1. THE VERNIER SCALE

Equipment List:

- two 3 X 5 cards
- one ruler incremented in millimeters

What you will learn:

This lab teaches how a vernier scale works and how to use it.

I. Introduction:

A vernier scale (Pierre *Vernier*, ca. 1600) can be used on any measuring device with a graduated scale. Most often a vernier scale is found on length measuring devices such as vernier calipers or micrometers. A vernier instrument increases the measuring precision beyond what it would normally be with an ordinary measuring scale like a ruler or meter stick.

II. How a vernier system works:

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 <u>nine</u> divisions on the main scale.** 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.
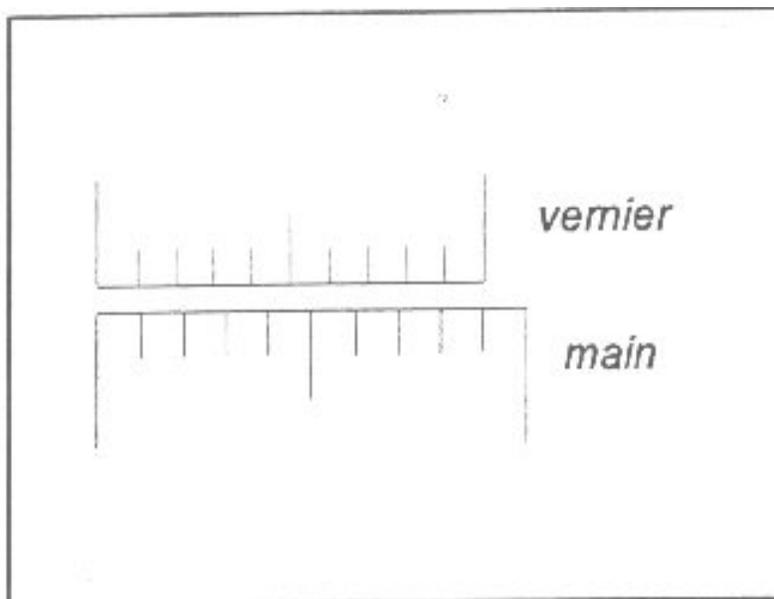

Figure 1: Ten vernier divisions in the space of nine main scale divisions, a scale ratio of 10:9.

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 X 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.
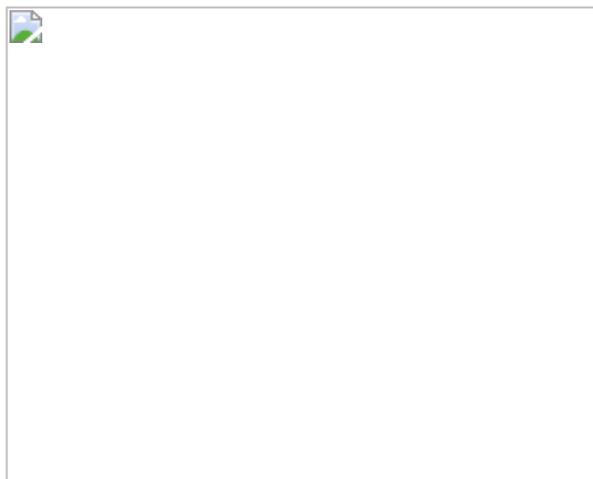
In practice, the **left** sides of the two scales are not matched up as above. Instead, the two left sides of each scale are *offset* by an amount corresponding to the length measured. In figure 3, the two scales are still off by 0.6 divisions as in figure 2 above, however in figure 3 the scales match 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.
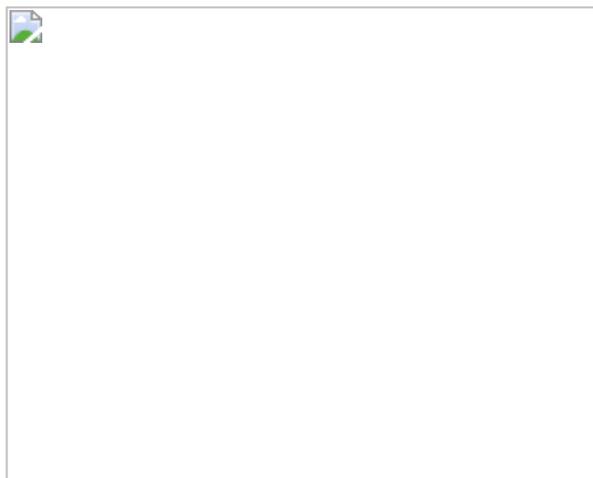

### III. Measuring an object's length the vernier way:

In measuring the length of an object with vernier calipers, the first two significant figures are read from the main scale. Find where the left edge of the vernier scale crosses the main scale and record the corresponding values immediately so you don't forget them. In figure 4 on the next page, you should confirm that the first two significant figures of the measurement are 2.7 units. This information could be obtained without using a vernier; this is just standard measuring procedure. It is the third significant figure that must be obtained using the vernier scale.

In figure 4, see that the vernier and main scale divisions align where the **vernier** scale reads 0.4. Actually, in terms of the total instrument this corresponds to a value of 0.04 units, **not** 0.4. Thus, the measurement of the box's length would 2.74 units.

See that the first two numbers are read from the main scale and the third number from the vernier. Confirm the full measurement in figure 4.
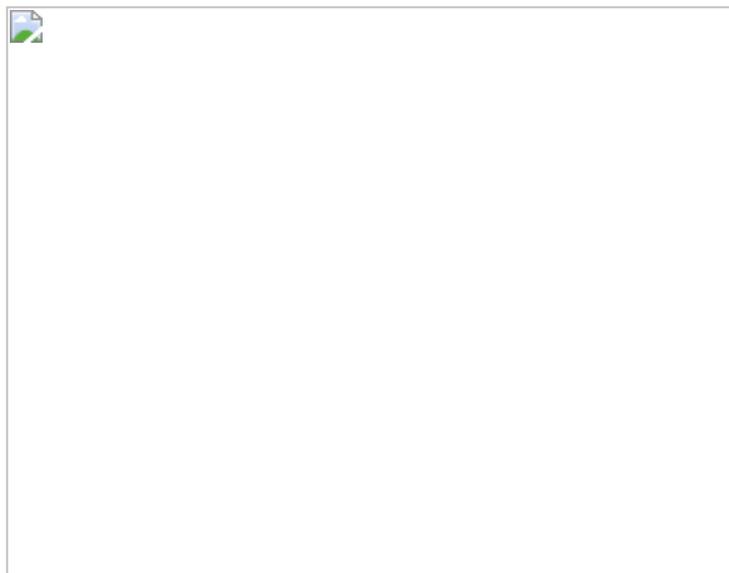
IV. Using the vernier calipers provided: In figure 5 below, the relation between the vernier and main scale is not one of ten in the space of nine but of twenty in the space of nineteen. This increases the precision of the instrument.
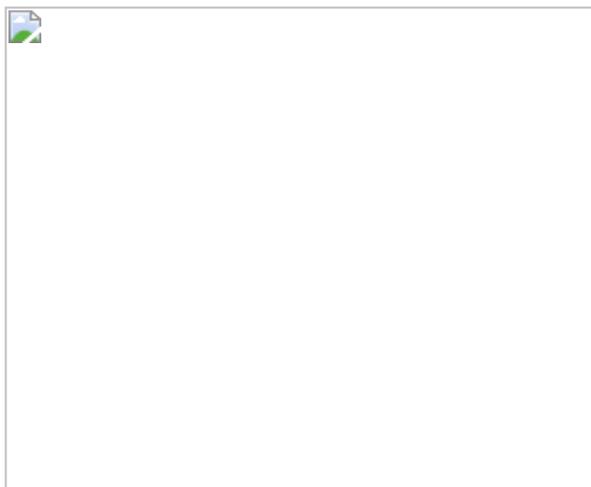
V. The absolute uncertainty of your vernier calipers: You will note a 1/20 mm (one twentieth of a millimeter) printed on the right side of the main scale. 1/20 mm corresponds to 1/200 of a centimeter or in decimals, 0.005 cm. Take this value to be the absolute uncertainty in your scale reading, although some people prefer to use 0.003 cm instead, the choice is yours. Below in figure 6, the reading to three significant figures would be 4.26 cm. But notice the two increments between the vernier and main scale are not perfectly aligned. You should interpolate the vernier scale to read to *three* decimal places. Confirm the reading to be about (4.259 ± 0.005) cm and see that it is not 4.261 cm since the left-side zero mark on the vernier scale is *closer* to the left side zero on the main scale and so the reading is *smaller* in value than 4.260.
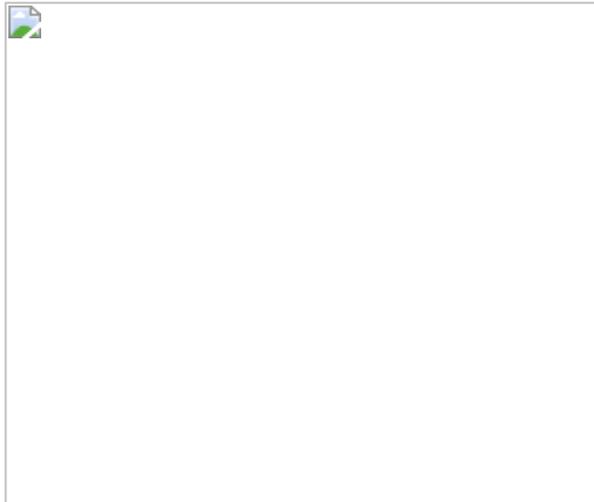
VI. Making your own vernier scale:

1. Take two 3 X 5 cards provided by your instructor.

2. Using your ruler and a sharp pencil, mark the **top** edge of one card once every centimeter starting from the left edge of the card all the way to the right side. The very left edge of this card will be the "zero". Every centimeter mark after the zero will be labelled 1, 2, 3, and so on. Write at the bottom of this card: "MAIN SCALE". Examine figure 7 for a rough idea of what you are to do.

3. Take the second card and place it before you on the lab table. At the **bottom** of this card mark an increment every *nine millimeters* starting at the left most edge. Mark ten increments only, each separated by *nine millimeters*. Label each increment with a 1, 2, 3, and so on until you reach 10. Label this card "VERNIER SCALE".

4. You have made your first (and last?) vernier scale which will measure an interpolation of the main scale to a tenth of a centimeter (one millimeter). For one more significant figure, you could interpolate the vernier scale as well.

Use your hand made vernier to measure a few straight lines that you draw into your lab book. Confirm the measurement with your vernier calipers with the measurement from a meter stick. Place the left edge of your MAIN SCALE card at the left edge of the line. Then place the **left** edge of your VERNIER SCALE at the **right** edge of the line. Record the length of the line to two decimal places in centimeters (i.e., 2.34 cm).