

Name _____

Lab Partners _____

Measurement and Error Analysis with Calipers

Introduction:

Accurate measurement requires appropriate tools. When measuring a tabletop, for instance, one could use a meter stick to produce a suitable measurement. The meter stick has gradations small enough to attain a measurement to within millimeters. Therefore, one can make a measurement accurate to within a thousandth of a meter. This is good accuracy if the table is roughly a meter or longer.

To measure a table top the most appropriate instrument would be:

- (a) a ruler (b) a meterstick (c) a vernier caliper

By this reasoning one can see that measuring something like the thickness of a pencil with a meter stick would be inappropriate. Assuming a pencil is roughly 5 millimeters in diameter, one would want a tool that could give measurements accurate to a fraction of a millimeter. The vernier and micrometer calipers were developed to perform such measurements.

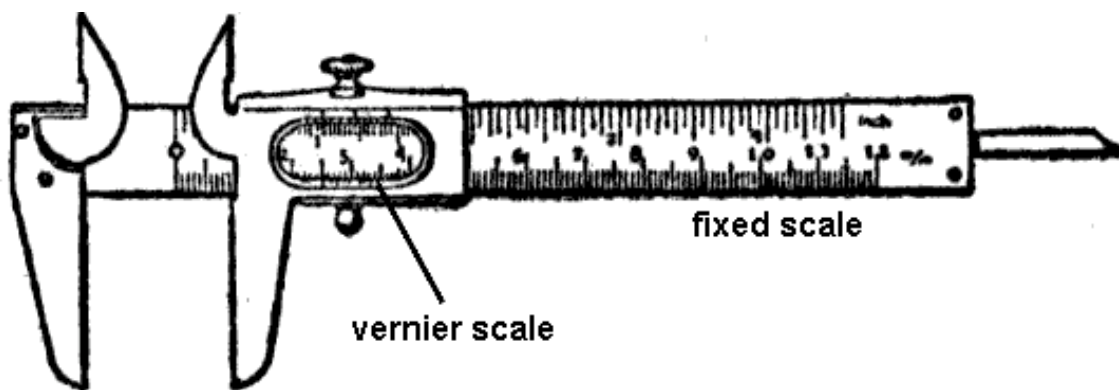


figure 1

The *vernier caliper* (figure 1) is a fairly simple measurement tool. It has two parts: a stem with the main scale (cm, mm, and inches) and the vernier, a secondary scale, which slides along the stem and allows for identification of fractions of the main scale. Each part of the caliper culminates in a jaw to grasp the item being measured. Ten vernier scale divisions fit within nine stem divisions (remember the stem is the fixed part), so each vernier division is $9/10$ as long as a stem division. When the jaws of the caliper are closed, the first line of the vernier, the zero line, coincides with the zero line of the main scale. This means that the first division of the vernier is 0.1 mm from the first main scale division, the third division of the vernier is 0.3 mm away, etc.

To make a measurement with the vernier caliper, the jaws must be tightly closed around an object. Wherever the zero line of the vernier falls indicates the number in the tenths place of the measurement. The next line on the vernier that aligns with the main scale indicates the hundredths place. (Refer to figure 2 for examples)

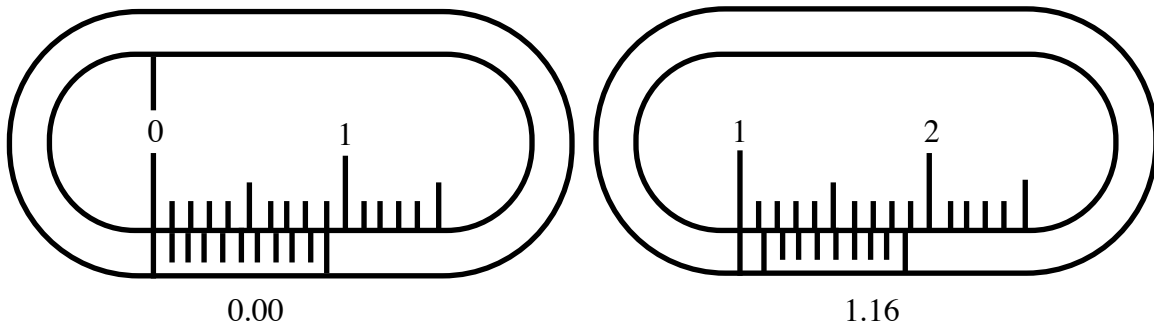


figure 2

In figure 2 above, circle the lines that indicate the 6 hundredths place on the right caliper scale.

The *micrometer caliper* (figure 3) is another tool for measuring short lengths. It is slightly more accurate than the vernier caliper, because it can measure to within thousandths of a millimeter.

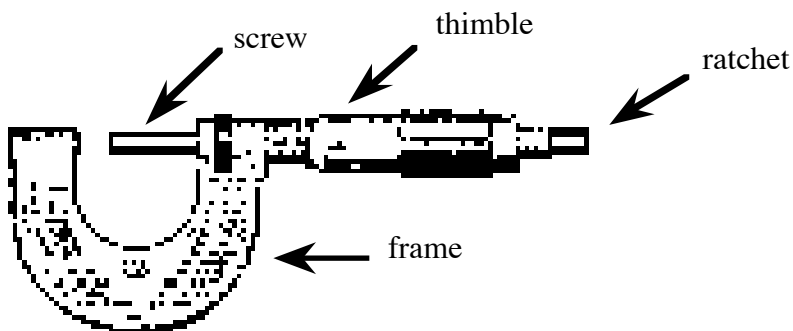


figure 3

To use the micrometer caliper, an object must be placed between the screw and the frame. The thimble is then turned to advance the screw until the object is almost gripped. Then, the ratchet is used to finish gripping the object. When it slips on the screw and clicks, enough force has been applied. The ratchet ensures that the caliper is not damaged through over-tightening. Like the vernier caliper, there are two scales on the micrometer caliper, a circular scale on the thimble and a longitudinal scale along the barrel containing the screw. The longitudinal scale is divided into half millimeters, and the circular scale has fifty divisions. Rotating the circular scale through one full revolution advances the screw by 0.5 mm (the distance between two marks on the longitudinal scale). Rotating the thimble through one scale division (the distance between marks on the circular scale) advances the screw $1/50^{\text{th}}$ of 0.5 mm or 0.01 mm.

On the micrometer caliper, rotating the circular scale through one revolution advances the screw by:

- (a) 0.5 cm (b) 0.01 mm (c) 0.5 mm

To read the micrometer, there are two features to observe. The first is the position of the circular scale on the longitudinal scale. This gives you the number of millimeters. The next feature to note is which line on the circular scale aligns with the axial line on the longitudinal scale. This gives the fractional portion of the millimeter reading (for example if the 10 on the circular scale lines up with the axial line on the longitudinal scale, you have .10 of a mm). Then the two readings are added together to obtain a final measurement.

Using your micrometer caliper, measure the width of a pencil in mm, and record the measurement: _____ mm.

Procedure:

1. Draw a 4-inch line with a ruler on a piece of paper. Measure the line in centimeters to the greatest precision the ruler will allow. Record the number of centimeters and then calculate the conversion factor between inches and centimeters (i.e. divide the two numbers, don't forget the division rule for significant figures).

Use the golden rule for reporting measurements:

Report all of the digits that you know with certainty, plus the first digit that you must estimate.

Length of line:

____ in How many significant figures are in your measurement? (remember this is determined by your ruler) ____

Which is the uncertain digit? ____

____ **cm** How many significant figures are in your measurement? ____

Which is the uncertain digit? ____

Calculation of Conversion Factor : (take the ratio of your measurements)

2. Now calculate the percent error between the actual value (look it up in your text) and the value you came up with.

Definition of Percent Error :

$$\% \text{ error} = \left| \frac{\text{your result} - \text{accepted value}}{\text{accepted value}} \right| \times 100\%$$

3. Take a cylindrical mass and measure its diameter and height three times with the vernier caliper. Record this in table 1 (Make sure everyone gets to read and confirm the measurements before they are recorded)

Also, make sure to take the caliper off the mass between measurements.

| | <i>Height (cm)</i> | <i>Diameter (cm)</i> | <i>Radius (cm)</i> |
|--------------------------------|------------------------|--------------------------|------------------------|
| <i>Trial 1</i> | | | |
| <i>Trial 2</i> | | | |
| <i>Trial 3</i> | | | |
| <i>mean</i> | | | |
| <i>standard deviation</i> | | | |
| $\sigma_{\text{statistical}}$ | | | |
| $\sigma_{\text{instrumental}}$ | | | |

Table 1: Measurements of a Cylindrical Mass with a Vernier Caliper

Sample Calculation for Mean:

Sample Calculation for Standard Deviation:

Sample Calculation for $\sigma_{\text{statistical}}$:

4. Take a penny and measure its diameter and height (thickness) three times with the micrometer caliper. Record this in table 2 (make sure everyone in the group gets to read and confirm the measurements before they are recorded).

| | Height (mm) | Diameter (mm) | Radius (mm) |
|--|------------------------|--------------------------|------------------------|
| Trial 1 | | | |
| Trial 2 | | | |
| Trial 3 | | | |
| mean | | | |
| standard deviation | | | |
| $\sigma_{\text{statistical}}$ | | | |
| $\sigma_{\text{instrumental}}$ | | | |

Sample Calculations:

Table 2: Measurements of a Cylindrical Mass with a Micrometer Caliper

5. Now find the volume of the cylindrical mass. (You can find the equation for the volume of a cylinder in Appendix I of your text.) Enter your results in table 3. Remember to use the mean values in your calculations.

Sample Calculation of Volume:

| | Vernier (cm^3) | Micrometer (mm^3) |
|---------------|---|--|
| Volume | | |

Table 3: Calculated Volume of a Cylindrical Mass

6. Now that you have the volume, estimate the error in your figures. (Refer to error analysis handout sample problem)

First, find the overall uncertainty in your measurements. Do this for both sets of data. Express your measurements for r and h as the mean \pm your overall uncertainty.

Vernier :

$$r = \text{___ cm} \pm \text{___ cm}$$

$$h = \text{___ cm} \pm \text{___ cm}$$

Micrometer :

$$r = \text{___ cm} \pm \text{___ cm}$$

$$h = \text{___ cm} \pm \text{___ cm}$$

Questions:

Please write answers on this sheet. Attach another sheet if necessary.

1. Does percent error pertain to accuracy or precision? Explain.
2. How could the error be improved in this experiment?
3. Why are several observations better than one in an experiment?