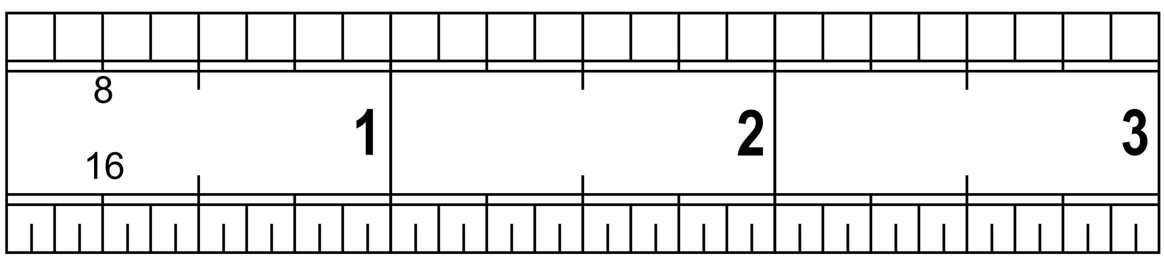
Sect 5.4 – Direct Measurements

Objective 1: Understanding Measuring Devices.

When using a measuring device, it is important to read the scale correctly. Sometimes we have to estimate accurately between scale divisions. In one's chosen field, it is important to practice using a measuring device to develop the skill and expertise to render accurate results. The more precise the measuring device, the smaller the scale divisions and hence the more care that needs to be employed when making a measurement. In this section, we will explore several different devices and learn how to read them correctly.

Objective 2: Understanding Measuring Length with Rulers.

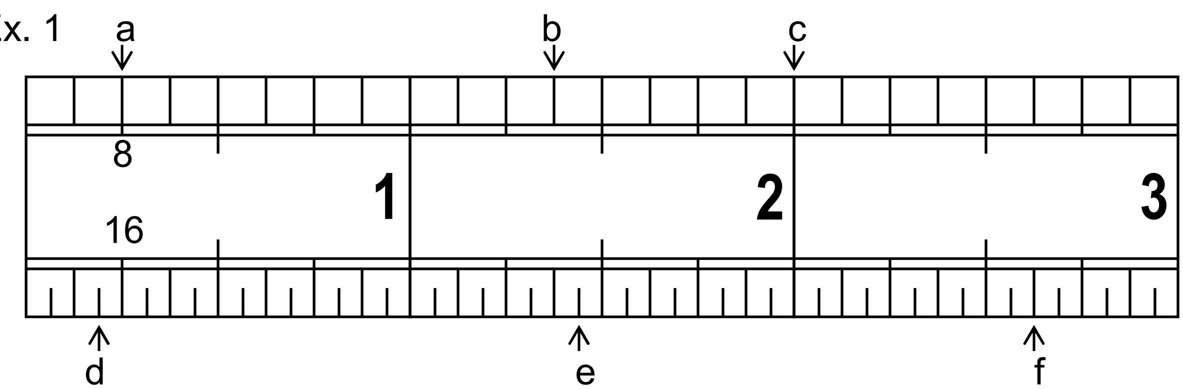
The most common measuring device people have encountered is a rule. Typically a ruler is in either in inches or centimeters and is usually subdivided into smaller units. A typical ruler might look like this:



On the top, each inch is split into 8 equal parts. Thus, the 8 indicates the length between two successive marks is one-eighth of an inch. On the bottom, each inch is split into 16 equal parts. Thus, the 16 indicates the length between two successive marks is one-sixteenth of an inch. Let's try reading some measurements:

Find the lengths marked on the ruler below:

Ex. 1



Solution:

a) a is marked on the second one-eighth mark after 0. That corresponds to $\frac{2}{8} = \frac{1}{4}$ in.

b) b is marked on the third one-eighth mark after 1. That corresponds to $1\frac{3}{8}$ in.

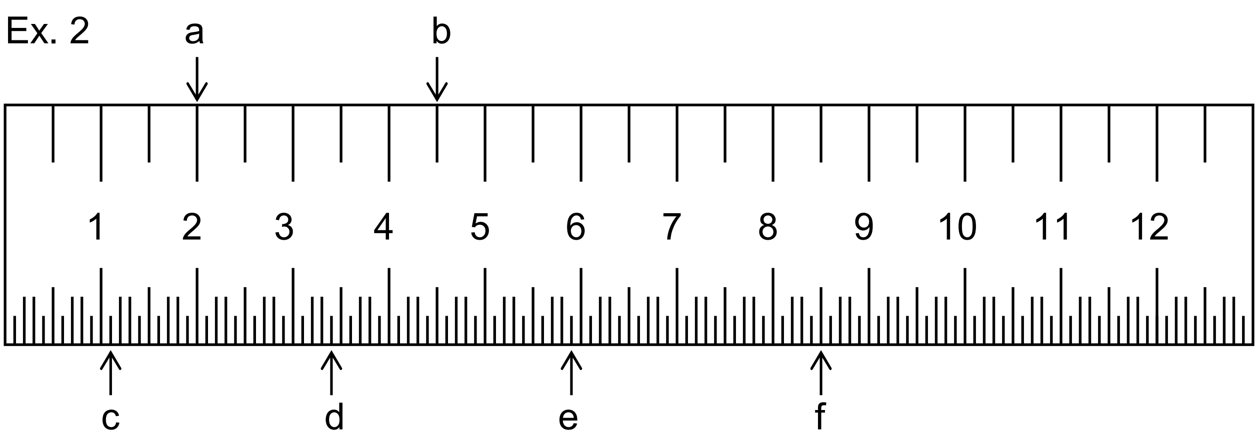
c) c is marked on the two mark. That corresponds to 2 in.

d) d is marked on the third one-sixteenth mark after 0. That corresponds to $\frac{3}{16}$ in.

e) e is marked on the seventh one-sixteenth mark after 1. That corresponds to $1\frac{7}{16}$ in.

f) d is marked on the tenth one-sixteenth mark after 2. That corresponds to $2\frac{10}{16} = 2\frac{5}{8}$ in.

Ex. 2



Solution:

a) a is marked on the two mark. That corresponds to 2 cm or 20 mm.

b) b is marked halfway between the 4 and 5 marks. That corresponds to 4.5 cm or 45 mm.

c) c is marked on the first one-tenth mark after 1. That corresponds to 1.1 cm or 11 mm.

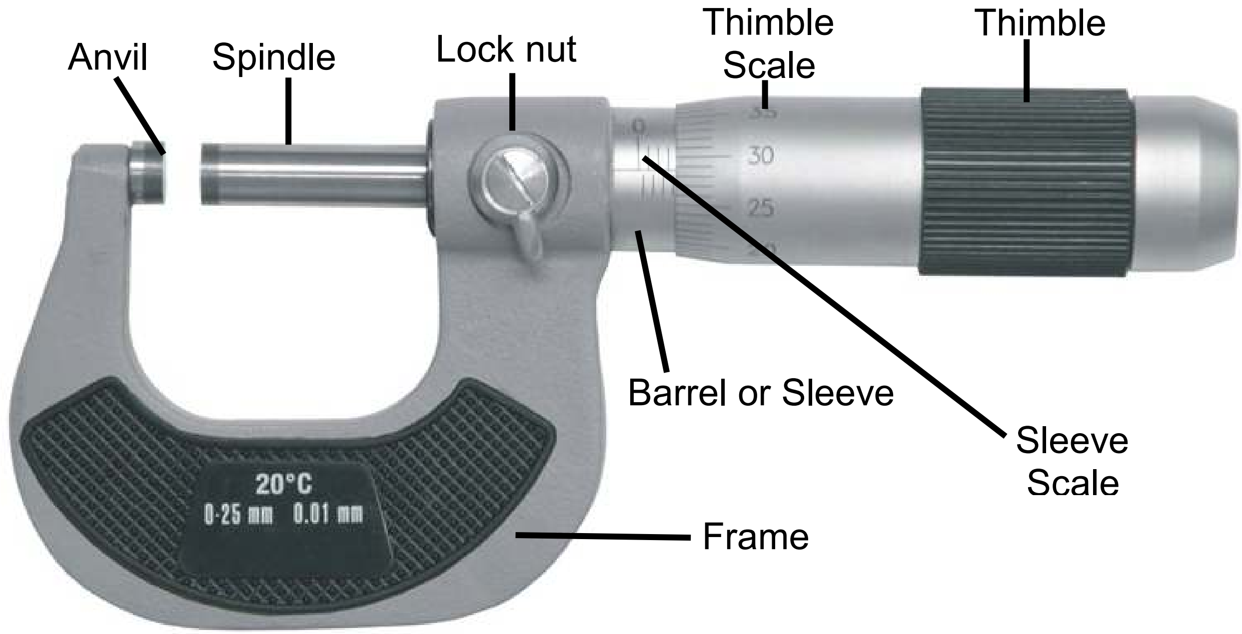
d) d is marked on the fourth one-tenth mark after 3. That corresponds to 3.4 cm or 34 mm.

e) e is marked on the ninth one-tenth mark after 5. That corresponds to 5.9 cm or 59 mm.

f) f is marked on the fifth one-tenth mark after 8. That corresponds to 8.5 cm or 85 mm.

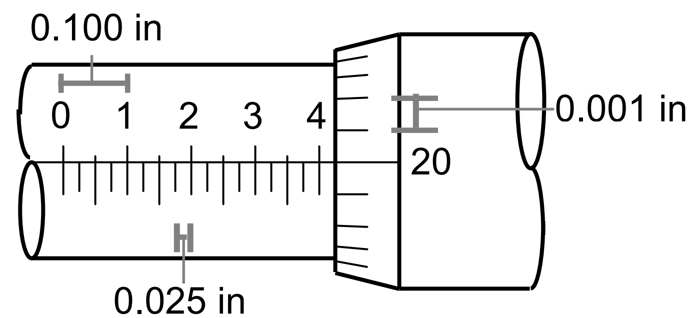
Objective 3: Understanding Measuring Length with Micrometers.

Rulers have their limitations on how precise they can measure lengths. For measuring lengths with greater precision, we will need to use a **micrometer**. A micrometer either uses inches or millimeters.



To measure the length of an object, we insert the object in between the end of the spindle and the anvil and turn the thimble until the spindle closes.

On the inch-system micrometer, there are two scales. The first scale is marked on the barrel or sleeve of the micrometer and the smallest division on this scale is one fortieth of an inch or $1 \div 40 = 0.025$ inches. If we turn the thimble one complete turn, the spindle will advance by one fortieth of an inch. The second scale is marked on the end of thimble itself and divides each turn of the thimble into 25 divisions. Thus, the smallest division on this scale is $0.025 \text{ in} \div 25 = 0.001 \text{ in}$. This means that an inch-system micrometer can measure of an object to the nearest thousandth of an inch.



There are four steps we follow when reading an inch-system micrometer.

Reading an Inch-System Micrometer:

I) Read the largest number visible on the sleeve and multiply that number by 0.100 in.

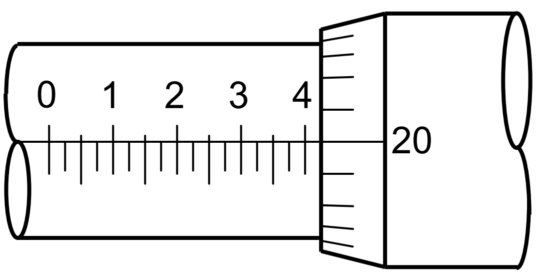
II) Read the number of marks after the number in you found in part a and multiply that result by 0.025 in.

III) Read the number on the thimble scale and multiply it by 0.001 in.

IV) Add the results from parts 1, 2 and 3 to find the measurement.

Determine the measurement of the following:

Ex. 3



Solution:

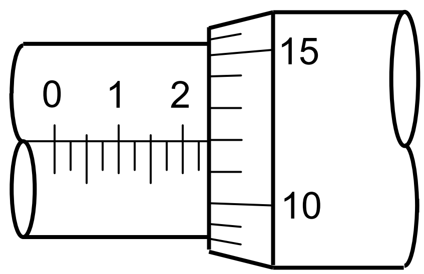
I) 4×0.100 in = 0.400 in

II) 0×0.025 in = 0.000 in

III) 20×0.001 in = 0.020 in

IV) 0.400 in + 0.000 in + 0.020 in = 0.420 in.

Ex. 4



Solution:

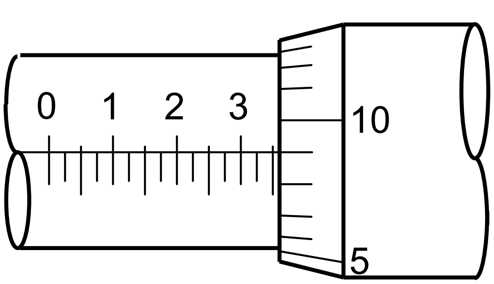
I) 2×0.100 in = 0.200 in

II) 1×0.025 in = 0.025 in

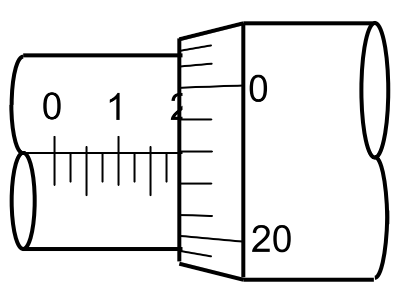
III) 12×0.001 in = 0.012 in

IV) 0.200 in + 0.025 in + 0.012 in = 0.237 in.

Ex. 5



Ex. 6



Solution:

I) 3×0.100 in = 0.300 in

II) 2×0.025 in = 0.050 in

III) 9×0.001 in = 0.009 in

IV) 0.300 in + 0.050 in + 0.009 in = 0.359 in.

Solution:

I) 1×0.100 in = 0.100 in

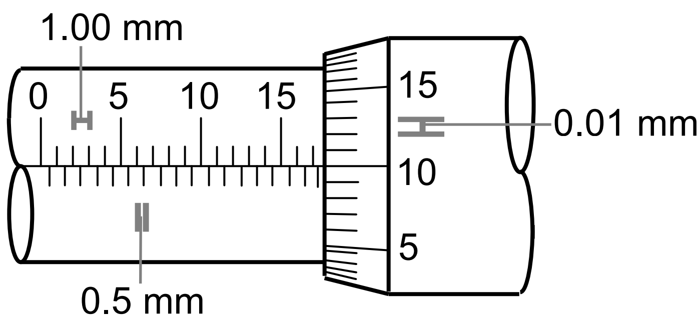
II) 3×0.025 in = 0.075 in

III) 23×0.001 in = 0.023 in

IV) 0.100 in + 0.075 in + 0.023 in = 0.198 in.

On the millimeter-system micrometer, there are two scales. The first scale is marked on the barrel or sleeve of the micrometer and the smallest division on this scale is 0.5 millimeters. If we turn the thimble one complete turn, the spindle will advance by 0.5 millimeters. The second scale is marked on the end of thimble itself and divides each turn of the thimble into 50 divisions. Thus, the smallest division on the scale is

0.5 mm ÷ 50 = 0.01 mm. This means that the mm-system micrometer can measure the width of an object to the nearest hundredth of a millimeter.



There are four steps we follow when reading a mm-system micrometer.

<u>Reading a Millimeter-System Micrometer:</u>

I) Read the largest mark visible on the sleeve above the horizontal line and multiply that number by 1.00 mm.

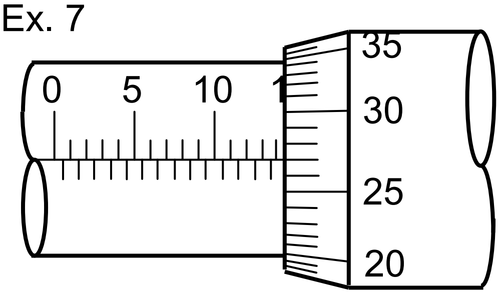
II) Read the number of marks below the horizontal line (either 0 or 1) after the mark you found in part a and multiply that result by 0.50 mm.

III) Read the number on the thimble scale and multiply it by 0.01 mm.

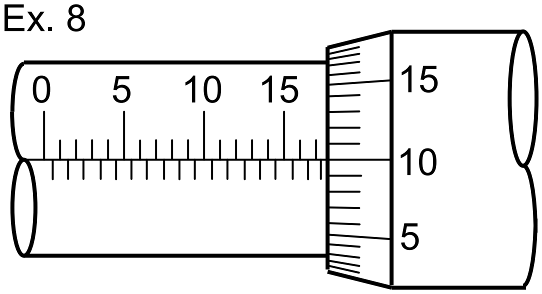
IV) Add the results from parts 1, 2 and 3 to find the measurement.

<u>Determine the measurement of the following:</u>

Ex. 7



Ex. 8



Solution:

I) 14 × 1.00 mm = 14.00 mm

II) 0 × 0.50 mm = 0.00 mm

III) 27 × 0.01 mm = 0.27 mm

IV) 14.00 mm + 0.00 mm + 0.27 mm = 14.27 mm.

Solution:

I) 17 × 1.00 mm = 17.00 mm

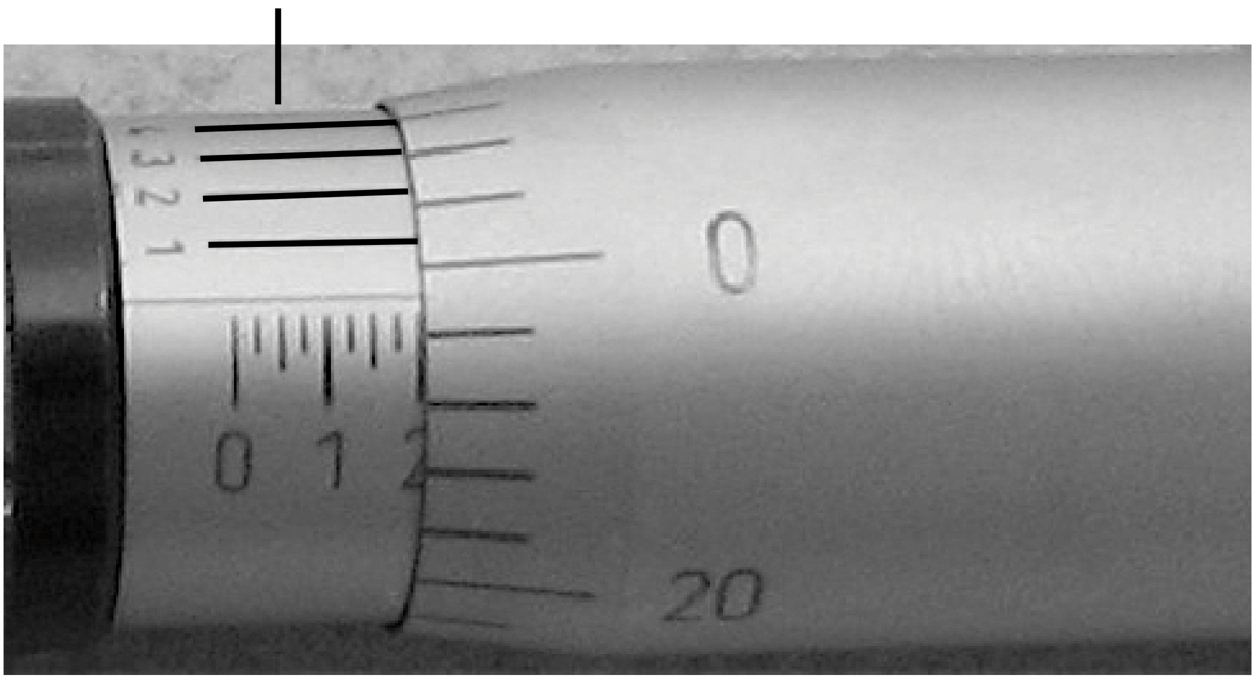
II) 1 × 0.50 mm = 0.50 mm

III) 10 × 0.01 mm = 0.10 mm

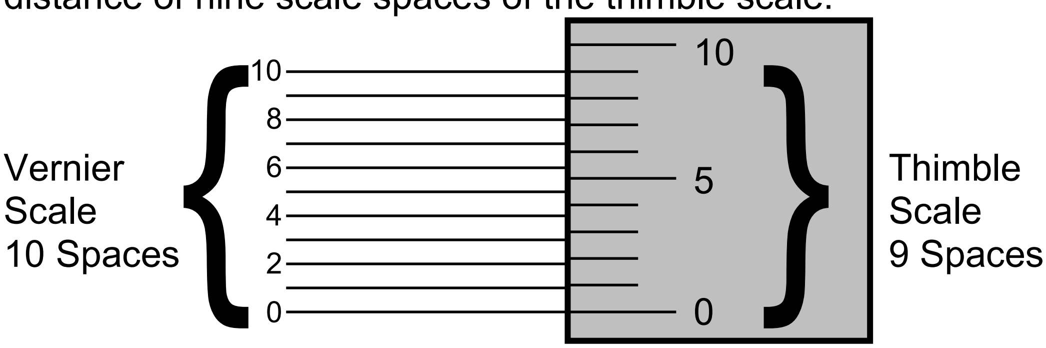
IV) 17.00 mm + 0.50 mm + 0.10 mm = 17.60 mm.

For more accurate measurements we can what is called a **Vernier Micrometer**. A vernier micrometer can measure the width of an object to the nearest ten-thousandth of an inch (0.0001 in) or the nearest thousandth of a millimeter. The vernier scale is on the sleeve of barrel as ten horizontal lines above the sleeve scale.

vernier scale



The total distance of the ten vernier scale spaces is equal to the total distance of nine scale spaces of the thimble scale:

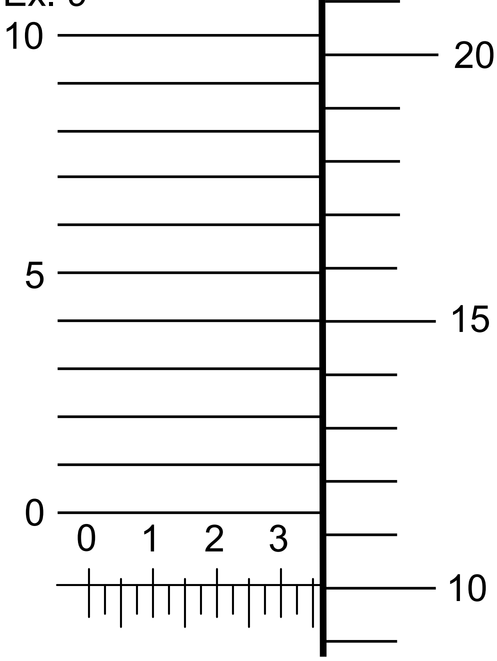


The difference between a space on the vernier scale and a space on the thimble space is 0.0001 inches. When reading a vernier micrometer, the first three steps are the same as for a regular micrometer. We will then add a fourth step:

IV) Find the number line of the vernier scale that exactly lines up with any line of the thimble scale. Multiply that result by 0.0001 inches and add it to the sum of the measurements from step I – III.

Determine the measurement of the following:

Ex. 9



Solution:

I) 3×0.1000 in = 0.3000 in

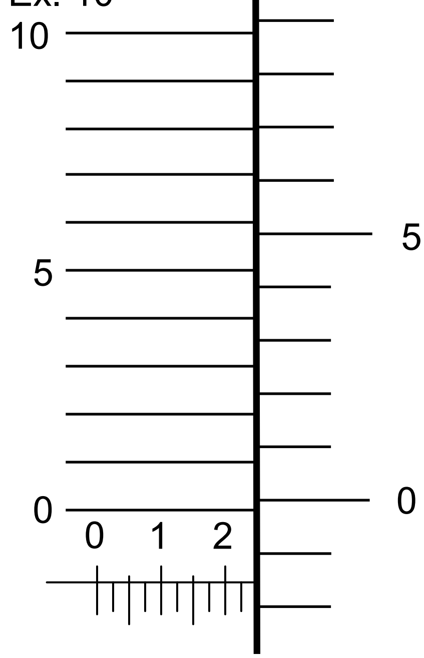
II) 2×0.0250 in = 0.0500 in

III) 10×0.0010 in = 0.0100 in

IV) 4×0.0001 in = 0.0004 in

$$\begin{array}{r} 0.3000 \\ 0.0500 \\ 0.0100 \\ +\ 0.0004 \\ \hline 0.3604 \text{ in} \end{array}$$

Ex. 10



Solution:

I) 2×0.1000 in = 0.2000 in

II) 1×0.0250 in = 0.0250 in

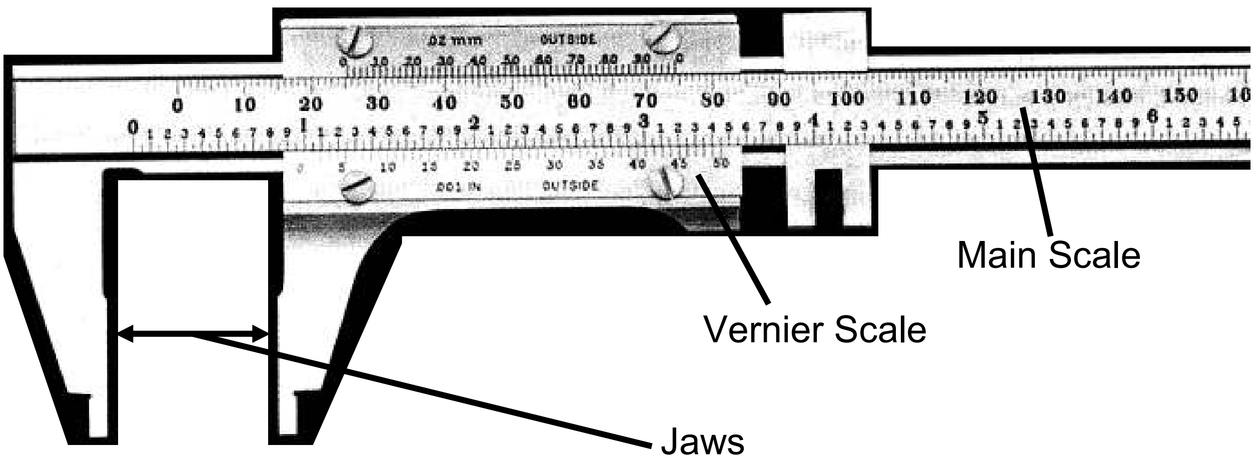
III) 23×0.0010 in = 0.0230 in

IV) 8×0.0001 in = 0.0008 in

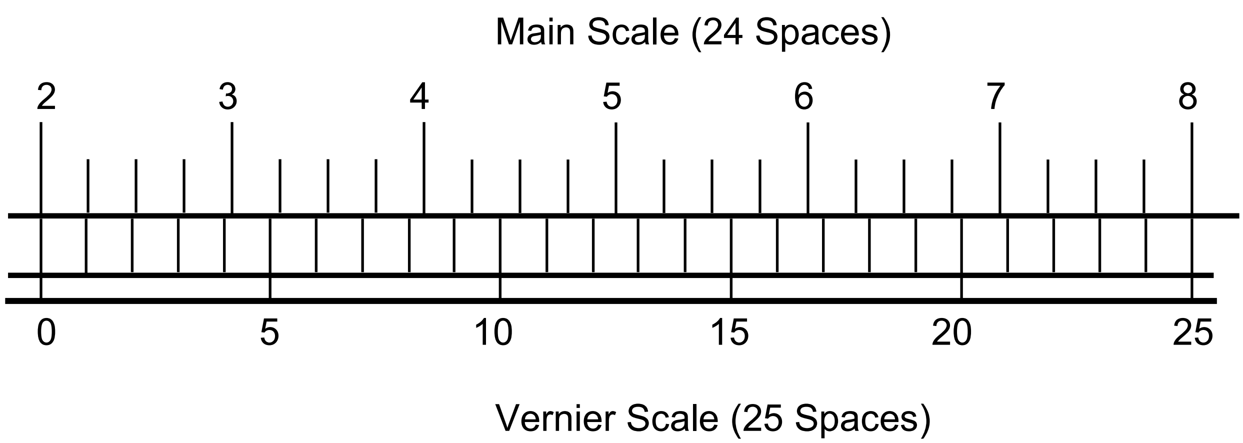
$$\begin{array}{r} 0.2000 \\ 0.0250 \\ 0.0230 \\ +\ 0.0008 \\ \hline 0.2488 \text{ in} \end{array}$$

Objective 4: Understanding Measuring Length with Vernier Calipers.

Another device that can measure the width of objects with greater precision than a ruler is a **Vernier Caliper**. The Vernier Caliper uses the same idea of the vernier scale on the micrometer to measure the width of objects to the nearest thousandth of an inch. Many modern vernier capiler will give a digital read out and can convert automatically between US and metric units.



Much like the inch-system micrometer, each inch of the main scale is divided into forty equal parts meaning that the smallest division on this scale is one fortieth of an inch or 1 ÷ 40 = 0.025 inches. The sliding vernier scale is like the thimble scale on the inch-system micrometer; each unit on the main scale is divide into 25 equal parts meaning that the smallest division is 0.025 in ÷ 25 = 0.001 in. With the vernier caliper, the total distance of the twenty-five vernier scale spaces is equal to the total distance of twenty-four scale spaces of the main scale:



Reading a Vernier Capiler:

I) Read the largest whole number inch to the left of the vernier zero on the main scale. This is the whole number of inches.

II) Read the largest tenth number inch to the left of the vernier zero on the main scale. Multiply this number by 0.100 in.

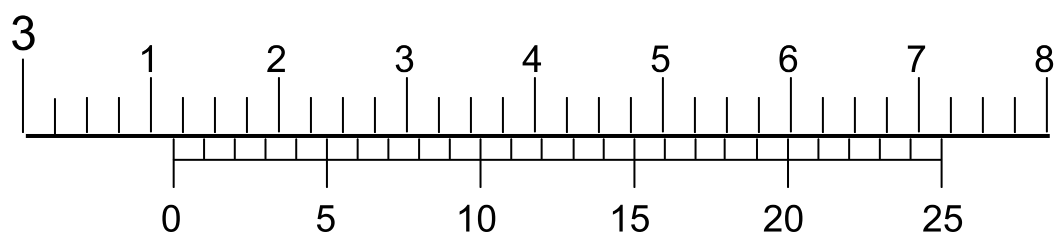
III) Read the number of marks after the number in you found in part b to left of the vernier zero and multiply that result by 0.025 in.

IV) Find the number line of the vernier scale that exactly lines up with any line of the main scale. Multiply that result by 0.001 inches.

V) Add the results from parts 1, 2, 3, and 4 to find the measurement.

Determine the measurement of the following:

Ex. 11



Solution:

I) The whole number of inches is 3.000 in.

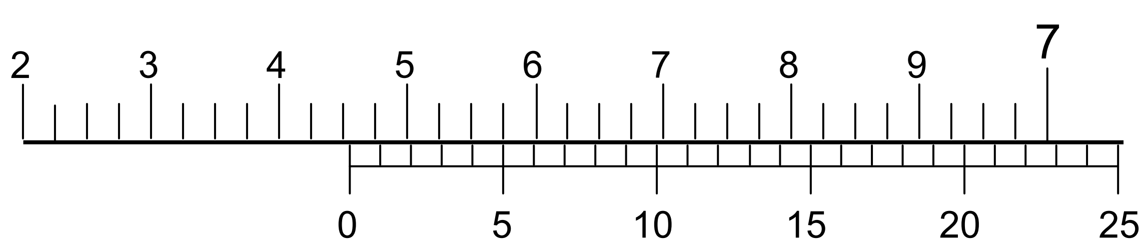
II) 1×0.100 in = 0.100 in

III) 0×0.025 in = 0.000 in

IV) 17×0.001 in = 0.017 in

V) 3.000 in + 0.100 in + 0.000 in + 0.017 in = 3.117 in.

Ex. 12



<u>Solution:</u>

I) The whole number of inches is 6.000 in.

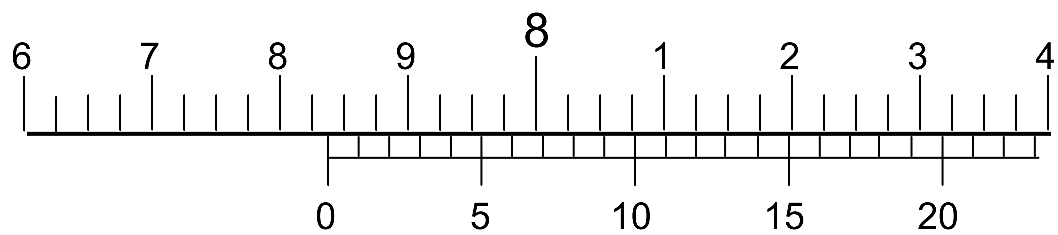
II) 4×0.100 in = 0.400 in

III) 2×0.025 in = 0.050 in

IV) 5×0.001 in = 0.005 in

V) 6.000 in + 0.400 in + 0.050 in + 0.005 in = 6.455 in.

Ex. 13



<u>Solution:</u>

I) The whole number of inches is 7.000 in.

II) 8×0.100 in = 0.800 in

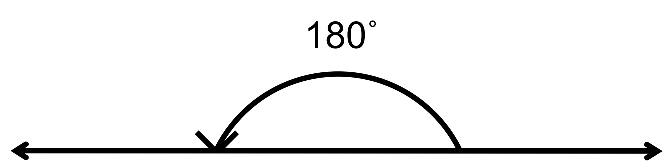
III) 1×0.025 in = 0.025 in

IV) 12×0.001 in = 0.012 in

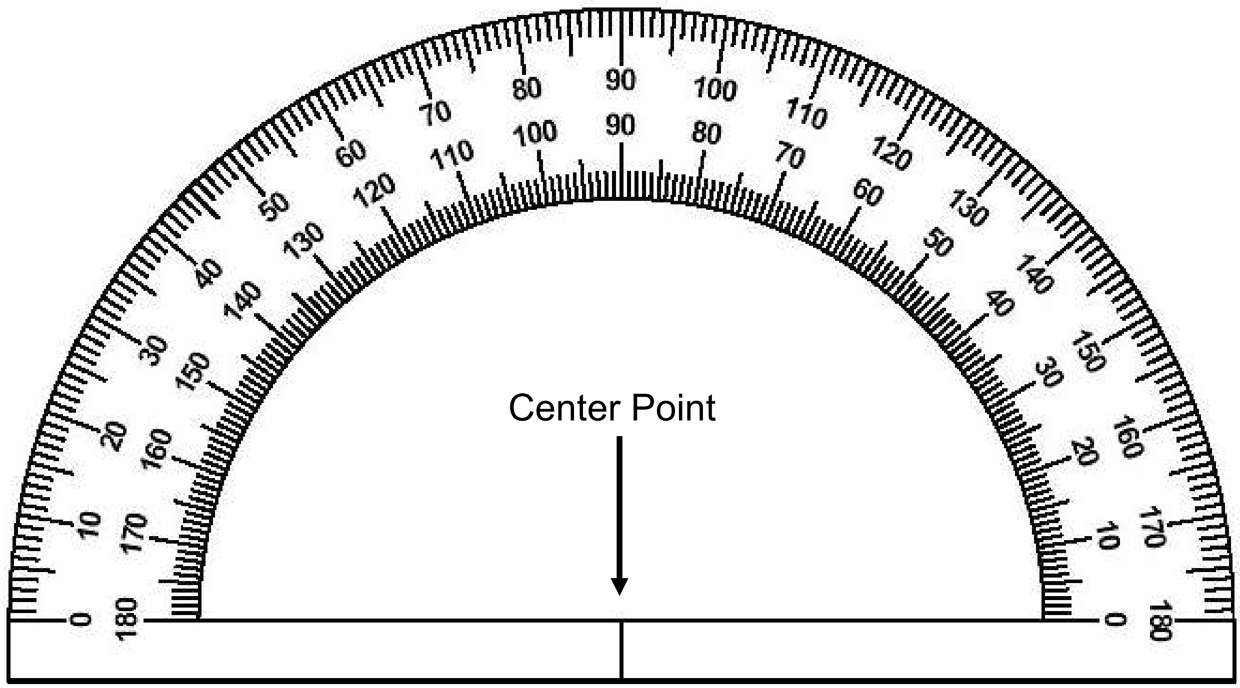
V) 7.000 in + 0.800 in + 0.025 in + 0.012 in = 7.837 in.

Objective 4: Understanding Measuring Angles with Protractors.

Two rays that share a common endpoint form an **angle**. The common endpoint is called the vertex of the angle and the two rays are called the sides of the angle. An angle is measured using units called degrees. There are 180° in an angle whose sides form a straight line.

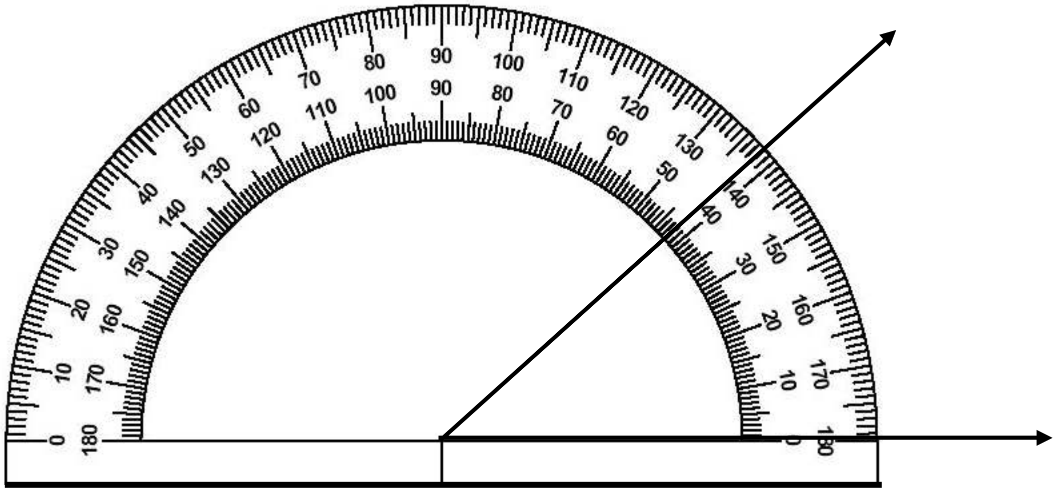


To measure angles or to draw angles, we us a device called a **Protractor**. In order to use a protractor accurately, the vertex of the angle must be placed in the middle of the base of the protractor (center point) and one of the sides must be along 0˚ – 180˚ baseline. Most simple protractors will measure an angle to the nearest degree.



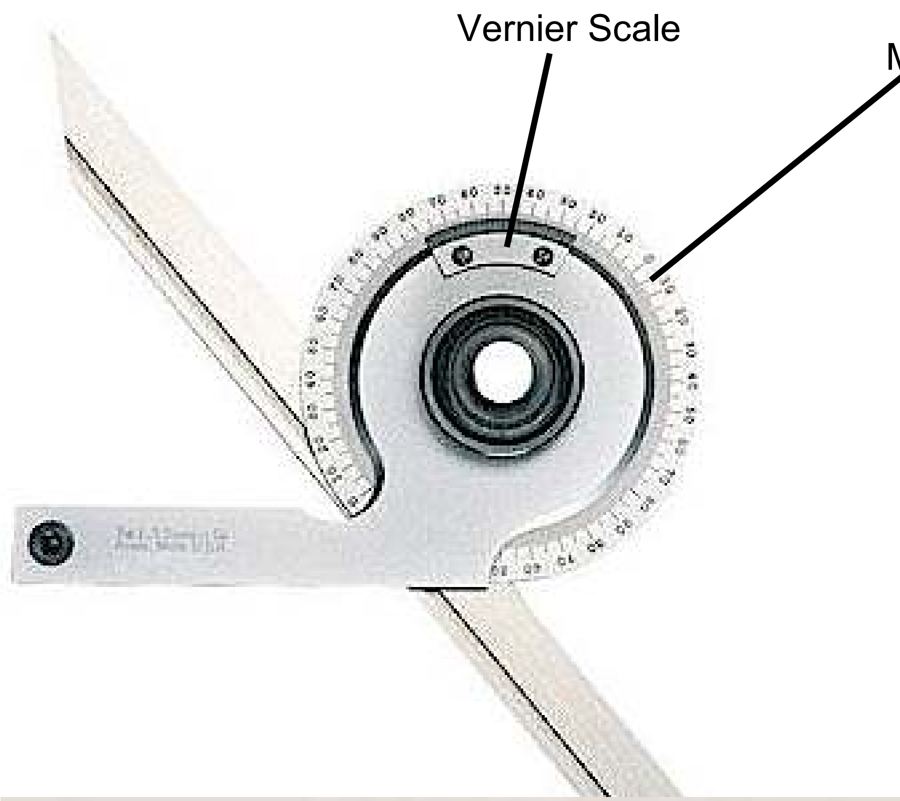
<u>Find the measure of the following angle:</u>

Ex. 14

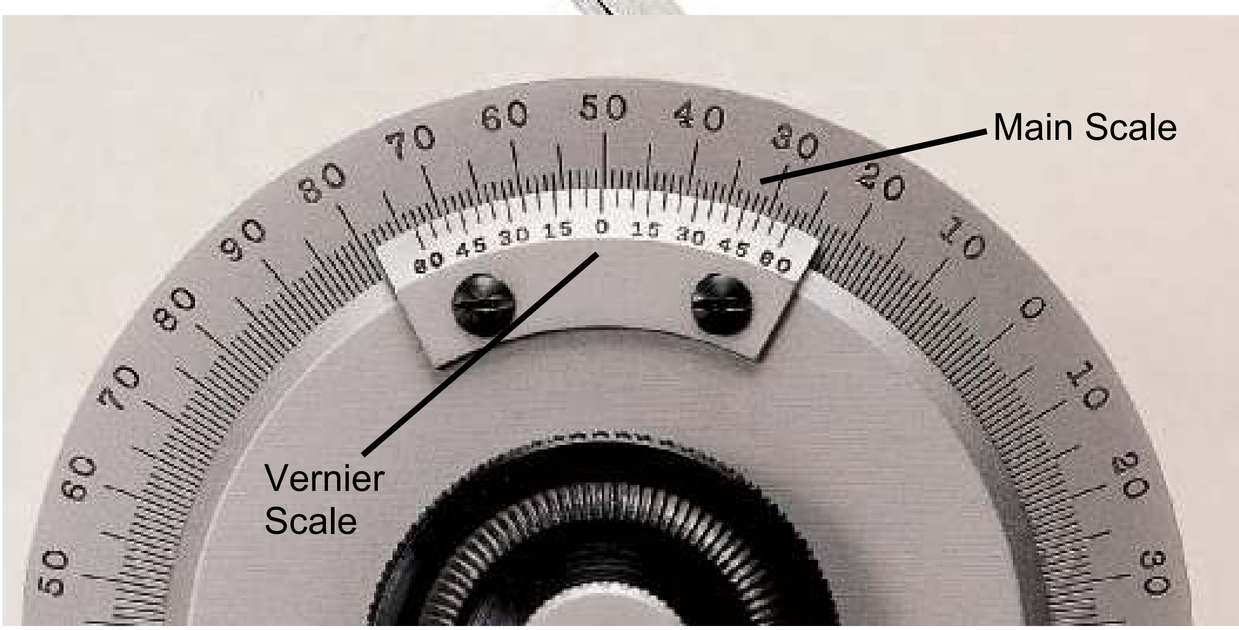


<u>Solution:</u>
The arrow goes through 42˚, so the angle is 42˚.

For more accurate measurements, we can use a bevel protractor. It has a precision of 0.5˚ or what is called 30 minutes. A degree can be broken down into 60 minutes. This is different from the time measurement of 60 minute. An angle measurement of 1 minute, written as 1', is 1/60 of a degree. To measure angle with a precision of 5 minutes or 1/12 of a degree, we will need to use a **Vernier Protractor**.



Each division on the vernier scale is five minutes. There are 12 spaces (60') on the vernier scale for every 23 spaces (23˚) on the main scale.



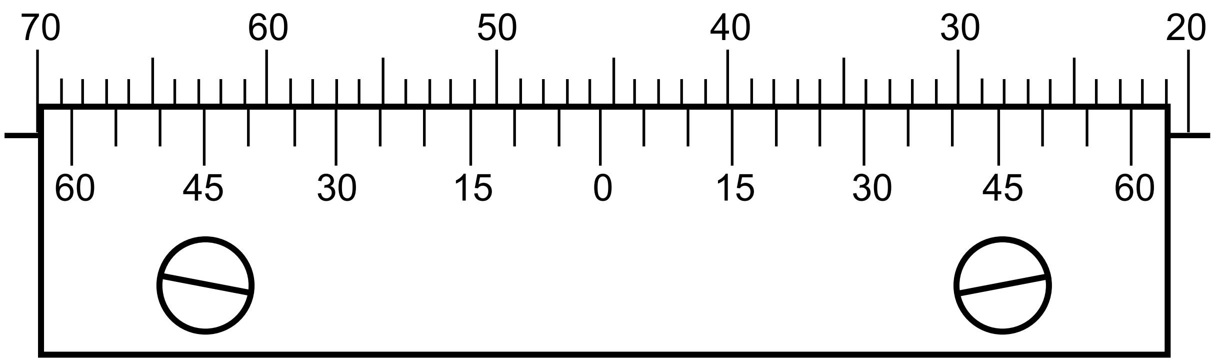
Reading a Vernier Protractor:

I) Read the largest whole number degrees on the main scale between 0˚ on the main scale and 0˚ on the vernier scale. This is how many degrees there are in the angle.

II) Reading in the same direction as in part a, find the number line of the vernier scale that exactly lines up with any line of the main scale. This is how many minutes are in the angle.

Find the measure of the following angle:

Ex. 15

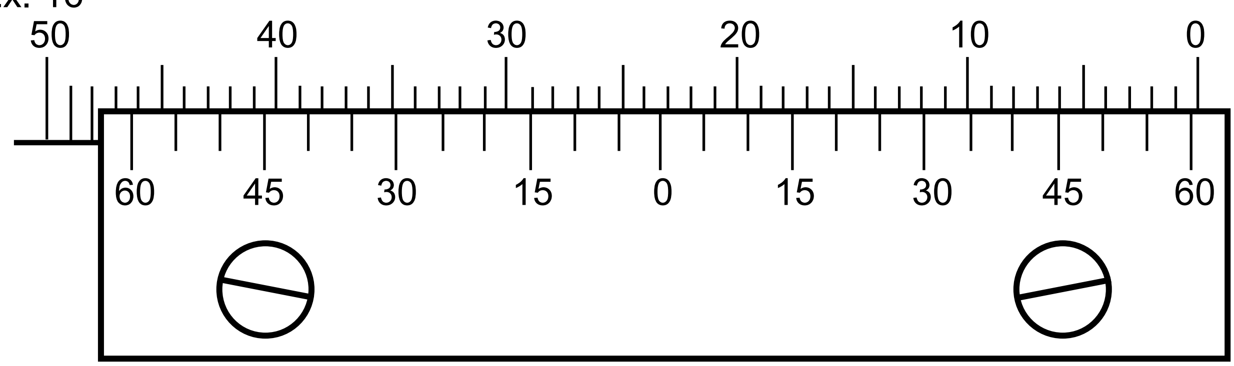


Solution:

I) The largest whole number is 45˚.

II) Looking to the left of zero, 30 on the vernier scale matches a mark on the main scale. So the minutes are 30'. Thus, the angle is 45˚ 30'.

Ex. 16



Solution:

I) The largest whole number is 23˚

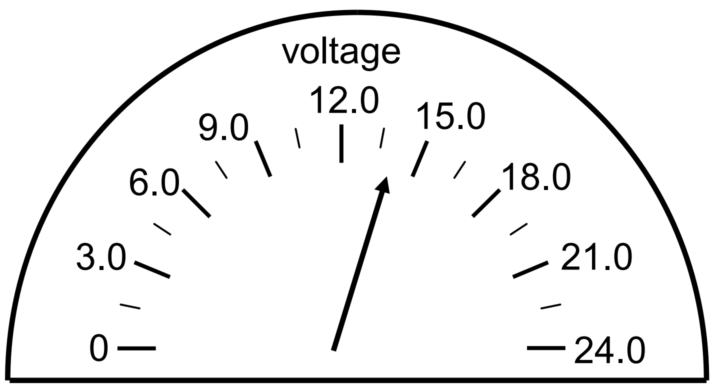
II) Looking to the left of zero, 20 on the vernier scale matches a mark on the main scale. So the minutes are 20'. Thus, the angle is 23˚ 20'.

Objective 5: Understanding Measuring with Meters.

Meters display a readout based upon an electrical pulse, air pressure, flow rates, speed of rotation, or speed. The range of the meter is the difference between the largest and smallest amount marked. The main divisions of the scale are the difference between the two successive labeled marks on the meter and the smallest divisions are the difference between two successive marks.

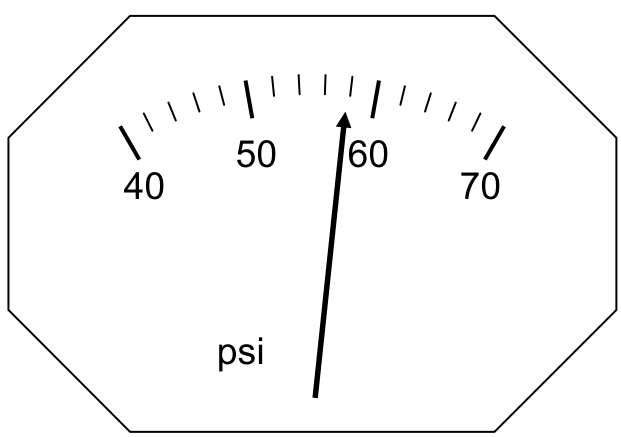
<u>Find the range, main divisions, smallest divisions, and the reading on the following volt meter:</u>

Ex. 17



<u>Solution:</u>
Range = 24.0 – 0.0 = 24.0 volts.
Main divisions = 3.0 volts.
Smallest divisions = 1.5 volts
Reading ≈ 14 volts

Ex. 18



<u>Solution:</u>
Range = 70 – 40 = 30 psi
Main divisions = 10 psi
Smallest divisions = 2 psi
Reading ≈ 58 psi

Objective 6: Using Gauge Blocks

Devices that measure the width of an object to a very precise number need to be made and checked. To do this, we can use a set of **gauge blocks**. Gauge blocks are a set of blocks with a very precise width and highly grounded opposite faces that fit together very tightly. Usually they are sold in standard sets of between 36 and 81 blocks. Using these blocks in a particular combination will yield the desired width. To find a particular measurement, we will combine some of the blocks to get the desired result. To figure out which blocks to use, we will start with the smallest place value and eliminate it and work our way right to left.

The widths of the blocks in a standard set of 36 gauge blocks are given below. We will use these in combination for the following examples:

0.0501 in	0.0510 in	0.0500 in	0.1100 in	0.1000 in	1.0000 in
0.0502 in	0.0520 in	0.0600 in	0.1200 in	0.2000 in	2.0000 in
0.0503 in	0.0530 in	0.0700 in	0.1300 in	0.3000 in	
0.0504 in	0.0540 in	0.0800 in	0.1400 in	0.4000 in	
0.0505 in	0.0550 in	0.0900 in	0.1500 in	0.5000 in	
0.0506 in	0.0560 in				
0.0507 in	0.0570 in				
0.0508 in	0.0580 in				
0.0509 in	0.0590 in				

Find the combinations of gauge blocks to form the following lengths:

Ex. 18 1.8723 in

Solution:

To get rid of the 3, use the 0.0503 in. block:

$$\begin{array}{rl} 1.8723 & \\ \underline{-\ 0.0503} & \text{Block \#1} \\ 1.8220 & \end{array}$$

To get rid of the last 2, use the 0.0520 in. block:

$$\begin{array}{rl} 1.8220 & \\ -\ 0.0520 & \text{Block \#2} \\ \hline 1.7700 & \end{array}$$

To get rid of the last 7, use the 0.0700 in. block:

$$\begin{array}{rl} 1.7700 & \\ -\ 0.0700 & \text{Block \#3} \\ \hline 1.7000 & \end{array}$$

To get rid of the 7, use both the 0.2000 in. and 0.5000 in. blocks:

$$\begin{array}{rl} 1.7000 & \\ -\ 0.5000 & \text{Block \#4} \\ \hline 1.2000 & \\ -\ 0.2000 & \text{Block \#5} \\ \hline 1.0000 & \end{array}$$

To get rid of the 1, use the 1.0000 in block:

$$\begin{array}{rl} 1.0000 & \\ -\ 1.0000 & \text{Block \#6} \\ \hline 0.0000 & \end{array}$$

So, we need six blocks:

$\boxed{\text{1.0000 in}}$ + $\boxed{\text{0.2000 in}}$ + $\boxed{\text{0.5000 in}}$ + $\boxed{\text{0.0700 in}}$ + $\boxed{\text{0.0520 in}}$ + $\boxed{\text{0.0503 in}}$

= 1.8723 in.

Ex. 18 2.5741 in

Solution:

To get rid of the 1, use the 0.0501 in. block:

$$\begin{array}{rl} 2.5741 & \\ -\ 0.0501 & \text{Block \#1} \\ \hline 2.5240 & \end{array}$$

To get rid of the last 4, use the 0.0540 in. block:

$$\begin{array}{rl} 2.5240 & \\ -\ 0.0540 & \text{Block \#2} \\ \hline 2.4700 & \end{array}$$

To get rid of the 7, use the 0.0700 in. block:

$$\begin{array}{rl} 2.4700 & \\ \underline{-\ 0.0700} & \text{Block \#3} \\ 2.4000 & \end{array}$$

To get rid of the 4, use the 0.4000 in. block:

$$\begin{array}{rl} 2.4000 & \\ \underline{-\ 0.4000} & \text{Block \#4} \\ 2.0000 & \end{array}$$

To get rid of the 2, use the 2.0000 in block:

$$\begin{array}{rl} 2.0000 & \\ \underline{-\ 2.0000} & \text{Block \#5} \\ 0.0000 & \end{array}$$

So, we need five blocks:

$\boxed{2.0000 \text{ in}} + \boxed{0.4000 \text{ in}} + \boxed{0.0700 \text{ in}} + \boxed{0.0540 \text{ in}} + \boxed{0.0501 \text{ in}}$

= 2.5741 in.