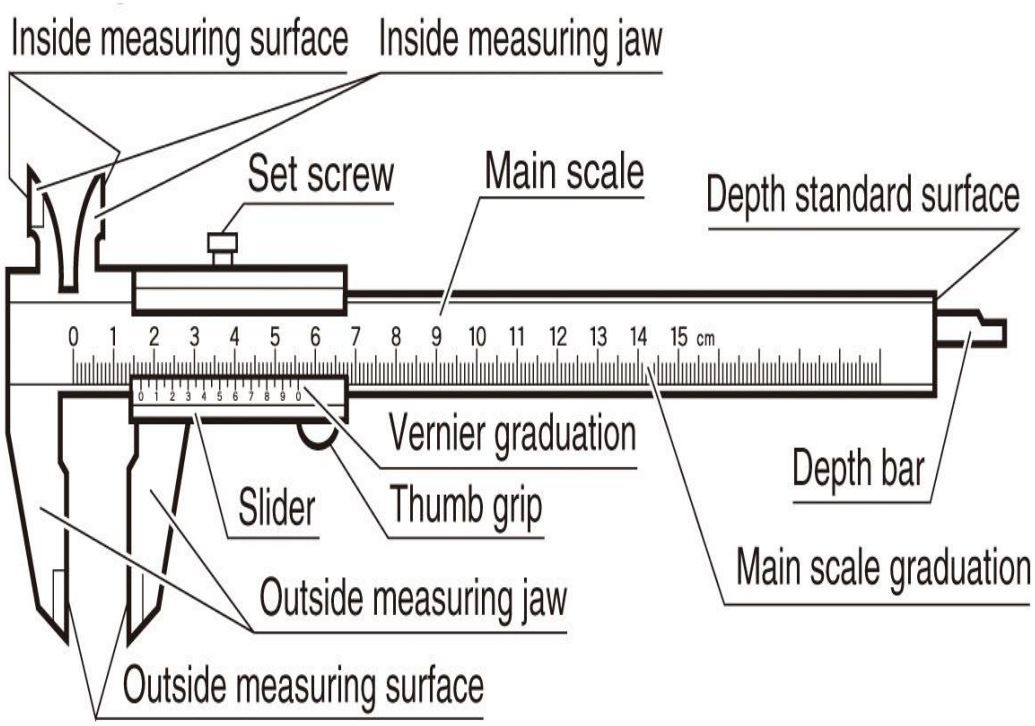
CHAPTER 2: MEASUREMENTS

2.1 Vernier Caliper

2.1.1 Introduction:

The main use of the vernier caliper is to measure the internal and external diameters of an object. The word caliper means any instrument with two jaws which is used to determine the diameters of objects.
The principle of the vernier caliper is that when two scales or divisions slightly different in size are used, then the difference between them is used to increase the accuracy measurement.

2.1.2 Vernier Caliper Part Description

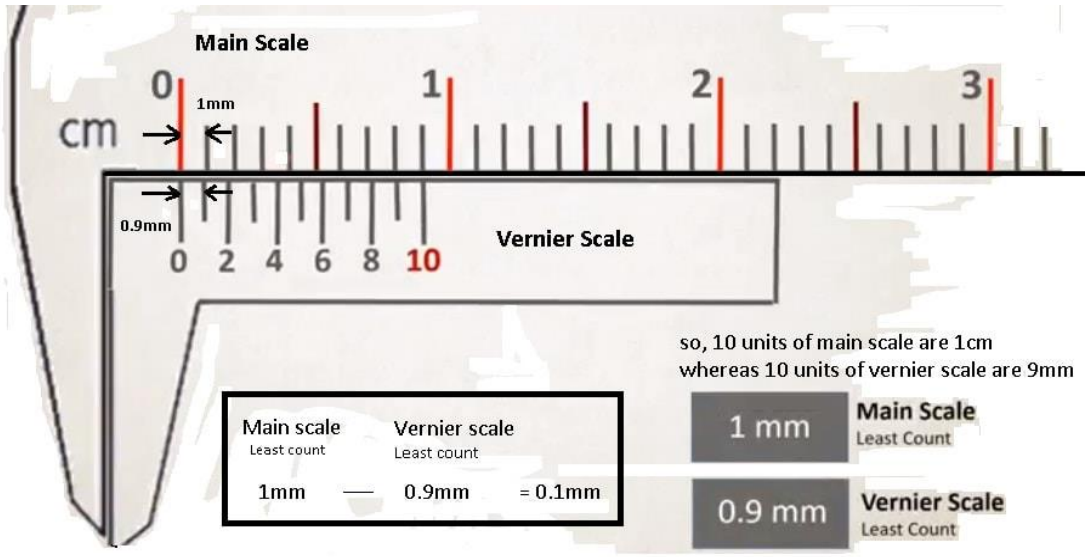


The main elements of the vernier caliper are the

- **Main Scale marked in inches and fractions**
- **Vernier scale gives interpolated measurements to 0.1 mm or better**
- **Vernier scale gives interpolated measurements in fraction of an inch**
- **Thumbscrew is located at the bottom of the vernier scale.**
- **Lock screw is used to fix the position of the jaws once the object is positioned.**
- **Depth Bar can be used to measure the depths of holes or steps.**
- **Outside jaws used to measure external diameter or width of an object.**
- **Inside jaws used to measure internal diameter of an object.**
- **Thumb grip used to block movable part to allow the easy transferring of a measurement.**

2.1.3 The Principle of Vernier Caliper

A scale cannot measure objects which are smaller than 1mm but a vernier caliper can measure objects up to 1mm. As already know that vernier caliper has two scales the main scale and the vernier scale together this arrangement is used to measure very small lengths like 0.1mm.



Here the main scale has the least count of 1mm and vernier scale has the least count of 0.9mm. So therefore 10 unit of the main scale is 1cm whereas 10 unit of vernier scale is 0.9mm. The unit of the vernier scale is 9mm. So this difference between the main scale and vernier scale which is 0.1mm is the working principle of vernier caliper.

2.1.4 Vernier Caliper Least Count

The difference between the value of one main scale division and the value of one Vernier scale division is known as the least count of the Vernier.
Let's assume if the value of one main scale division is 1mm and the total number of division on vernier scale 10mm then the least count will be 0.1mm. Thus least count is defined as the smallest distance that can be measured from an instrument.

$$\text{Least count} = \frac{\text{Value of one main scale division}}{\text{Total number of division on vernier scale}}$$

$$\text{let's assume} \qquad = \frac{1}{10} = 0.1\ \text{mm is least count}$$

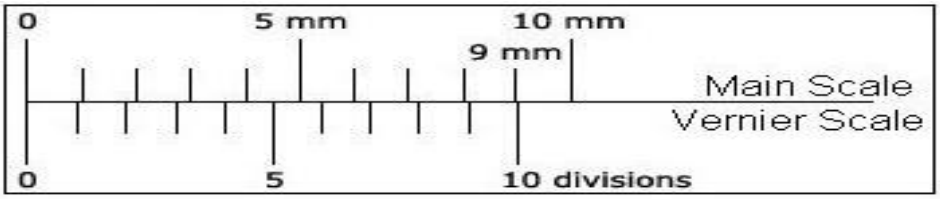
2.1.5 Vernier Caliper Zero Error

Zero error in the vernier caliper is a mathematical error due to which, the zero of the vernier scale does not coincide with the zero of the main scale.
In other words, if the zero mark on the vernier scale doesn't coincide with the zero mark on the main scale, then the error that occurs is called zero error. They are of 2 types.

1. **No zero error**
2. **Positive zero error**
3. **Negative zero error**

1) No Zero Error

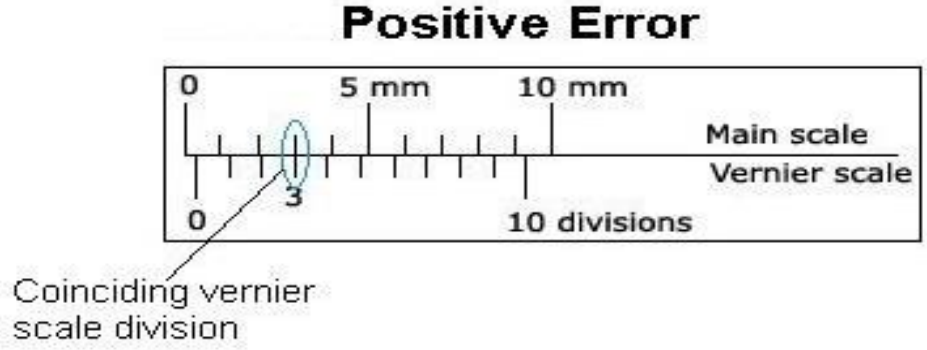
In no zero error, when we bring two jaws together. You will see zero of the Main scale is coinciding with the zero of the vernier scale.



No Zero Error Zero error = 0

2) Positive Zero Error

In positive zero error, let's bring these jaws together. You see, the zero of vernier scale is ahead of main scale zero. Or you can say zero of vernier scale is at the right side of main scale zero.

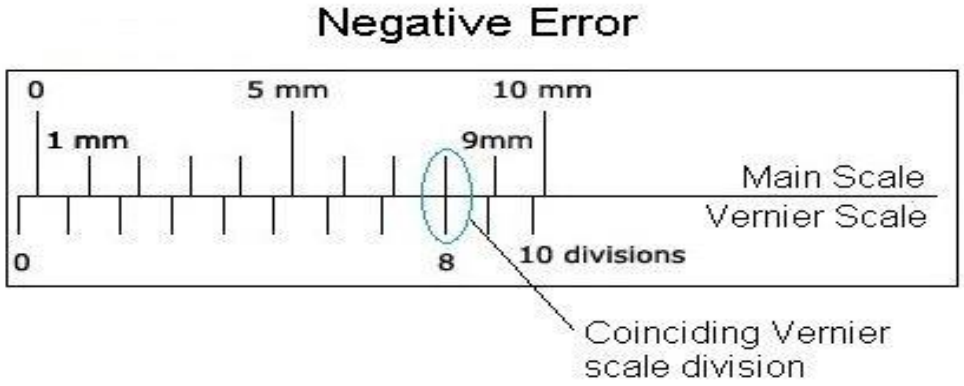


Calculation of Positive error:
Coinciding vernier scale Div. = 3
Zero Error = Coinciding V.S Div. X Least count
= 3 X 0.01cm
= +0.03cm

Thus it is positive error it is indicated with "+".

3) Negative Zero Error

In negative zero error, we will bring the two jaws together. Here you can see zero of vernier scale is the back side of main scale zero. Or to the left of main scale zero.



Calculation of Negative error:

Coinciding vernier scale div.= **8**

Difference = Total div. - Coinciding div.

= 10 - 8 = 2

Now, **Zero error = Difference X Least count**

= 2 X 0.01cm

= -0.02 cm

The minus sign indicates the negative error in vernier caliper.

2.1.6 EXAMPLE 1:

The external measurement (diameter) of a round section piece of steel is measured using a vernier caliper, metric scale.

MATHEMATICAL METHOD

A) **The main metric scale is read first and this shows that there are 13 whole divisions before the 0 on the hundredths scale. Therefore, the first number is 13.**

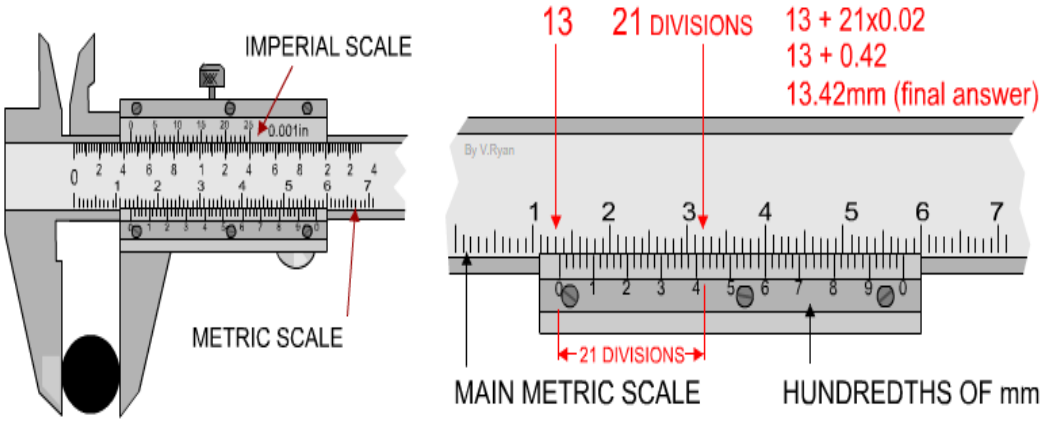
B) **The' hundredths of mm' scale is then read. The best way to do this is to count the number of divisions until you get to the division that lines up with the main metric scale. This is 21 divisions on the hundredths scale.**

C) **This 21 is multiplied by 0.02 giving 0.42 as the answer (each division on the hundredths scale is equivalent to 0.02mm).**

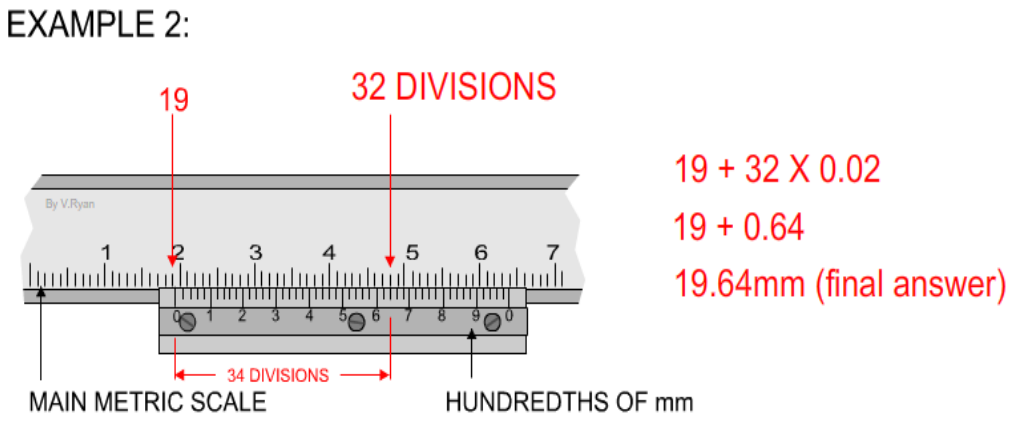
D) **The 13 and the 0.42 are added together to give the final measurement of 13.42mm (the diameter of the piece of round section steel).**

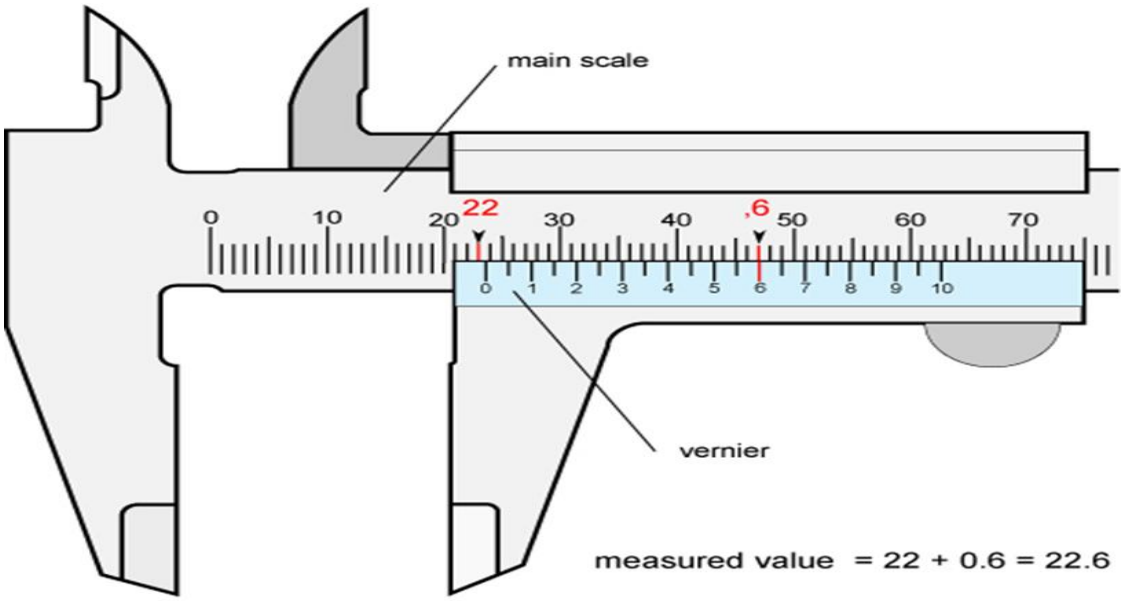
2.1.7 COMMONSENSE METHOD

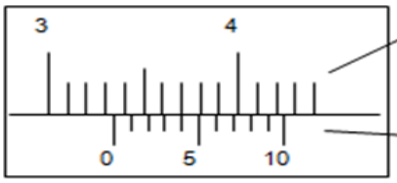
Alternatively, it is just as easy to read the 13 on the main scale and 42 on the hundredths scale. The correct measurement being 13.42mm.



2.1.8 EXAMPLE 2: (To zoom in to see the scale - right click mouse and select zoo.

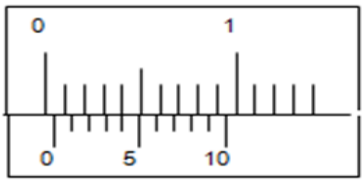






measured reading = 3.3 + 0.04 = 3.34

fig. (a)

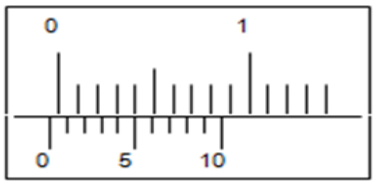


Vernier scale zero is left of main scale zero

Correct measurement with
positive error = 3.34 - 0.04 = 3.30

positive zero error = 0.04

fig. (b)



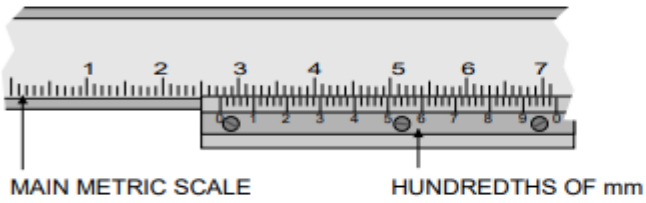
Vernier scale zero is right of main scale zero

Correct measurement with
negative error = 3.34 - (-0.04) = 3.38

negative error = - 0.04

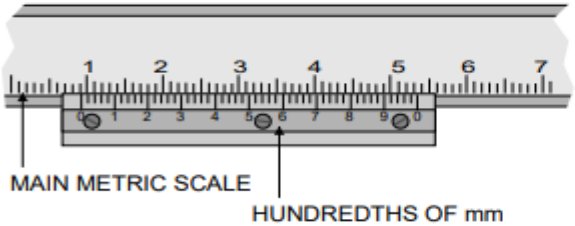
fig. (c)

QUESTION 1:



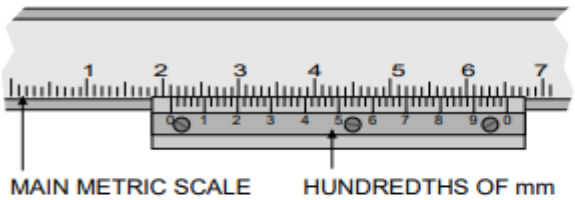
ANSWER: _____

QUESTION 2:



ANSWER: _____

QUESTION 3:



ANSWER: _____

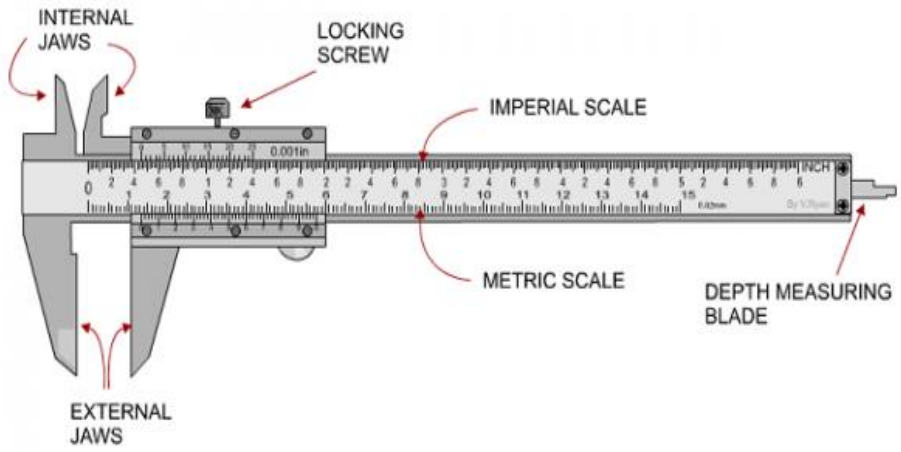
2.1.9 Types of Vernier Caliper

Following are the different types of Vernier Caliper:

1. **Flat edge vernier caliper**
2. **Knife edge vernier caliper**
3. **Vernier gear tooth caliper**
4. **Vernier depth gauge**
5. **Flat and knife edge vernier caliper**
6. **Vernier height gauge**
7. **Vernier dail caliper**

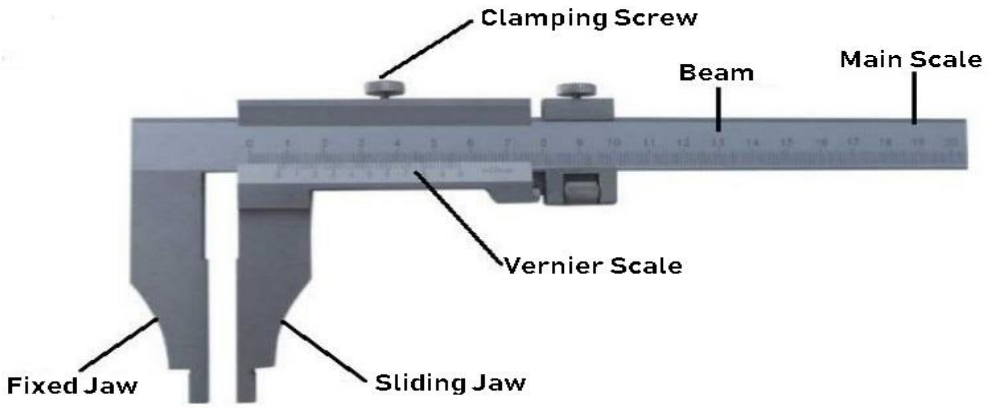
1) Flat Edge Vernier Caliper

This type of vernier is used for normal functions. We can take outer measurement of a job's length, breadth, thickness, and diameter, etc.



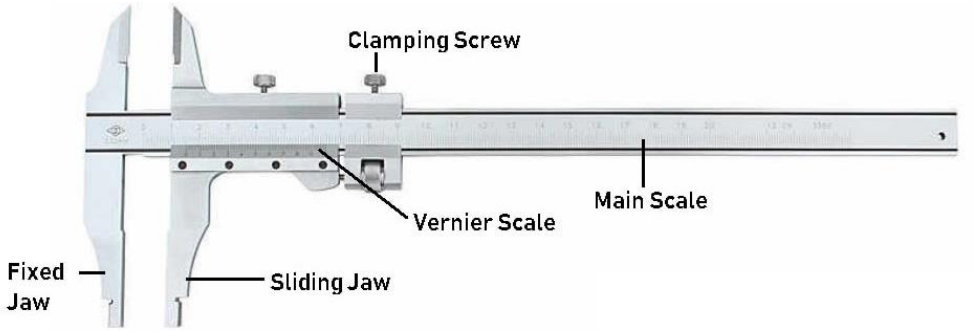
2) Knife Edge Vernier Caliper

The edge of this vernier caliper is like a knife. Other parts of this vernier caliper are like other vernier calipers as shown in the figure. This vernier caliper is used for measuring narrow space, a distance of holes of I bolt, etc.



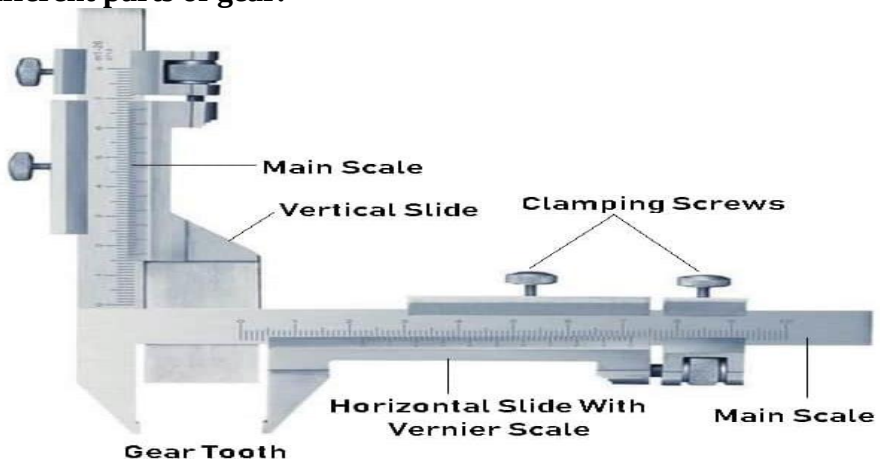
3) Flat And Knife Edge Vernier Caliper

Some companies also make vernier calipers which have their jaw like an ordinary vernier caliper from one side but have knife-edge jaw at the other side, as shown in the figure.



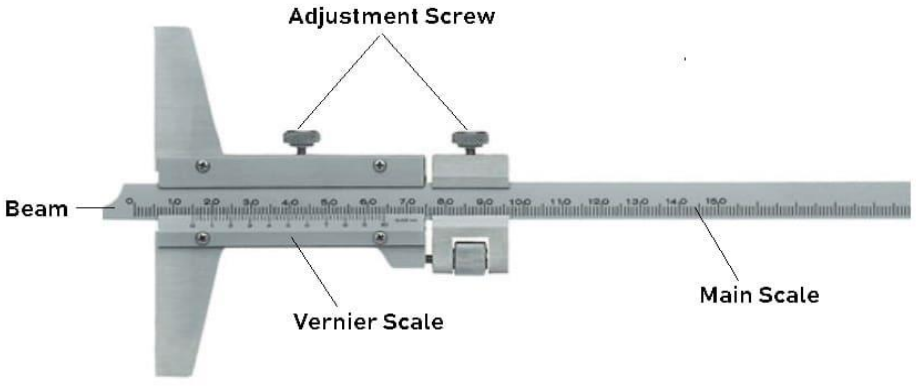
4) Vernier Gear Tooth Caliper

With the vernier caliper, the thickness of a tooth of gear can be taken form its pitch circle. In other words, the vernier caliper is used to measure different parts of gear.



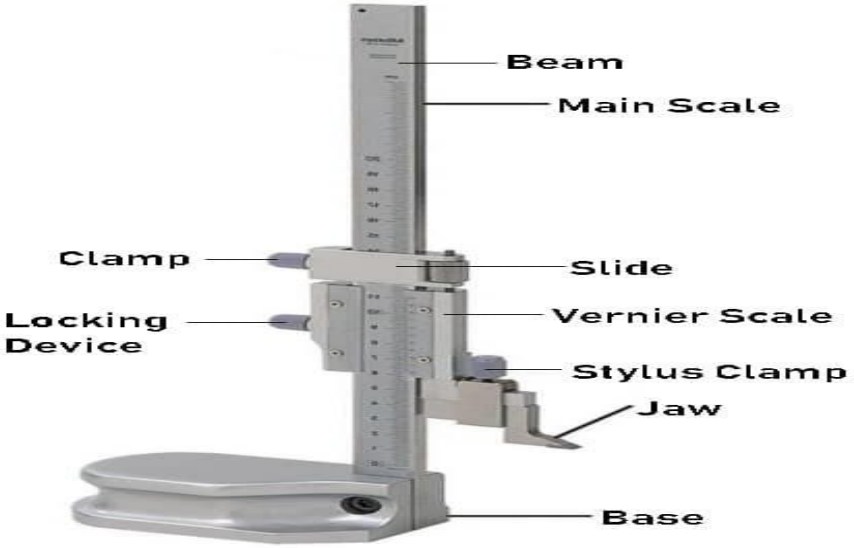
5) Vernier Depth Gauge

As is evident from its name, this instrument is used for measuring the depth of the slot of a job, its hole or groove.



6) Vernier Height Gauge

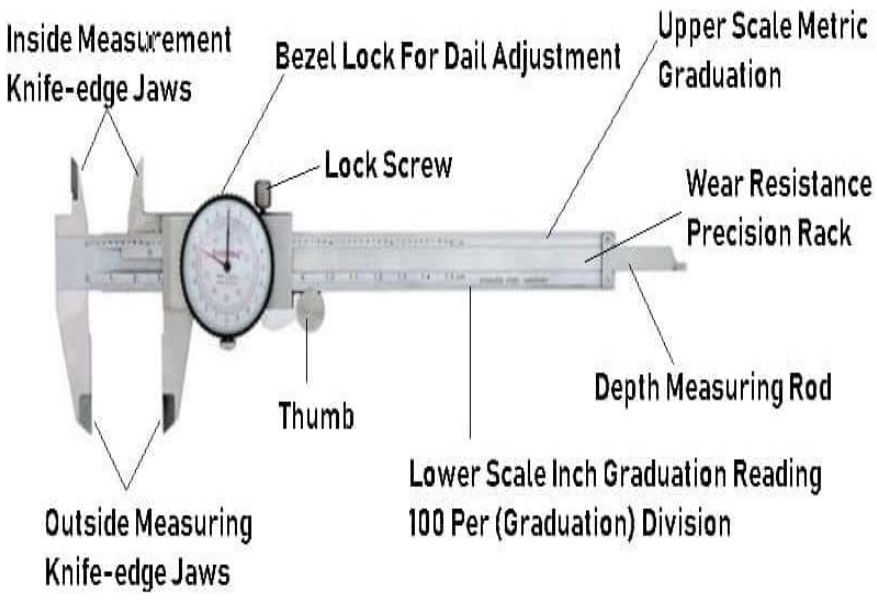
It is used for taking accurate measurement of height of a job or for marking.



Vernier Height Gauge

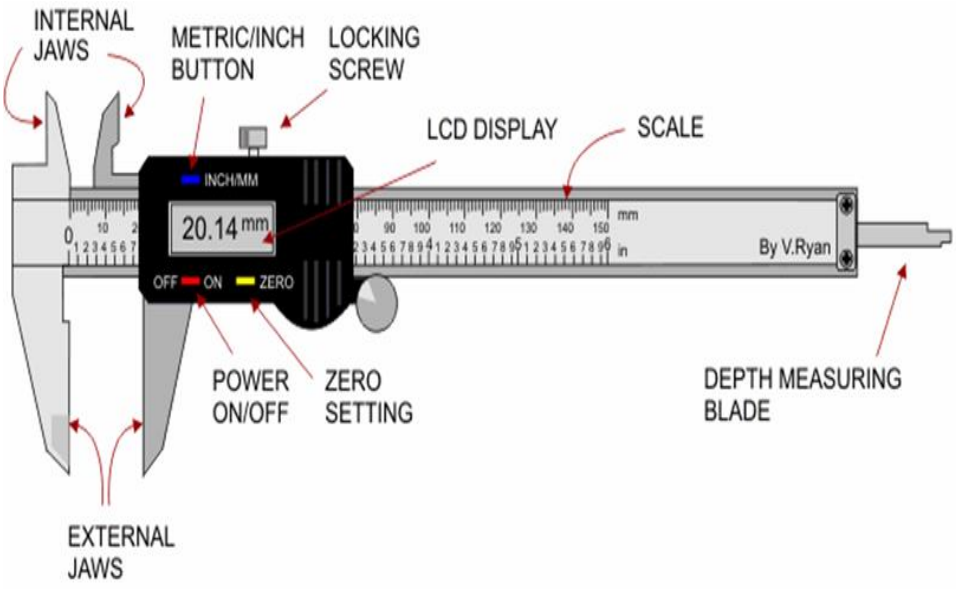
7) Vernier Dial Caliper

For this purpose, nowadays Vernier Dial calipers are being used. In place of the vernier scale, it contains a graduation dial as shown in the figure.



8. Digital or Electronic Calipers

Digital or electronic calipers are enormously inexpensive and precise measuring tools. Taking reading of objects in these types of calipers are easy as compare to manual vernier caliper. Digital calipers normally contain a resolution of 10 µm with a precision of 30 to 40 µm.



2.2 Micrometer Screw Gauge

The micrometer is an improvement over the measurement of the vernier calliper scale discussed in the past article.
The accuracy of vernier calliper remains to be 0.02 mm, but most of the engineering precision work demands greater accuracy with sensitivity for which an instrument having both these should be used.

2.2.1 Types of Micrometer Screw Gauge

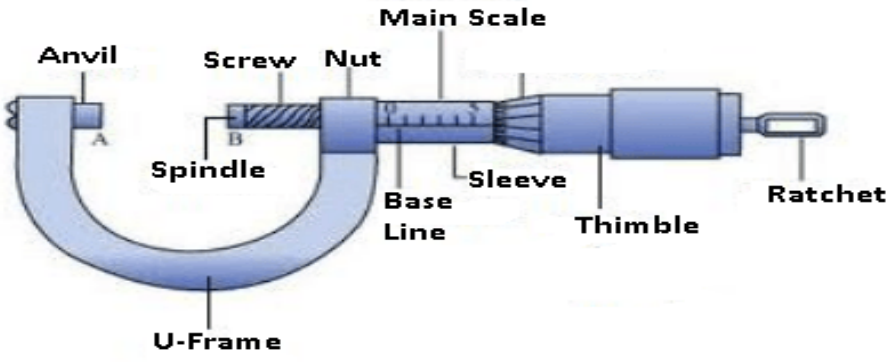
The following are the four common types of micrometer screw gauge and 3 special purpose types of micrometers.

1. **Outside Micrometer**
2. **Inside Micrometer**
3. **Micrometer Depth Gauge**
4. **Bench Micrometer**
5. **Special Purpose Micrometer**
    1. **Screw Thread Micrometer**
    2. **Vee-Anvil Micrometer**
    3. **Thickness Micrometer**

1. Outside Micrometer

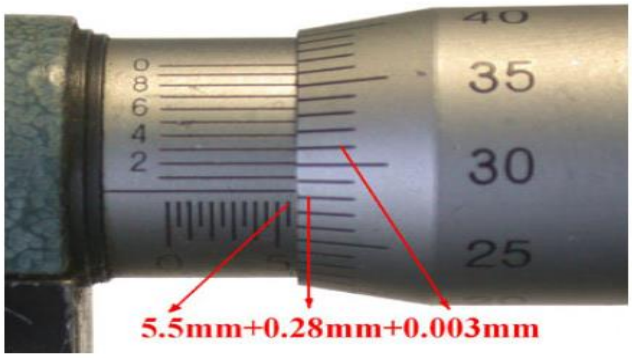
Below shown the general arrangement of outside micrometer and its various parts. Regardless of the type or size of an outside micrometer, they contain the basic parts like:

1. **Frame**
2. **Anvil and spindle**
3. **Ratchet driver**
4. **Thimble and barrel**
5. **Adjusting Nut.**



2.2.2 Micrometer Reading

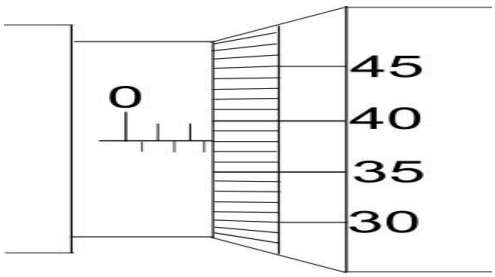
As we know that the screw thread is rotated by the thimble which indicates the one-sided revolution and the whole revolutions being counted on the barrel of the instrument.



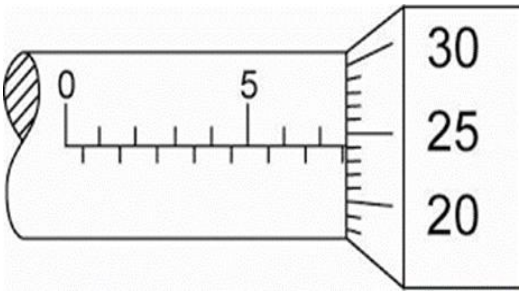
2.2.3 EXAMPLE MEASURE READINGS

Using the first example seen below:

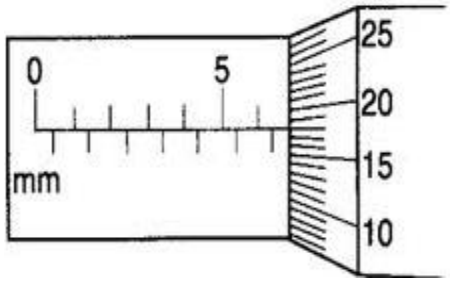
1. **Read the scale on the sleeve. The example clearly shows12 mm divisions.**
2. **Still reading the scale on the sleeve, a further ½ mm (0.5) measurement can be seen on the bottom half of the scale. The measurement now reads 12.5mm.**
3. **Finally, the thimble scale shows 16 full divisions (these are hundredths of a mm).**
   The final measurement is 12.5mm + 0.16mm = 12.66



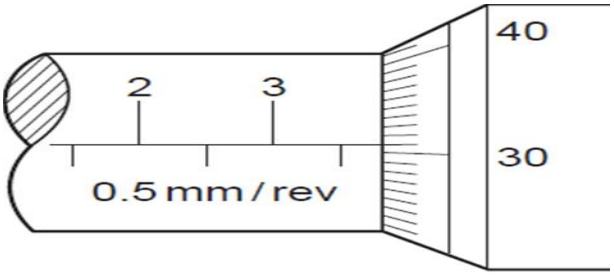
Total Measurement = mm



Total Measurement = mm



Total Measurement = mm

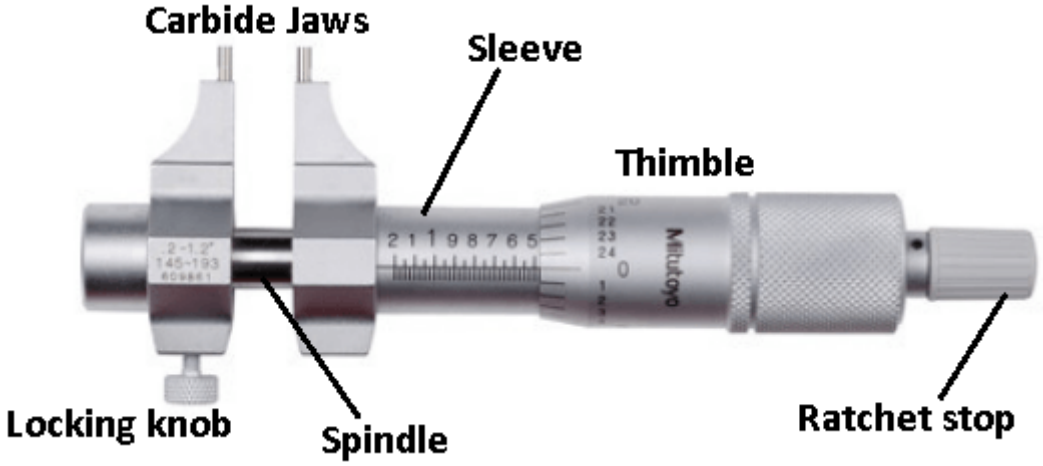


Total Measurement = mm

	ANSWER:
	ANSWER:
	ANSWER:
	ANSWER:

2.2.4 Inside Micrometer Calipers

The figure below shown an inside micrometer. This types of micrometers, they do not have U-shape frame and spindle. The measuring tips are constituted by the jaws with contact surfaces which are hardened and ground to a radius.

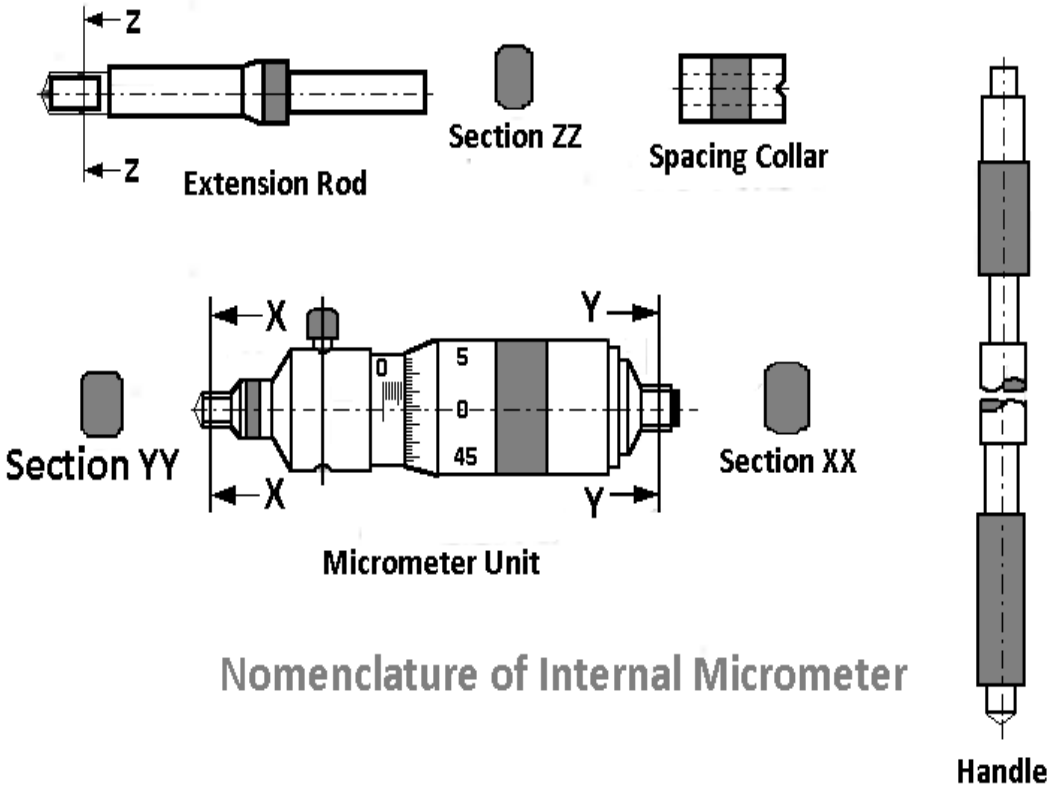


One jaw is held stationary at the end the second one moves by the movement of the thimble. A locknut is provided to check the movement of the movable jaw. These are used for inspecting of small internal dimensions. Its range is from 5 to 50 mm. It is not so widely used.

2.2.5 Parts of Inside Micrometer

Inside micrometer are used for the measurement of larger internal dimensions. It consists of four parts:

1. **measuring head or micrometer unit**
2. **Extension Rods.**
3. **Spacing collars.**
4. **Handle**



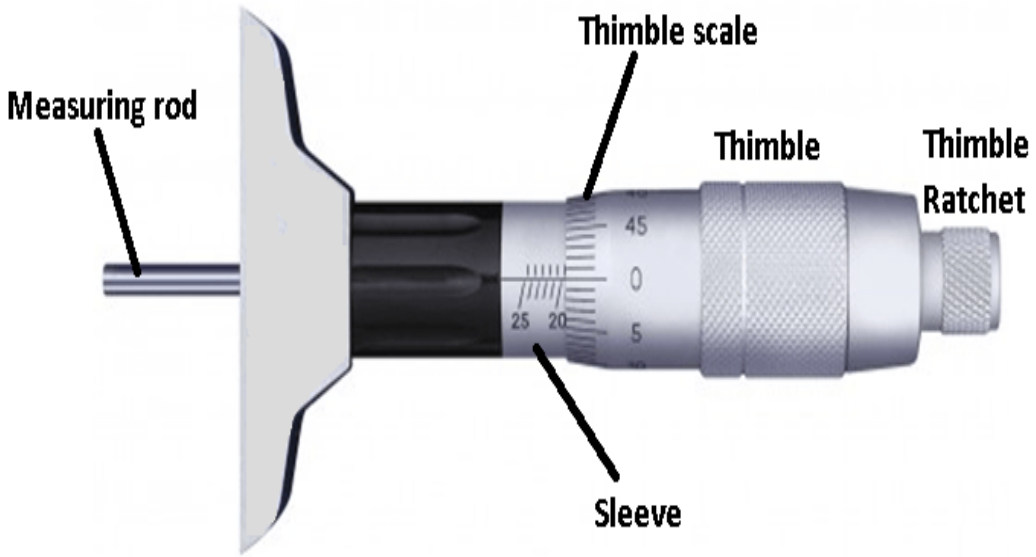
Nomenclature of Internal Micrometer

2.2.6 Micrometer Depth Gauge

This types of micrometers are used for measuring the depth of holes. Micrometer depth gauge is used for measuring the depth of holes, slots and recessed areas.

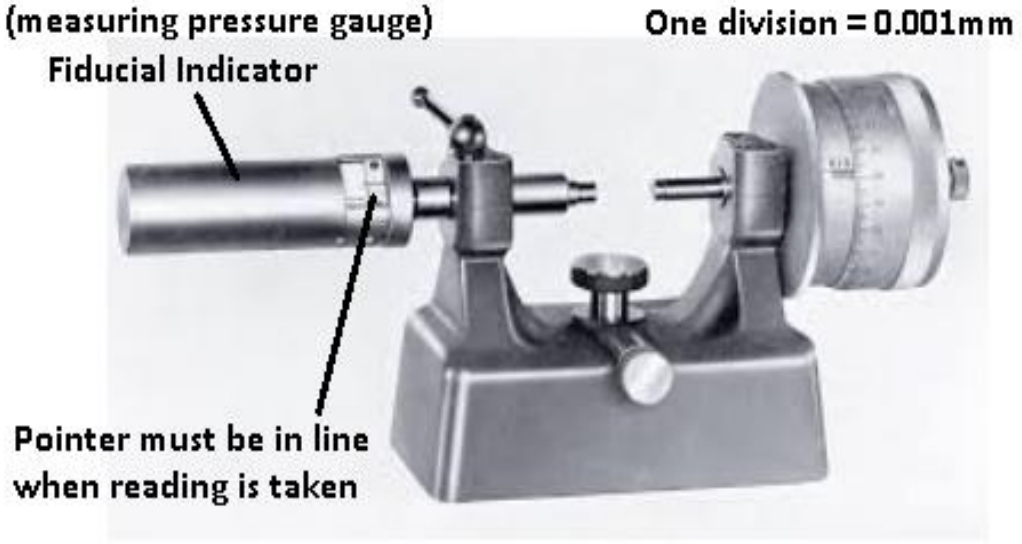
For the large range of measurements, extension rods can be used. The screw of the micrometer depth gauge has a range of 20mm or 25mm.

The length of the micrometer depth gauge caries from 0 to 225mm. The rod is inserted through the top of the micrometer. The rod is marked after every 10mm so that it could be clamped at any position.



2.2.7 Bench Micrometer

The bench micrometer principle makes use of a magnifying technique i.e., a gap of 0.01mm between the anvils is equivalent to a division width of the thimble of about 1mm.



2.2.8 Advantages Bench Micrometer

1. **Large diameter thimble permits the greater number of divisions around the large circumference, thus promoting better accuracy.**
2. **The fixed anvil is replaced by a fiducial indicator to ensure constant measuring pressure. This divide is more reliable than the rachet.**
3. **Micrometer screw errors will have a minimal effect since the screw is used over a very small large during measurement.**

2.2.9 Disadvantages Bench Micrometer

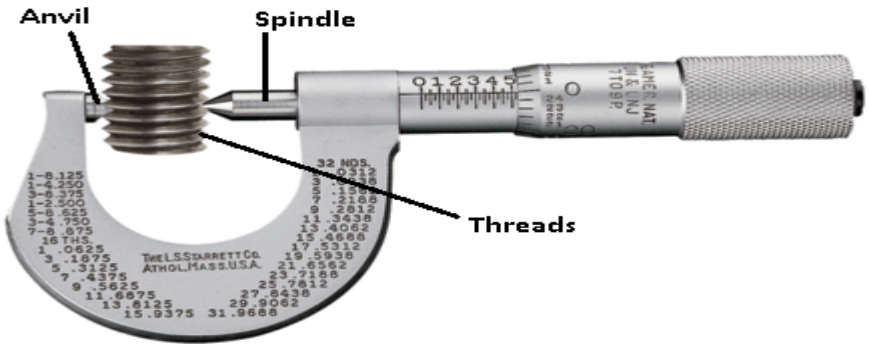
1. **Only one disadvantage is that it can only be used as a compare to and is extremely sensitive and embodies scientific principles to enable measured errors to be greatly magnified.**

2.2.10 Special Purpose Micrometers

The basic principle of micrometer remains the same even for special purpose micrometers, but based on the application they are classified into,

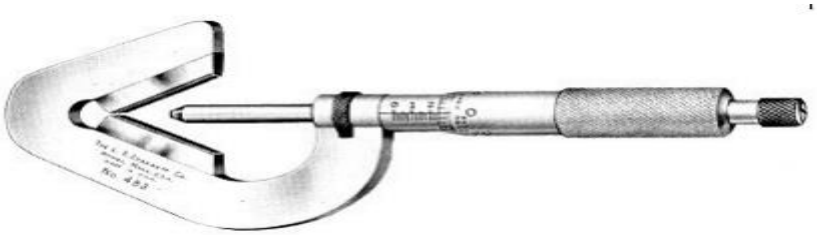
1 Screw Thread Micrometer

This types of micrometers are similar to the ordinary micrometer with the difference that it is equipped with a special anvil and spindle.



2 Vee – Anvil Micrometer

They are designed for measuring odd-fluted taps, milling cutters, and reamers, as well as checking out of roundness to tenths of thousands accuracy. In these types of micrometers, the angle of Vee equals 60 degrees and the apex of the Vee coincides with an axis of the spindle.



3 Thickness Micrometer

It is not convenient to use the ordinary micrometer for measuring the thickness of the tube (cylinder) or sleeve because of the concavity of the internal surface.

In this types of micrometers are used for measuring the thickness of cylinder walls meant for this purpose the anvil is provided with a spherical measuring surface of the frame is cut away on the outside to permit the anvil being introduced into tubes of diameter as small as 5.00mm in an alternative design shown in the figure.

2.2.11 Advantages of Micrometer Screw Gauge

1. **More accurate than rules.**
2. **Greater readability than rules or vernier.**
3. **No parallax error.**
4. **Small, portable and easy to handle.**
5. **Relatively inexpensive.**
6. **Retains accurately better than verniers.**
7. **Has to wear adjusting facility.**
8. **End measurement.**

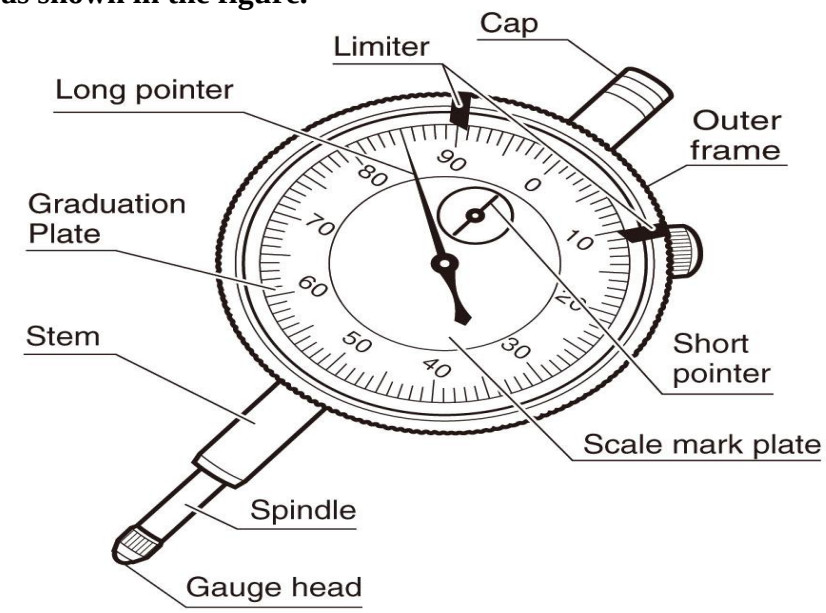
2.2.12 Disadvantages Micrometer Screw Gauge

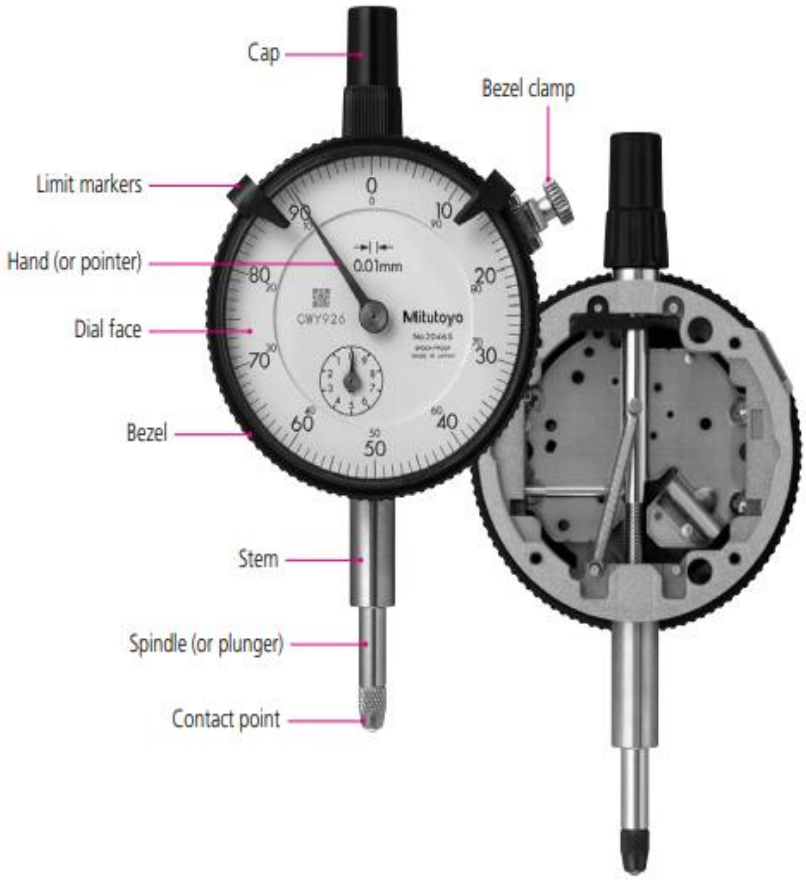
1. **Short measuring range**
2. **Single-purpose instrument**
3. **Limited wear area of the anvil and spindle tip.**
4. **End measurements only.**

2.3 Dial Indicator

Dial Indicator is the most commonly used mechanical comparator. It works on the principle of Rack and pinion system i.e., the linear movement of the spindle is magnified by rack and pinion arrangement. It consists of a robust base whose surface is flat and a pillar supporting a bracket in which a spindle fitted with a pinion and a dial scale.
By the use of slip gauges, the dial scale is set to zero representing the basic size of the part. This is used for inspection of small machined parts. This type of comparator used with different attachments.

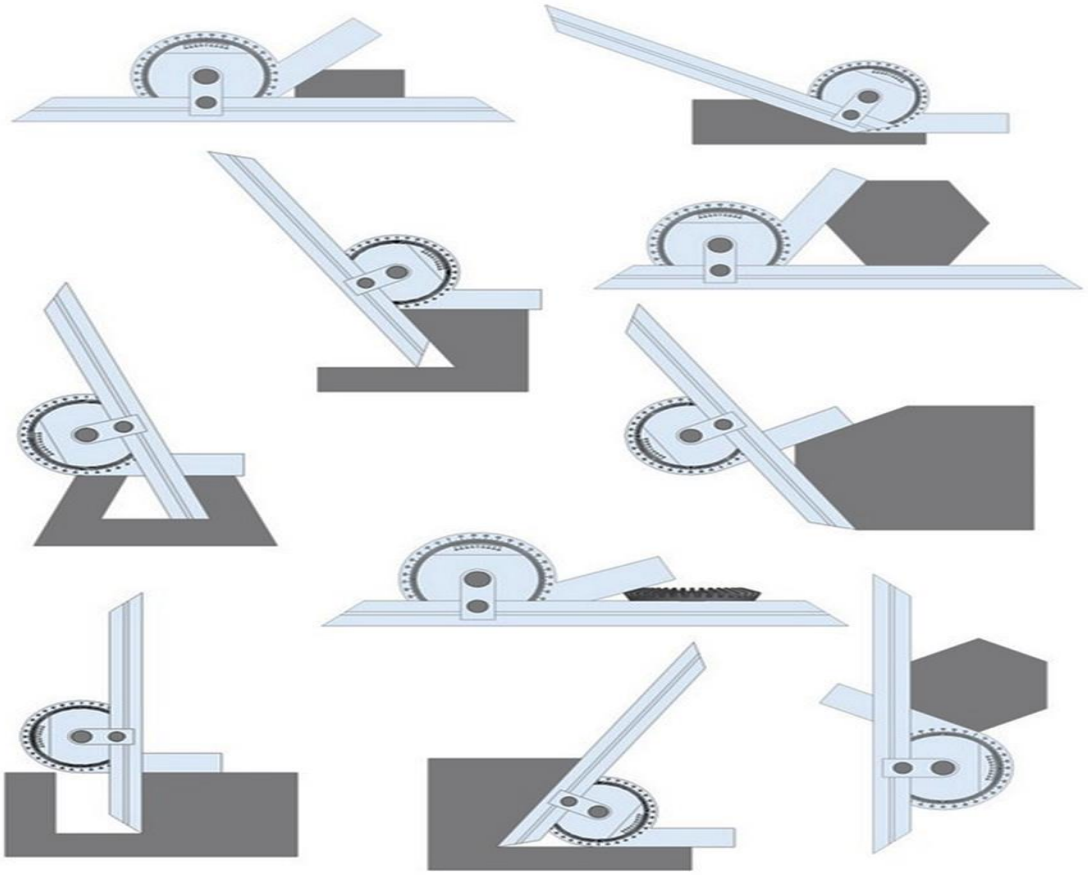
So that it may be used for a large number of works. For example, with a V-block attachment, it can be used for checking out of roundness of a cylindrical component as shown in the figure.





2.4 Bevel Protractor

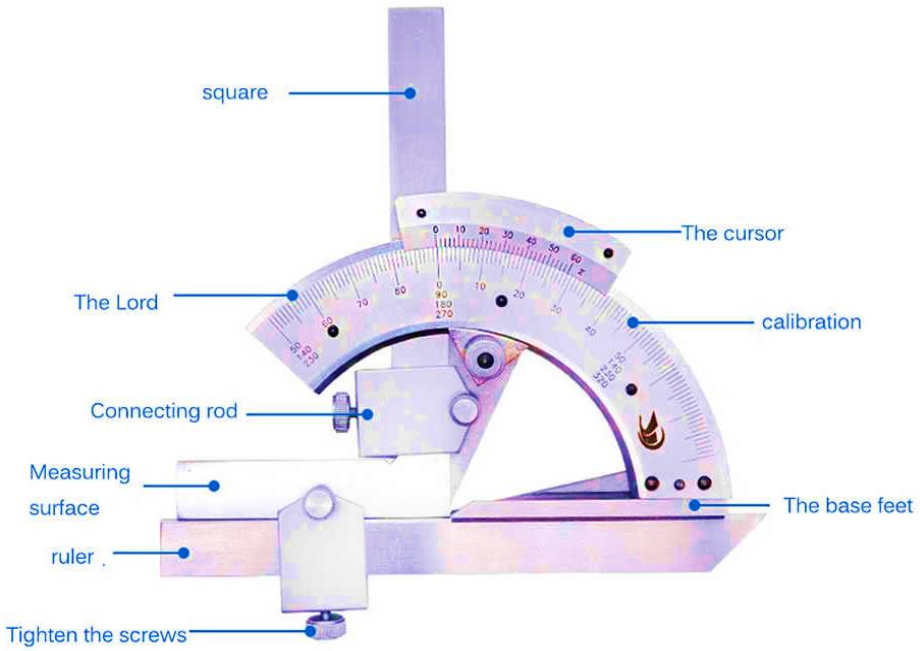
- **In geometry, a protractor is a circular or semicircular instrument used for measuring an angle or a circle.**
- **The units of measurement used are normally degrees.**
- **Some protractors are half-discs that have existed since ancient times.**
- **More advanced protractors, like Bevel Protractor, have one or two swinging arms, which help in measuring the angle.**
- **A bevel protractor is a graduated circular protractor it has a pivoted arm used for measuring or marking off angles.**
- **Sometimes vernier scales are attached to give more accurate readings.**
- **It has broad application in mechanical and architectural however with the availability of modern drawing software like CAD the tool is less likely used in that sphere.**
- **Universal bevel protractors are also utilised by toolmakers, as they measure angles by mechanical contact they are classified as mechanical protractors.**

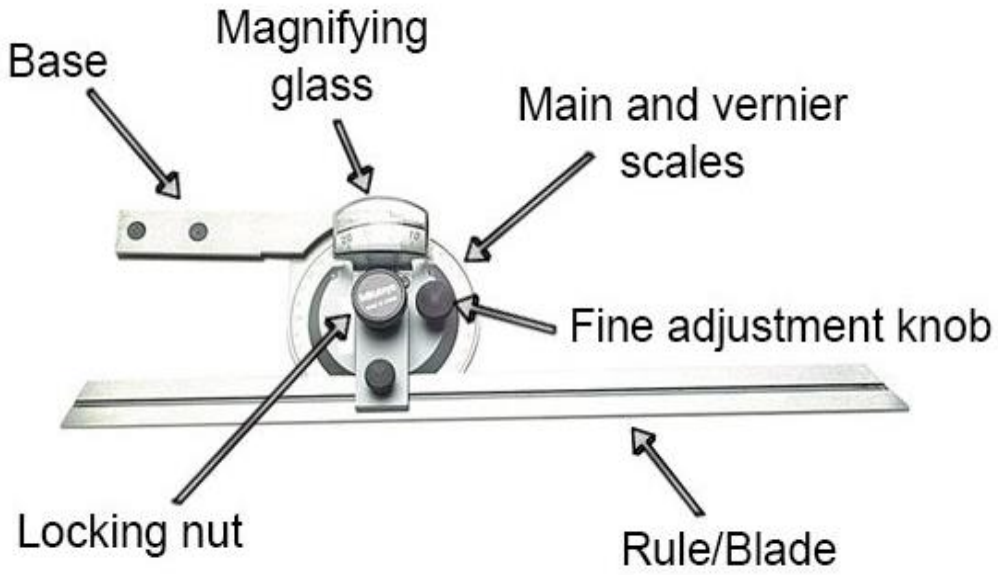


2.4.1 Types of Bevel Protractor

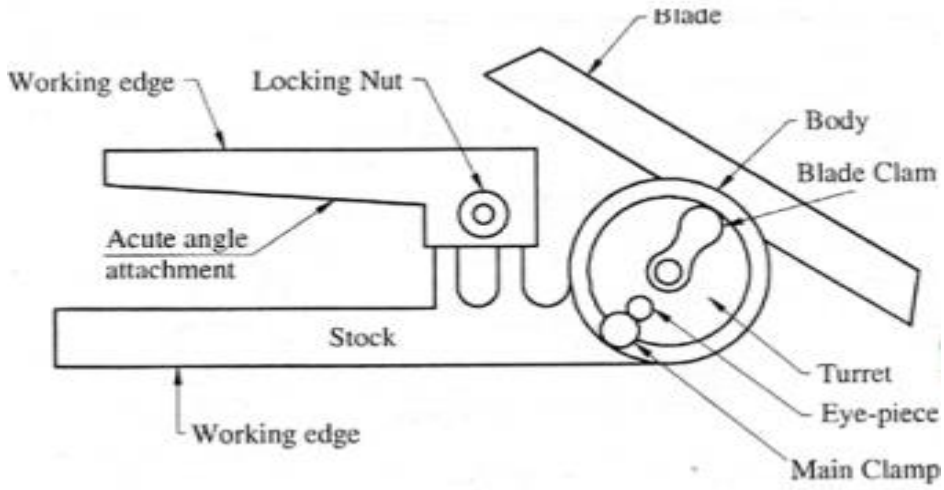
The following figure shows the nomenclature of both types of bevel protractors.

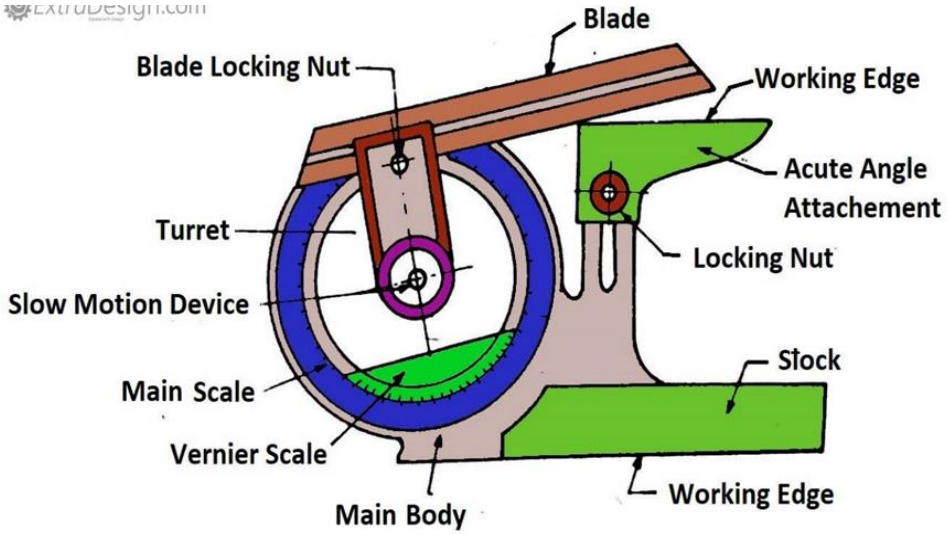
1. Mechanical Bevel Protractor





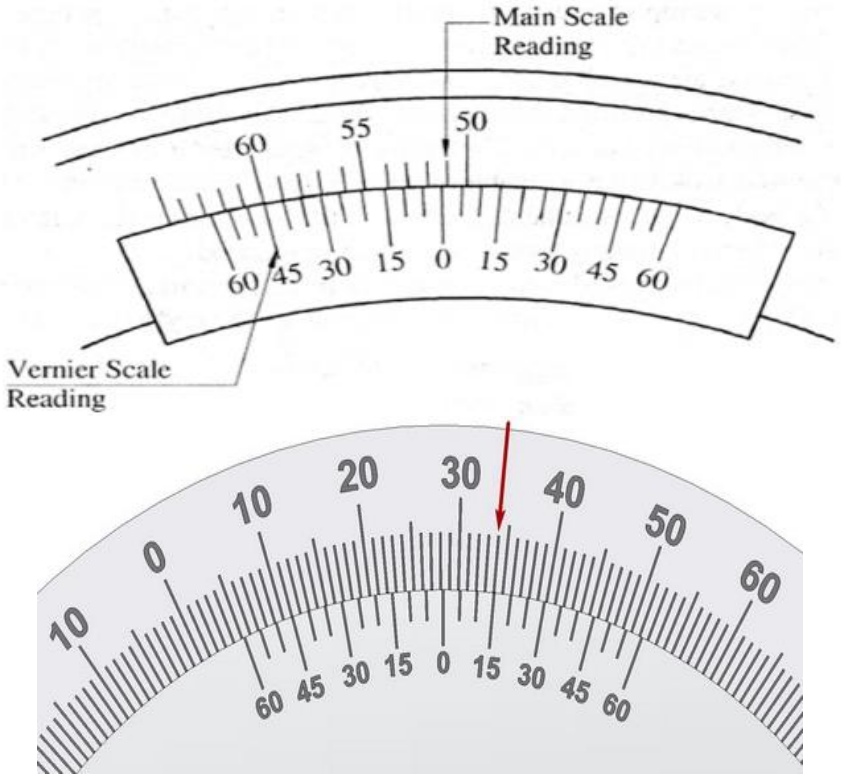
2. Optical Bevel Protractor





2.4.2 Main Scale & Vernier Scale Reading

The figure shows on the main scale are graduated in degrees of arc. It has 12 divisions on each side of the centre zero. These are marked 0-60 mins of the arc so that each division equals 1/12 of 60 that is 5 min of arc.
These 12 divisions occupy equal space as 23° on the main scale. Therefore each division of the vernier scale is equal to 1/12 of 23° or 1(11/12) °.
Thus the reading of the vernier protractor is equal to the largest "whole" degree of the main scale + the reading on the vernier scale in line with the main scale division.
= Main scale reading, 51° + Vernier 45 mark in line with the main scale
= 51°+ 45′



2.4.3 Advantages

Following are the advantages of bevel protractor:

1. **Bevel protractors are used to establish and test to bear angles in very close tolerance.**
2. **It can read 5 arc minutes (5′ or 112°) and can measure angles from 0 ° to 360 °.**
3. **By using bevel protractor you can get accurate measurements.**

2.4.4 Applications

Following are the application of bevel protractor:

1. **It is used for checking the inside bevelled face of a ground surface.**
2. **Used for checking 'V' blocks.**
3. **It is used to measure acute angles.**

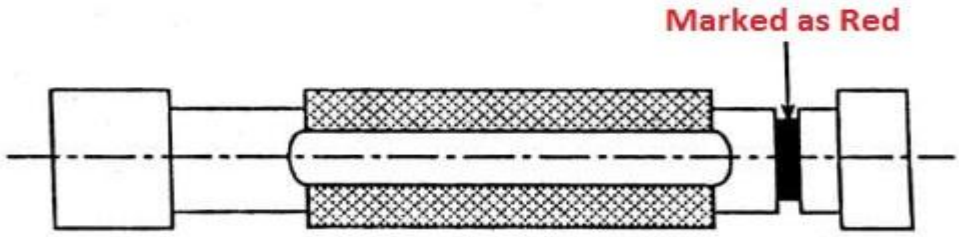
2.5 Main Types of Limit Gauges

2.5.1 Plain Plug Gauges

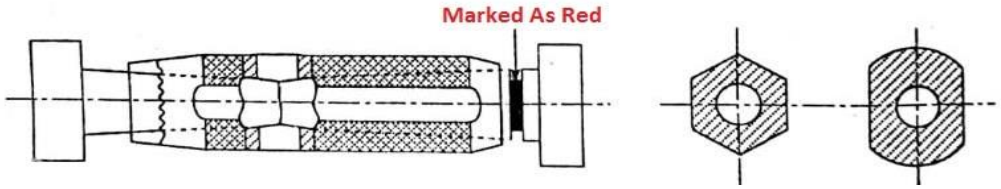
Plain plug gauges are used for checking plain or unthreaded holes and shafts. The plain plug gauges are the double-ended type for sizes up to 63 mm and of single-ended types of sizes above 63 mm. The plain plug gauges are designated by 'GO' and 'NOGO' as applicable.

2.5.2 Types of Plain Plug Gauges in Normal Practice are

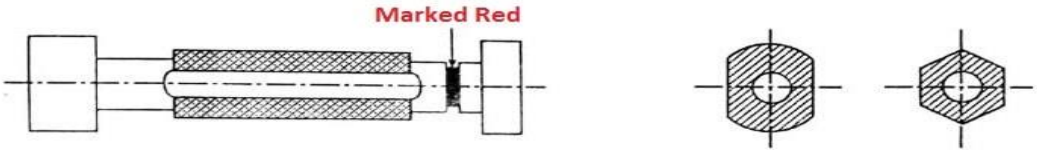
- **GO and NOGO plain plug gauges for sizes up to 10 mm.**



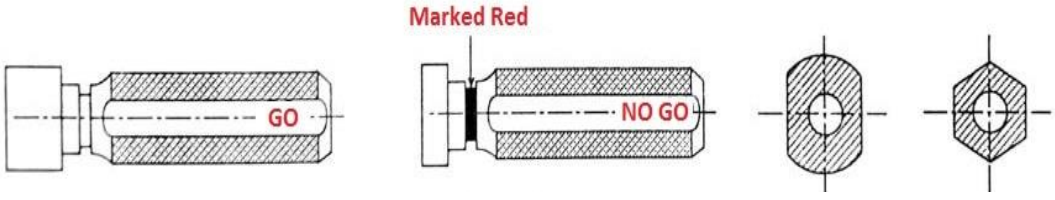
- **GO and NOGO plain plug gauges for size over 10 mm and up to 30 mm (Taper Inserted Type)**



- **1.3 GO and NOGO plain plug gauges for sizes over 30 mm and up to 63 mm of fastened type.**



- **1.4 Go and NOGO plain plug gauges for sizes over 63 mm and up to 100 mm of fastened type.**



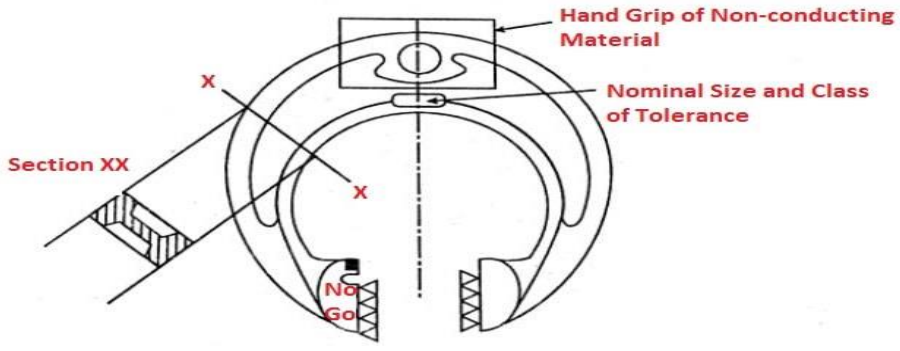
- **1.5 GO and NOGO plain plug gauges for sizes over 100 mm and up to 250 mm of flat type. This is a shell form plug gauge. Each plug is relieved to reduced weight.**

2.5.3 Snap Gauges or Gap Gauges

A snap gauge consists of a plate or frame with a parallel faced gap of the required dimension. The snap gauges are used for both cylindrical and non-cylindrical work as compared to ring gauges which are used only for cylindrical work. There are basically classified into two types,

1. Rib Type Snap Gauges

It is a double-ended type snap gauges which are used or checking sizes in the range of 3 mm to 100 mm and single-ended progressive type snap gauges are suitable for the size to range of 100 to 250 mm.
The gauging surface is hardened up to 720 H.V and suitably stabilised, ground and lapped. The other surfaces are finished smooth.

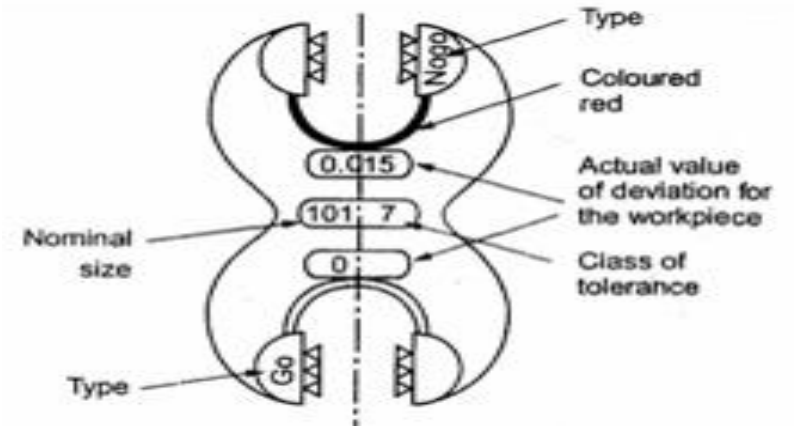


'GO' and 'NO GO' Snap Gauges for Sizes Over 100 mm and Upto 250 mm

2. Plate Snap Gauges

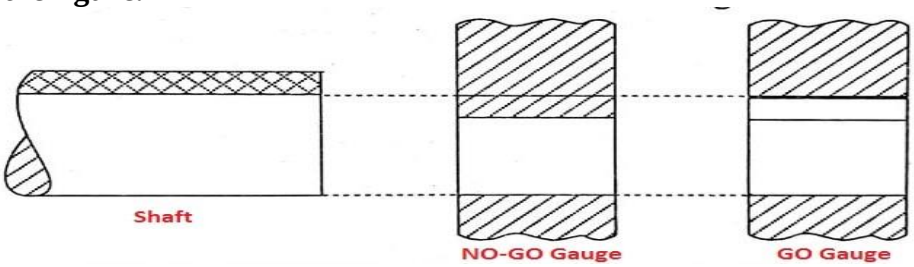
It is a double-ended type snap gauges are used for sizes in the range of 2 to 100 mm and single-ended progressive type in the size range of 100 to 250

mm. These plate snap gauges are usually made of wear-resistant steel of suitable quality. The gauging surfaces are suitably hardened, stabilized, ground and lapped. Other surfaces are smooth finished. The gauges are plainly flat and all sharp corners and edges are removed.



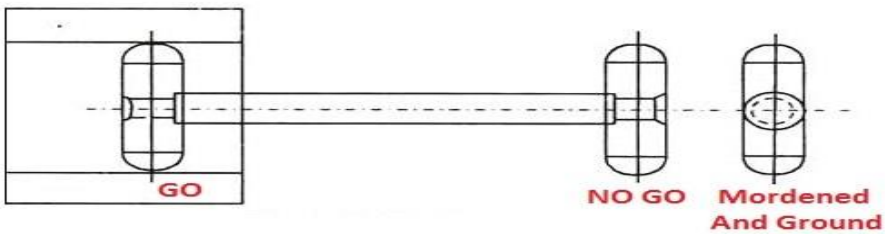
3. Ring Gauges

Ring gauges are limit gauges for gauging the shafts and are used in a similar manner to that of GO and NOGO plug gages. A ring gauge consists of a piece of metal in which a hole of the required size is based as shown in the figure.



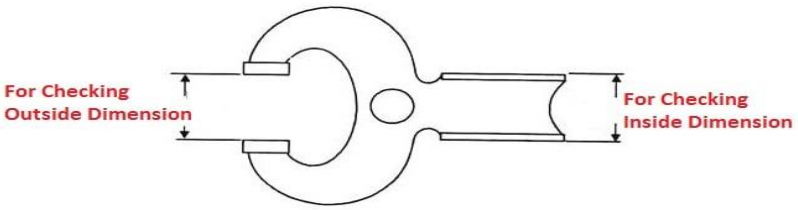
4. Pin Gauges

When the holes to be checked are larger than 75 mm, such as an automobile cylinder, it is available to use a pin gauge as shown in fig.
During the measurement, the gauge is located lengthwise in the cylinder bore and measurement is done. These types of gauges are particularly useful in the measurement of grooves or slot widths.



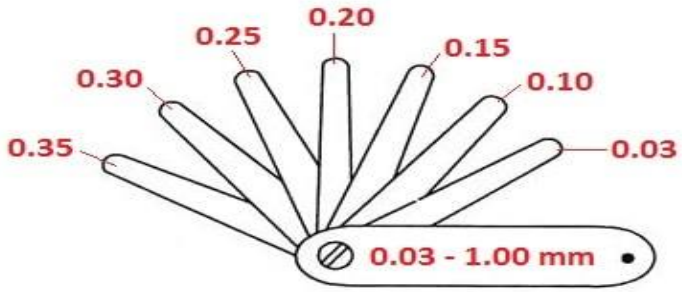
5. Calliper Gauges

A calliper gauge is similar to a snap gauge but it is used to check both the inside and outside dimensions of the product. One end of calliper gauge checks the inside dimensions (hole diameter), while the other end measures the outside dimensions (shaft diameter).



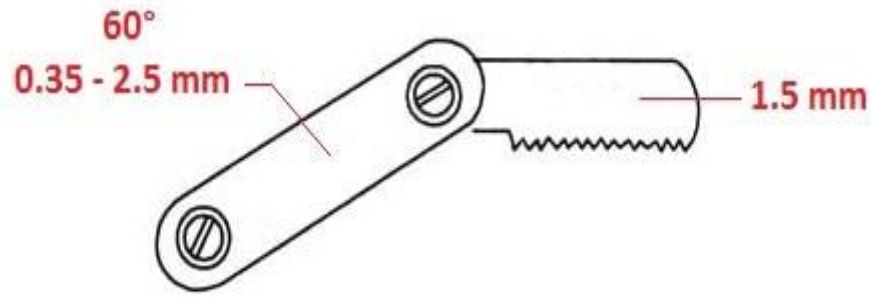
6. Feeler Gauge

It is also known as a thickness gauge. Feeler gauges are often used to measure the clearance between the components. These gauges are excellent for the measurement of narrow slots, measuring clearance, determining small spacing, and determining the fit between mating parts.



7. Screw Pitch Gauges

The screw pitch gauge is also called a thread gauge which looks related to a filler gauge. Each strip or blade has several teeth, precisely shaped in standard thread form. They are used to check the pitch of screw threads.



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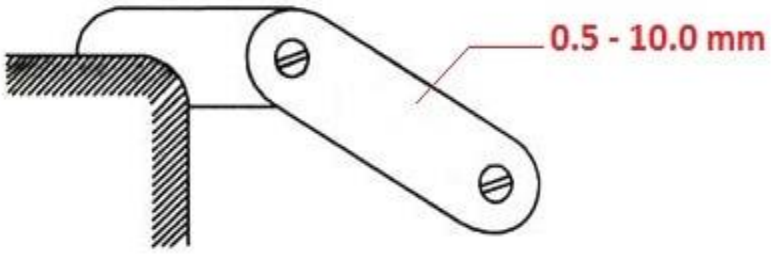
8. Radius or Fillet Gauge

These gauge types are used to check the concave and convex radii on corners or shoulders. It is also useful for layout work and inspection of components in various industries. It is used as a template when grinding of cutting tools.



2.6 Block Gauge

A gauge block is a block of metal or ceramic with two opposing faces ground precisely flat and parallel, a precise distance apart. Standard grade blocks are made of a hardened steel alloy, while calibration grade blocks are often made of tungsten carbide, chromium carbide or ceramic because they are harder and wear less.

2.6.1 Grades

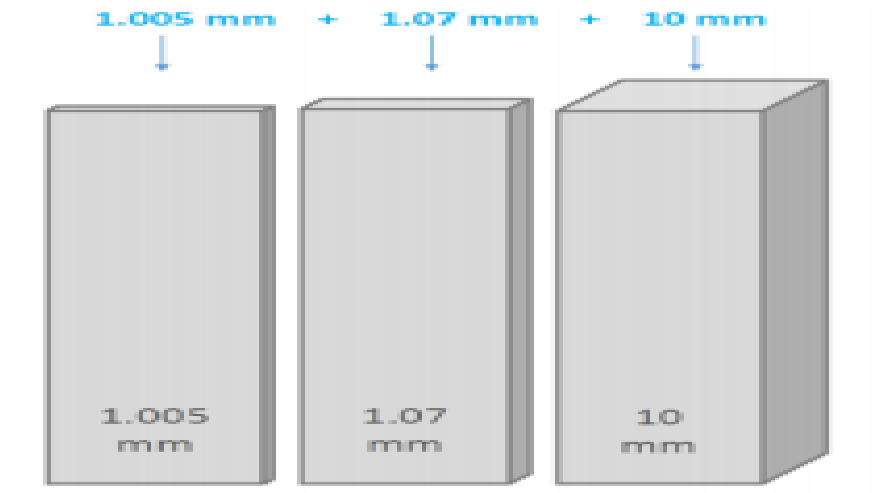
Tolerances will vary within the same grade as the thickness of the material increases.

- **Reference (AAA): small tolerance (±0.05 µm) used to establish standards**
- **Calibration (AA): (tolerance +0.10 µm to −0.05 µm) used to calibrate inspection blocks and very high precision gauging**
- **Inspection (A): (tolerance +0.15 µm to −0.05 µm) used as toolroom standards for setting other gauging tools**
- **Workshop (B): large tolerance (tolerance +0.25 µm to −0.15 µm) used as shop standards for precision measurement.**

2.6.2 How to wring gauge blocks

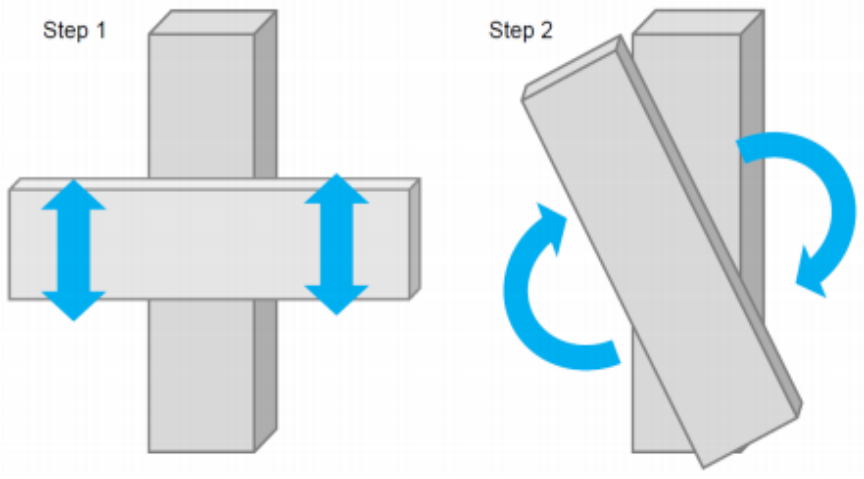
Once you've selected the gauge blocks you need, you need to combine them to achieve your desired width. You can stick gauge blocks stick to each other through a process called wringing, which is possible because of the phenomenon of molecular attraction between the two lapped surfaces and a thin film of molecules trapped between the surfaces (which is known as the wringing film).

Wringing: Method one Hold the faces of two gauge blocks firmly together in a cross shape. Slide the top gauge block up and down along the surface of the bottom gauge block until it no longer moves easily (step 1 in Figure 6). Then, rotate the top gauge block until it is in line with the bottom gauge block (step 2 in Figure 6). This method works well for larger gauge blocks.



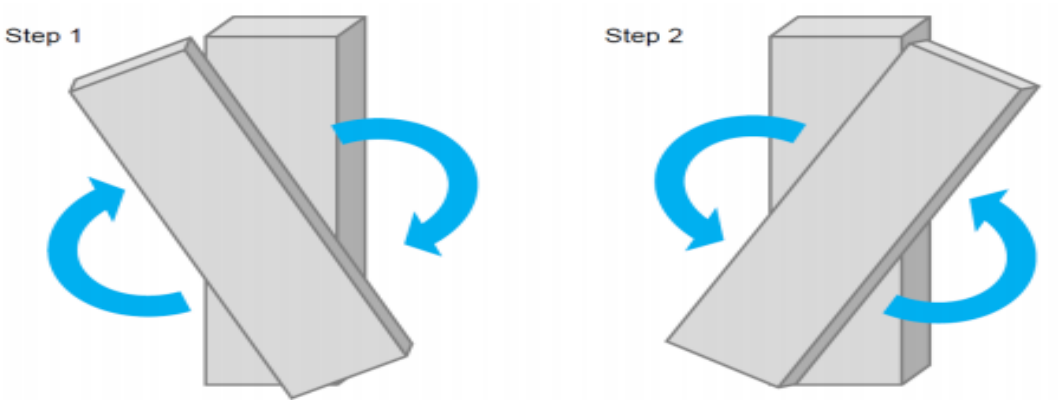
2.6.3 Wringing: Method two

Hold the faces of two gauge blocks firmly together in a cross shape. Rotate the top gauge block from side to side (Figure 7) as if you are turning a dial back and forth. When the gauge block no longer rotates easily, rotate the gauge blocks until they line up.



2.6.4 Wringing: Method three

Slide the top gauge block straight onto the second gauge block lengthwise onto the bottom gauge block (Figure 8). Slide together firmly, then line up all edges. This method works best with thinner gauge blocks.



2.6.5 Advantages of Limit Gauges:

1. **Quicker Inspection Method:**
   It is quicker than direct measurement. The time to inspect on shop-floor is minimized.
2. **Used In-Mass Production:**
   Limit gauges are conveniently used in mass production for checking and controlling various dimensions.
3. **Ensure Interchangeability:**
   A Limit gauge ensures interchangeability and hence components can be assembled without difficulty.
4. **Need Semiskilled Operator:**
   Limit gauges can easily be used by semi-skilled operators.
5. **Check both Linear and Geometric Features:**
6. **A proper designed limits gauge can check both linear and geometric features simultaneously.**
7. **Economical:**
   Limit gauges are economical in their own cost as well as in inspection cost.