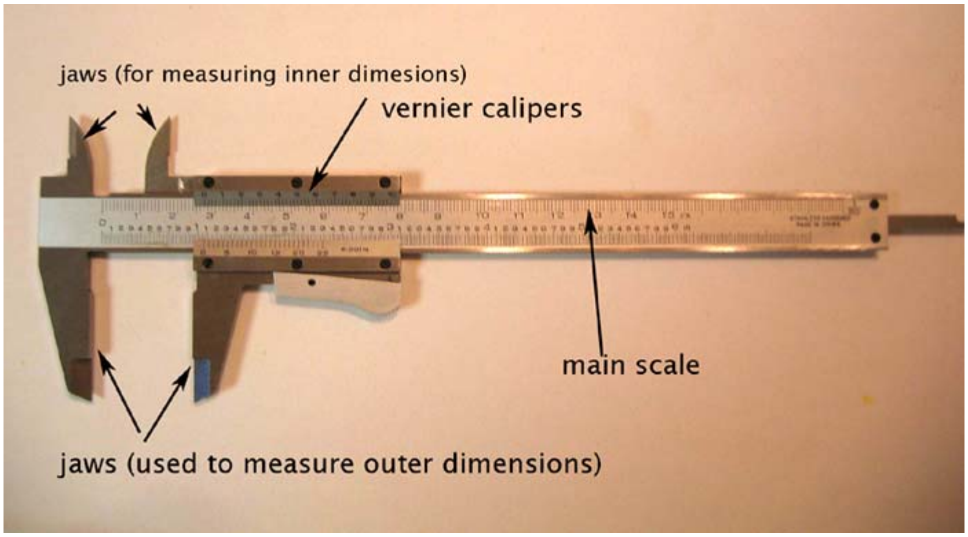
2 Using the Vernier Calipers

The Vernier caliper is an instrument that allows you measure lengths much more accurately than the metric ruler. The smallest increment in the vernier caliper you will be using is (1/50) mm = 0.02 mm = 0.002 cm. Thus, the uncertainty is

$$\Delta x = \left(\tfrac{1}{2}\right) 0.002 \text{ cm} = 0.001 \text{ cm}.$$

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 (at least this is the way the ones De Anza has are constructed). Thus, the length of each scale vernier division

*These notes are largely drawn from the first lab explanation of Prof Eduardo Luna.



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.

2.1 More details about how a Vernier Scale works[1]

A vernier scale slides across a fixed main scale. The vernier scale shown below in figure 1 is subdivided so that ten of its divisions correspond to nine divisions on the main scale. (10/9 is easier to see than 49/50.) When ten vernier divisions are compressed into the space of nine main scale divisions we say the vernier-scale ratio is 10:9. So the divisions on the vernier scale are not of a standard length (i.e., inches or centimeters), but the divisions on the main scale are always some standard length like millimeters or decimal inches. A vernier scale enables an unambiguous interpolation between the smallest divisions on the main scale.

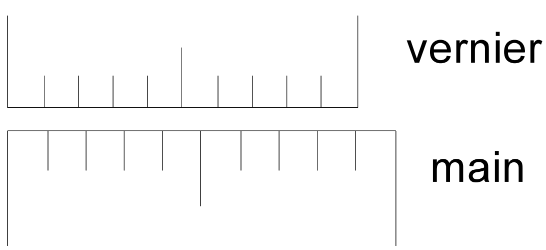


Figure 1: A 10/9 Vernier scale.

[1]This section is drawn from the first lab explanation of Prof David Newton.

Since the vernier scale pictured above is constructed to have ten divisions in the space of nine on the main scale, any single division on the vernier scale is 0.1 divisions less than a division on the main scale. Naturally, this 0.1 difference can add up over many divisions. For example, after six divisions have been spanned by both scales, the difference in length between the vernier and main scale would be $6 \times 0.1 = 0.6$ divisions. In figure 2 below, both the vernier and main scale start evenly at the left. After a distance of six increments they differ in length by 0.6 increments as is indicated by the two dotted lines.

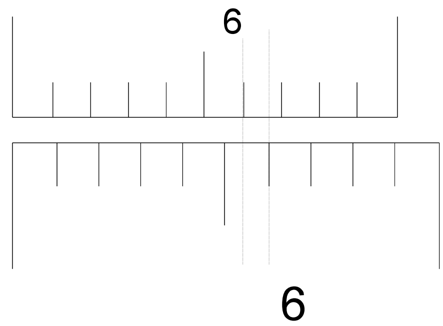


Figure 2: In the span of six divisions, the difference between the vernier and main scale is 0.6 divisions.

When using the Vernier calipers for a measurement, the object in the jaws will cause an offset in the two scales on the *left* edge of the scales. In figure 3, the two scales are still off by 0.6 divisions as in figure 2 above, however in figure 3 the scales match up along the dotted vertical line on the right side instead of matching up on left side as in figure 2. In figure 3, we would say the two dotted vertical lines on the left side of the figure are separated by 0.6 divisions of length in the same sense that the two lines in figure 2 are separated by 0.6 divisions. Study and compare figures 2 and 3 to understand how a vernier system works.

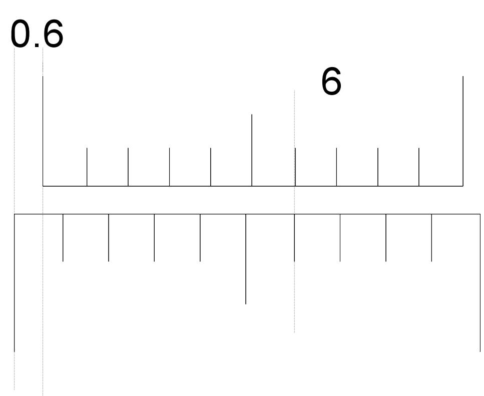
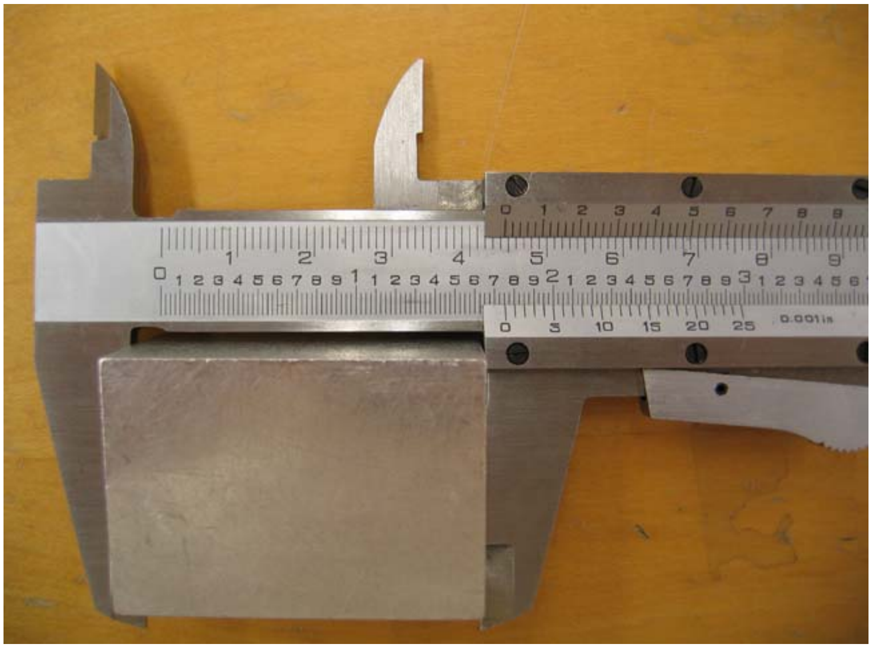


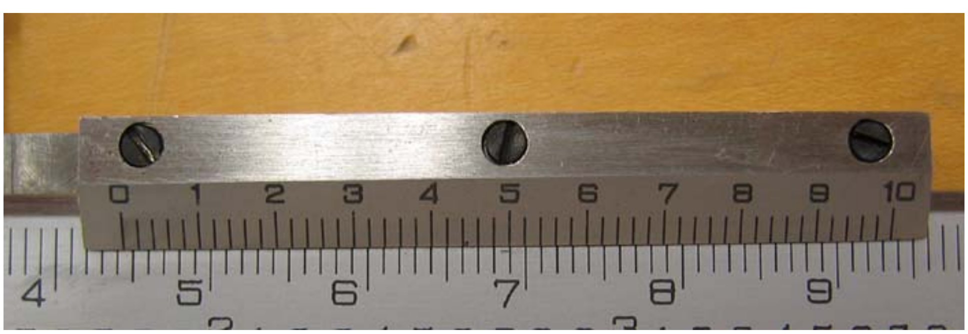
Figure 3: The offset on the left is 0.6 divisions, so now the 6th line aligns exactly with the main scale.

2.2 Making a measurement

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, lets consider measuring the length of the aluminum block below.

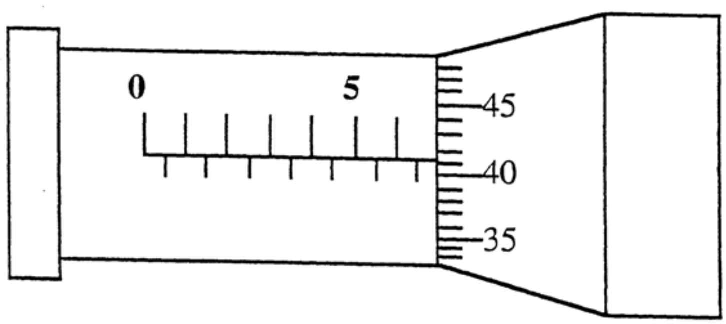


Note that the zero line on the vernier scale falls between the 4.4 cm and 4.5 cm mark on the main scale. Thus, the first significant digits are 4.4 cm. The remaining two digits are obtained by noting which line on the vernier scale (0,2,4,6,8) coincides best with a line on the main scale. Looking closely at the picture below indicates that the 4.6 line lines up the closest with a mark on the main scale. Therefore, the reading is 4.446 cm. Or in standard form 4.446 cm ± 0.001 cm.



3 Using The Micrometer Caliper

The micrometer caliper has a linear scale engraved on its sleeve and a circular scale engraved on what is properly called the thimble. The linear scale is divided into divisions of 1 mm and is 25 mm long. Half-millimeter marks are provided below the linear scale. The circular scale has 50 divisions. One complete revolution of the circular scale moves the thimble 0.5 mm along the linear scale so that the distance between the jaws is also changed to 0.5 mm. Since the circular scale has 50 divisions, rotating it through one circular-scale division, will cause the rod to move through a distance equal to 1/50 of 0.5 mm, or 0.01 mm. Thus the numbers on the circular scale represent hundredths of a millimeter. A micrometer caliper can be used to measure lengths directly to 0.01 mm, and by estimating tenths of a circular scale division, it can be used to estimate lengths to 0.001-0.002 mm. Measurements made with a micrometer caliper can be estimated to thousandths of a millimeter. The total micrometer caliper reading is the sum of the readings on the main and circular scales. In the figure to the left, notice the main scale which is marked with a 0 and a 5. These indicate millimeters. Below the main scale are marks at the half way points between mm marks. These l/2 mm marks are present because one revolution of the thimble moves the thimble only 1/2 mm down the barrel. Possible settings and readings of the micrometer caliper are shown here.



In the example, the half-millimeter mark to the right of the sixth main scale mark is visible. So the reading is somewhere between 6.5 and 7.0 mm. The line on the main scale points to a point of the barrel just slightly past the 41 mark. So we can estimate the last place of the reading to be 0.002 mm. The reading is then 6.5 mm + 0.41 mm + 0.002 mm = 6.912 mm = 0.0069 12 meters. This shows that we can estimate micrometer readings to one thousandth of a millimeter. The final value is $(6.912 \pm 0.005) \times 10^{-3}$ m.