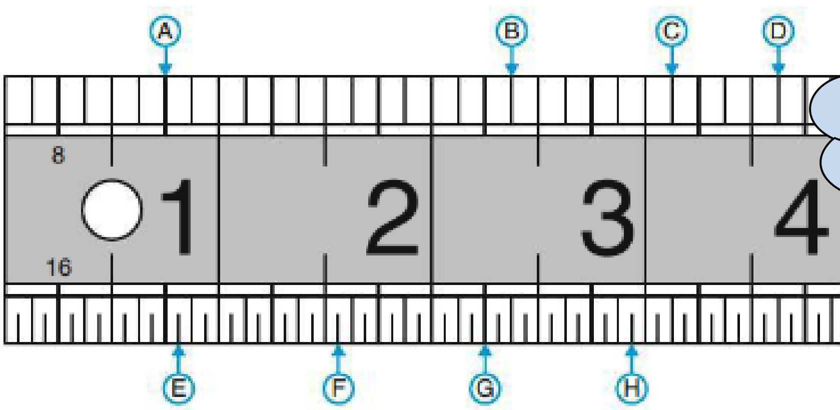
Reading various instruments may come up in your future job.

Technology Integrated Mathematics
Class Notes
Measurement: Direct Measurements (Section 5.5)

Many instruments like voltmeters or calipers give a digital readout. However, many will need to be read manually. We will learn about common instruments.

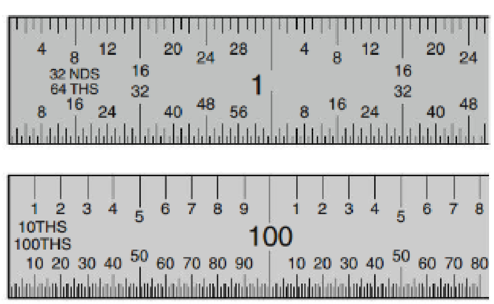
Length Ruler or Rule:
We will be given a rule of some scale which we will need to figure out and then read. To use any scale, first count the number of spaces in a 1-inch interval. This tells you the size of the smallest division (by dividing 1 by the number of spaces). We will use the following ruler as an example.



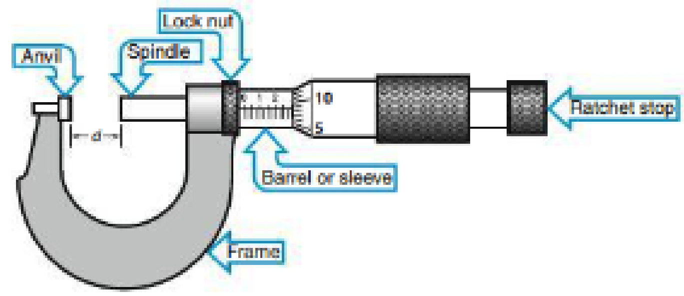
Count the spaces for each scale (top and bottom) in 1 inch.

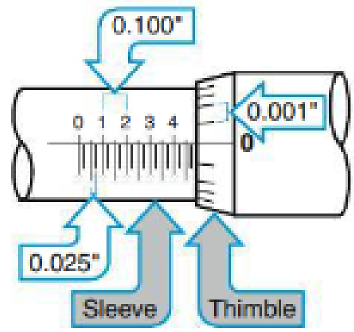
expl 1: Find the lengths marked by the letters A, C, and G.

Other rules are broken into other denominations like 32nds, 64ths, or hundredths as seen here. The procedure used will be similar.



Micrometers:
These will be used to measure lengths with greater accuracy than can be gotten from a ruler. Here is a picture of a manual one with a zoomed in version of the measurement end.





Two scales are used on a micrometer. The first scale, marked on the sleeve, records the movement of a screw machined accurately to 40 threads per inch. Each of the smallest divisions on this scale are worth 0.025 inch. The second scale is marked on the rotating spindle. One complete turn of the thimble advances the screw one turn, or 1/40 inch. The thimble has 25 divisions, so that each mark on the thimble scale represents a spindle movement of $\frac{1}{25}\times\frac{1}{40}=\frac{1}{1000}=0.001$ inch. This explains how we read the instrument.

Reading a Micrometer:
Step 1: Read the largest numeral *visible* on the sleeve and multiply this number by 0.100 inch.

Step 2: Read the number of additional scale *spaces visible* on the sleeve. (This will be 0, 1, 2, or 3.) Multiply this number by 0.025 inch.

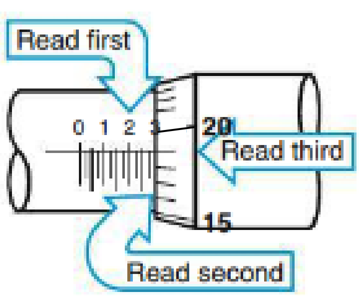
Step 3: Read the number on the thimble scale opposite the horizontal line on the sleeve and multiply this number by 0.001 inch.

Step 4: Add these products and you have the measurement.

A space is only counted if the right end marker is visible.

expl 2: Read the following micrometers.

a.)



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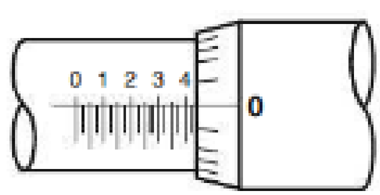


Metric Micrometers:
Metric micrometers are easier to read. Each small division on the sleeve represents 0.5 mm. The thimble scale is broken into 50 spaces. Therefore, each thimble division is $\frac{1}{50}\times 0.5 = 0.01$ mm.

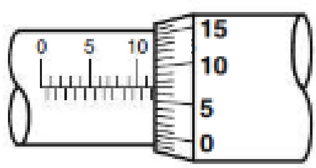
Reading a Metric Micrometer:
Step 1: Read the largest mark *visible* on the sleeve and multiply this number by 1 mm.

Step 2: Read the number of additional *half spaces visible* on the sleeve. These are on the *underside* of the scale. (This will be 0 or 1.) Multiply this number by 0.5 mm.

Step 3: Read the number on the thimble scale opposite the horizontal line on the sleeve and multiply this number by 0.01 mm.

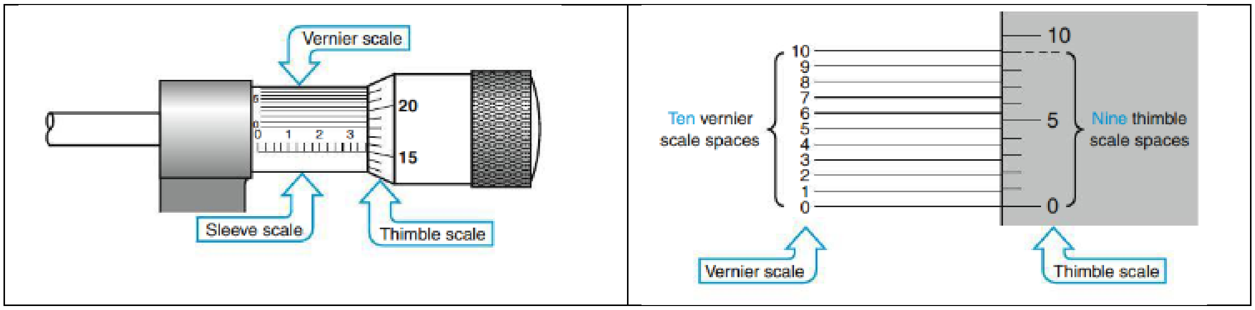
Step 4: Add these products and you have the measurement.

expl 3: Read this metric micrometer. Notice it has a different scale as before.



Vernier Micrometers:

The vernier micrometer can measure length to an accuracy of ± 0.0001 inch. It does this by adding another scale to the sleeve. This new scale appears as a series of ten lines parallel to the axis of the sleeve above the usual scale. Here is a picture with a close-up on the right.



The difference between a vernier scale division and a thimble scale division is one-tenth of a thimble scale division, or 1/10 of 0.001 inch which is 0.0001 inch.

Reading a Vernier Micrometer:

The first three steps are the same as given on page 2.

Step 1: Read the largest numeral *visible* on the sleeve and multiply this number by 0.100 inch.

Step 2: Read the number of additional scale *spaces visible* on the sleeve. (This will be 0, 1, 2, or 3.) Multiply this number by 0.025 inch.

Step 3: Read the number on the thimble scale opposite the horizontal line on the sleeve and multiply this number by 0.001 inch.

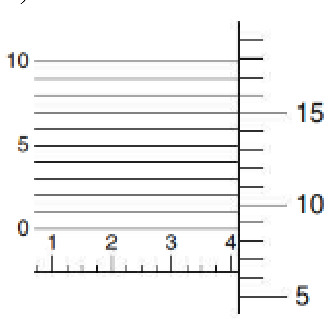
Step 4: Find the *smallest* number of the line on the vernier scale that lines up *exactly* with any line on the thimble scale. Multiply this number by 0.0001 inch.

Step 5: Add these products and you have the measurement.

These pictures may be hard to read due to printing or computer screen inaccuracy. Do your best.

expl 4: Read the following vernier micrometers.

a.)



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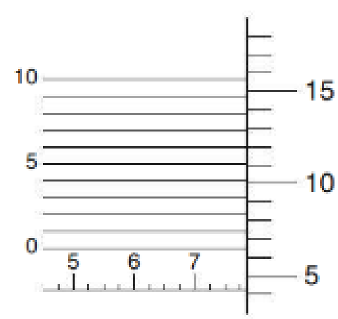
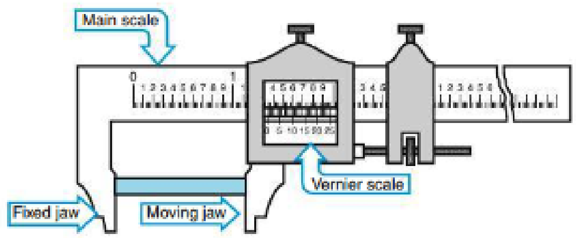


Vernier Calipers:

These calipers can measure lengths to an accuracy of ± 0.001 inch. On the manual instrument, each inch of the main scale is divided into 40 parts so that each smallest division on the scale is 0.025 inch. Every fourth division (or 1/10 inch) is marked with a number. The numbered marks represent 0.100, 0.200, 0.300, etc. inches.

The vernier scale is divided into 25 equal parts numbered by 5s. These 25 divisions on the vernier scale cover the same length as 24 divisions on the main scale. Instructions for reading these calipers is on the next page.



Reading Vernier Calipers:

Step 1: Read the number of whole-inch divisions on the main scale to the left of the vernier zero. This gives the number of whole inches.

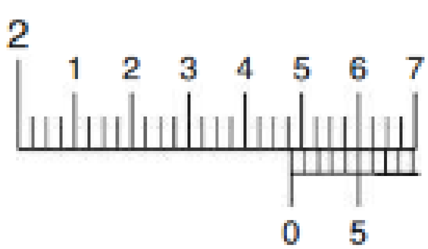
Step 2: Read the number of tenths on the main scale to the left of the vernier zero. Multiply this number by 0.100 inch.

Step 3: Read the number of additional *whole spaces* on the main scale to the left of the vernier zero. Multiply this number by 0.025 inch.

Step 4: On the sliding vernier scale, find the number of the line that lines up *exactly* with any line on the main scale. Multiply this number by 0.001 inch.

Step 5: Add these four products and you're there.

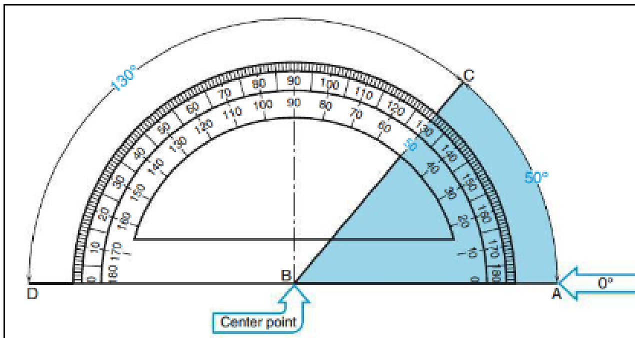
expl 5: Read the following vernier caliper. This is a zoomed-in version of the vernier window (my term) on the calipers.

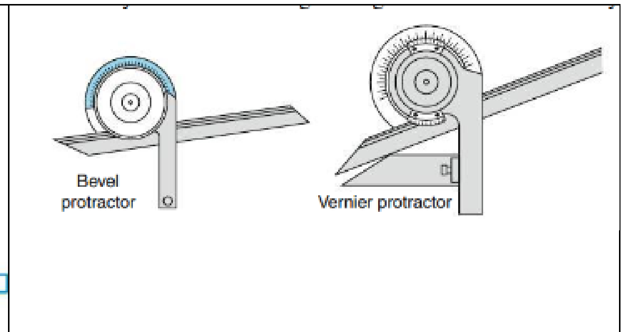


Protractors:
We use protractors to measure and draw angles. The one shown below will measure degrees with every ten degrees marked.

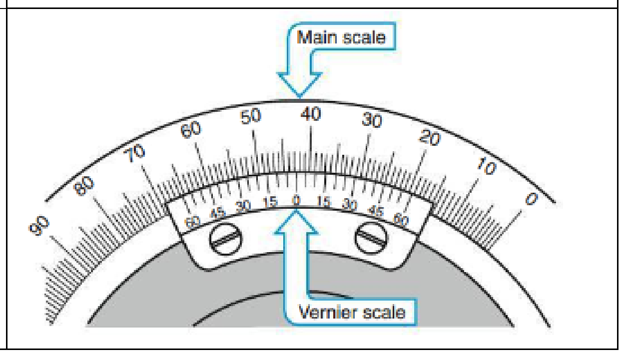
To use a protractor, we line up the vertex with the center point (at the base) and one side of the angle with the protractor base itself. You can read the protractor from either side; you will see numbers go both from left to right and from right to left.

The **bevel protractor** is useful in shopwork because it can be adjusted with an accuracy of ±0.5°. The angle is read from the movable scale. The **vernier protractor** can be used for an accuracy of ±1/60 of a degree (which is called a minute).





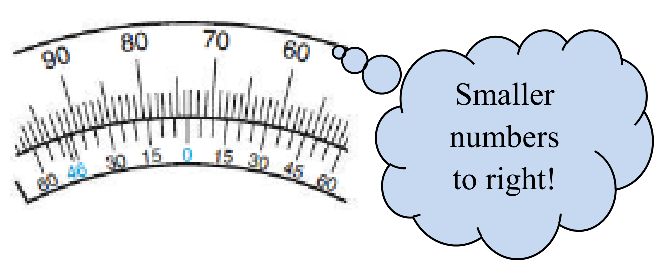
We will practice finding measures with the **vernier protractor**. The scale is shown to the right. You will be given the number needed in step 2 below (shown in blue). MML will also use blue to point out the zero on the vernier scale.



Reading a Vernier Protractor:
Step 1: Read the number of whole degrees on the main scale that is closest to the zero on the vernier scale. This will be the "degrees" of the angle, denoted by °.

Step 2: Find the vernier scale line on the *left* of the vernier zero that lines up *exactly* with a main scale marking. This will be the "minutes" of the angle, denoted by the symbol shown here: 12′

expl 6: Read the vernier protractor. You will be shown in blue the minutes from step 2.

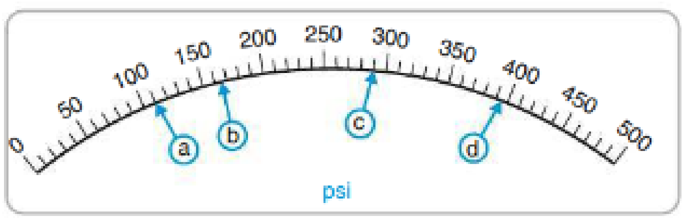


Meters with Uniform Scales:
Measuring instruments that convert the measurement into an electrical signal and then display it by means of a pointer and a decimal scale are called **meters**. They are used to measure electrical quantities such as voltage, current, and power, and quantities like air pressure, flow rates, or speed.

The **range** of a meter is its full-scale or maximum reading. The **main divisions** of the scale are marked with numbers. The **small divisions** will be marked with tick marks. On a **uniform scale**, all marks are equally spaced, and all divisions represent the same quantity.

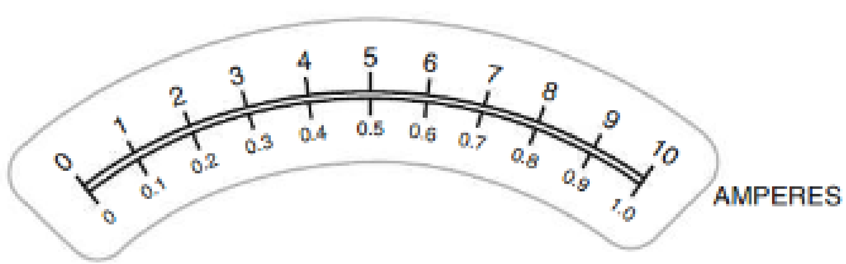
Again, we may see these scales used for various quantities but our example here will focus on psi, or pounds per square inch, a pressure reading.

expl 7: For the following meter, give the reading for points a and c. Include units.

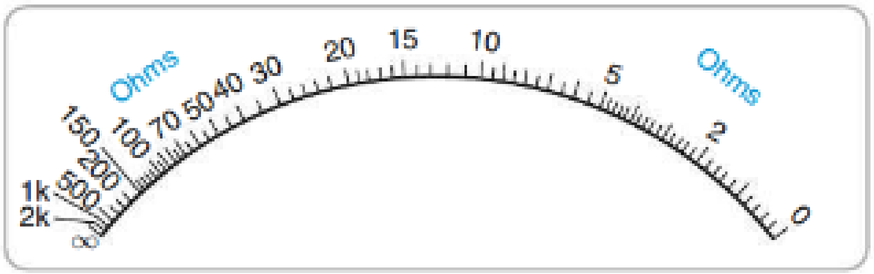


We may round to the nearest division or estimate if the pointer falls between divisions.

A **dual-scale meter** will have an upper and lower scale and allows the user to switch ranges as needed. Here is an example but we will *not* see it in the homework.



Meters with Non-Uniform Scales:
Here, spacing between divisions changes at various places along the scale. The number of units represented by each small division *also changes*. The following ohm-meter scale is an example.



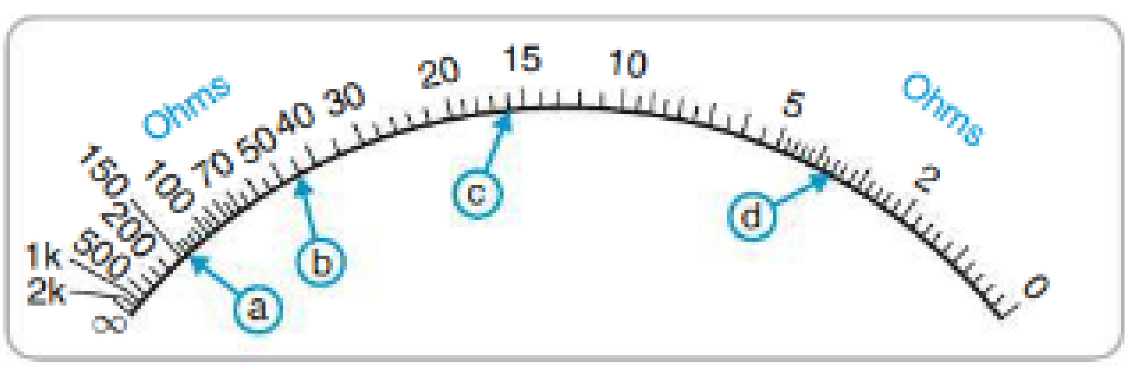
We start on the *right* side at 0. Notice that between 0 and 5 Ω (ohms), each one-ohm range contains *five* subdivisions, so that each of these small divisions represent 0.2 Ω. However, between 5 and 10 Ω, each one-ohm range contains *two* subdivisions. Therefore, each of these small divisions represents 0.5 Ω.

As you move to the left, the scale continues to compress, with each small division representing a larger number of units.

Here is a table that breaks down the various values for these subdivisions.

Range on the Scale	Value of Each Subdivision
0–5 Ω	0.2 Ω
5–10 Ω	0.5 Ω
10–20 Ω	1 Ω
20–30 Ω	2 Ω
30–100 Ω	5 Ω
100–150 Ω	10 Ω
200–500 Ω	100 Ω

expl 8: Read the following ohmmeter for points a and c.



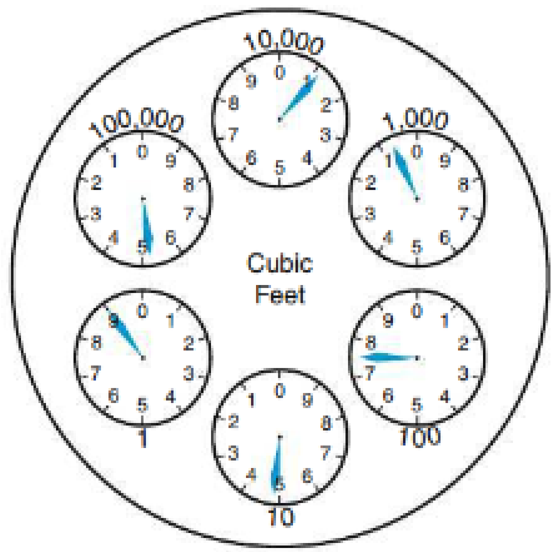
Meters with Circular Scales:

Some meters have two or more circular dials. Each dial represents a different unit. You must pair the reading on each dial with its unit value and then combine the results into a single measurement.

The meter shown here measures the number of cubic feet of water use. It contains six dials, each labeled with a power of ten ranging from 1 to 100,000.

To determine the number of cubic feet, read the dials in descending order, beginning with the 100,000 dial.

If the needle is between two numbers, always read the smaller one. If it's between 9 and 0, read the 9.

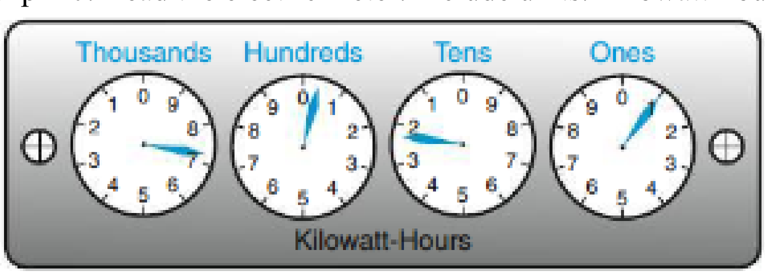


expl 9: Read the meter above. It is helpful to put out six dashes as shown. The units is shown in the center of the meter.

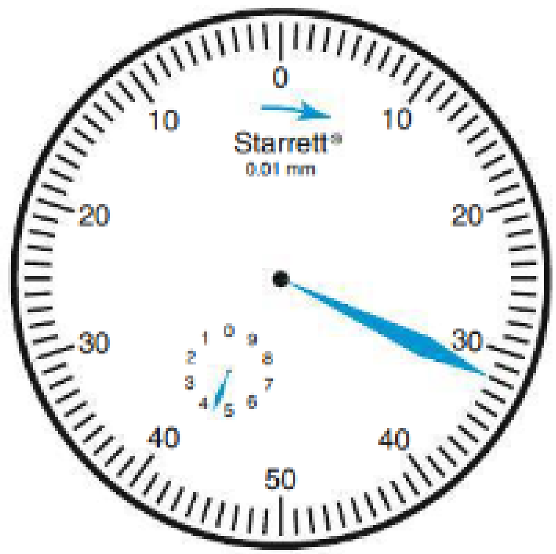
____ ____ ____, ____ ____ ____

Remember, if the needle is between two numbers, always read the smaller one.

expl 10: Read the electric meter. Include units. Kilowatt-hours is abbreviated as kWh.



Dial gauges (dial indicators):
Dial gauges or **dial indicators** are used to measure very small distances. They are useful to detect a small difference in height along a flat surface, to center cylindrical stock, to monitor the depth of drilled holes, and to perform other precise measurements.

Here we see a dial gauge. There is a large scale and a little scale within it. Also, notice the arrow at the top to indicate the needle has been rotating in that direction. (In real life, you must observe the direction of rotation.) **For the larger scale,** each small division represents 0.01 mm as indicated below the name Starrett. **The smaller scale** represents how many times the larger needle has rotated completely around its scale. Each complete revolution would equal 1.00 mm.	

In real life, you watch the needle rotate. If it rotates clockwise, we call that a **positive deflection**. If it rotates counter-clockwise, we call that a **negative deflection**. (This means either the measurement is larger or smaller than some standard or desired measurement.) For our purposes, the direction of rotation is given to us with the arrow at the top.

Reading a Dial Gauge:
Step 1: Notice the arrow at the top (or the direction the big needle goes) to know if it is a positive or negative deflection.

Step 2: Read the small scale, using the smaller number if the needle is between two numbers. Multiply this by 1.00 mm.

Step 3: Read the large needle, down to the small divisions. Multiply this by 0.01 mm.

Step 4: Add our two numbers and we have a reading. Do not forget to include the positive or negative sign.

expl 11: Read the dial gauge above. Include units.