# [ ME 472 ]

# Engineering Metrology & Quality Control

## [ CHAPTER 2 ]

## Linear & Angular Measurements

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**Measuring Tools & Instruments**

**Direct Measurements**
(conventional methods & tools)

**Indirect Measurements**
(with use of light, laser, sound, etc.)

**NEXT CHAPTER**

**Graduated (Scaled) Tools**
(linear & angular graduations incorporated into measuring system of the tool)

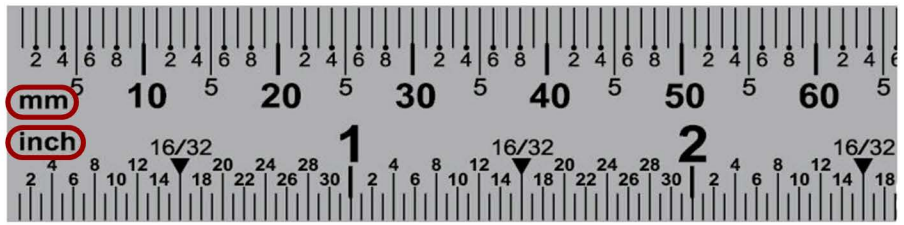
- Rules & Rulers
- Vernier Calipers
- Vernier Gauges
- Micrometers
- Protractors
- Dial Indicators

**Non-Graduated Tools**
(gauges & adjustable tools for the inspection of shape & dimensions)

- Calipers
- Gauges
- Gauge Blocks
- Sine Bar
- Special-Purpose Tools

# Graduated Linear Measurements: Rules & Rulers

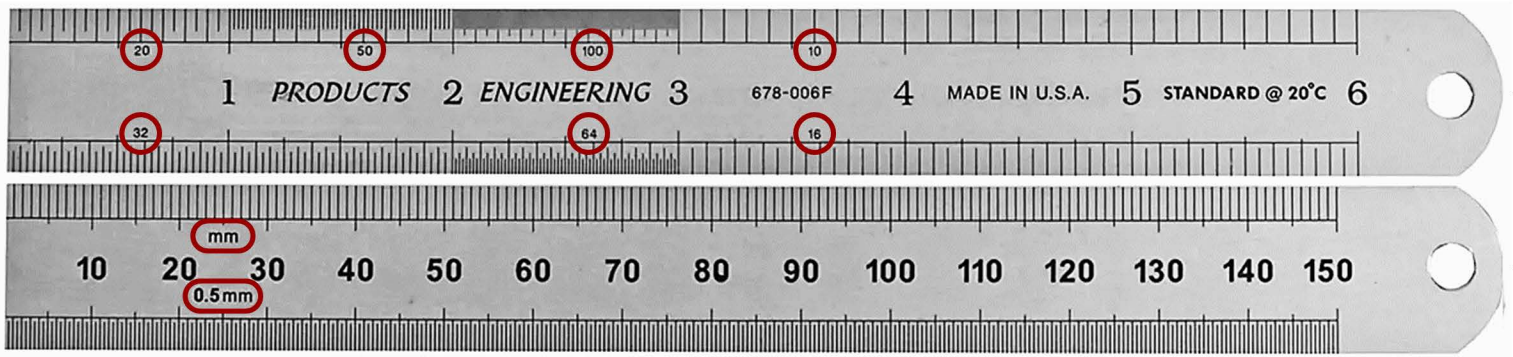
**Single-Sided**




← Upper: metric (1 mm)

← Lower: imperial (1/32 inch)

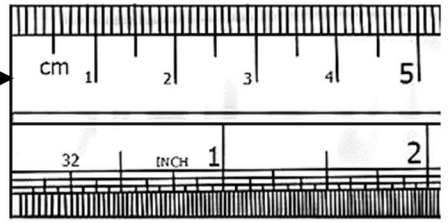
**Double-Sided**



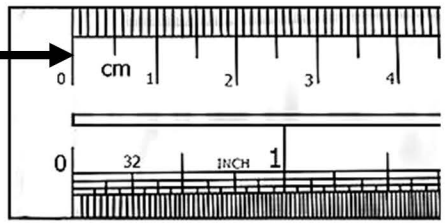

← Front Face: imperial (various graduations)

← Back Face: metric (1 mm & 0.5 mm)

**Rules** start measuring right at the edge →



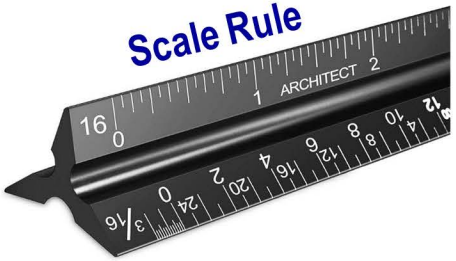

**Rulers** start measuring away from the edge (at the zero mark) →





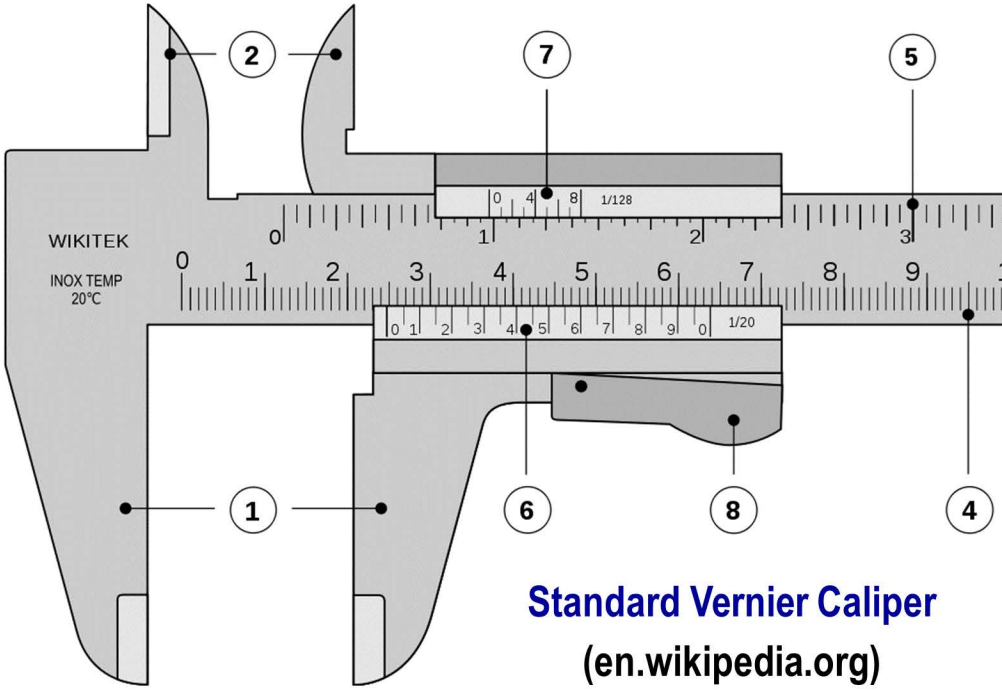
Centring (Center-Finding) Rule

Scale Rule




**Information on other types of Rules & Rulers:**
**www.wonkeedonkeetools.co.uk**

## Graduated Linear Measurements: Vernier Calipers

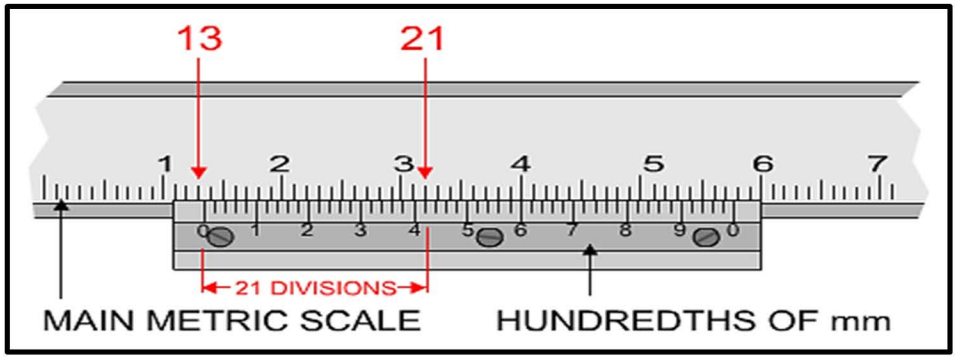


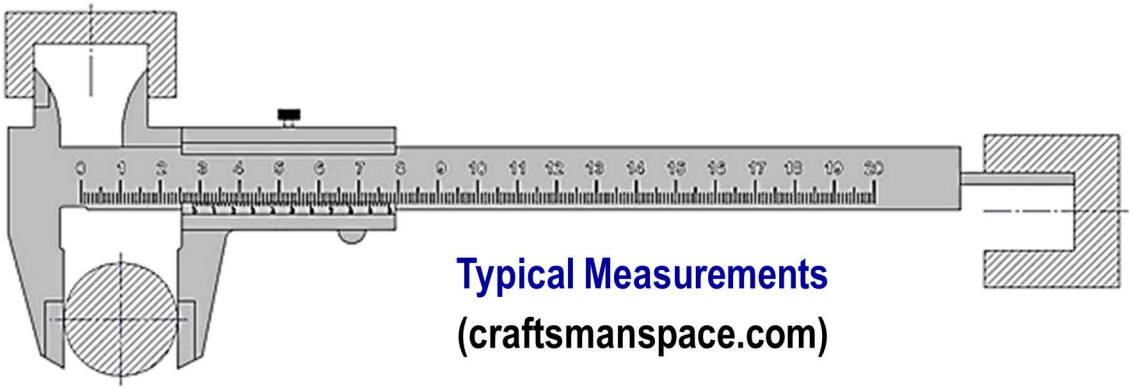

Standard Vernier Caliper (en.wikipedia.org)

1. **Outside Jaws** (used for external measurements)
2. **Inside Jaws** (used for internal measurements)
3. **Depth Probe** (used for depth measurements)
4. **Main Scale** (metric, cm)
5. **Main Scale** (imperial, inch)
6. **Vernier Scale** (metric, cm)
7. **Vernier Scale** (imperial, inch)
8. **Retainer** (used for locking the movable part)

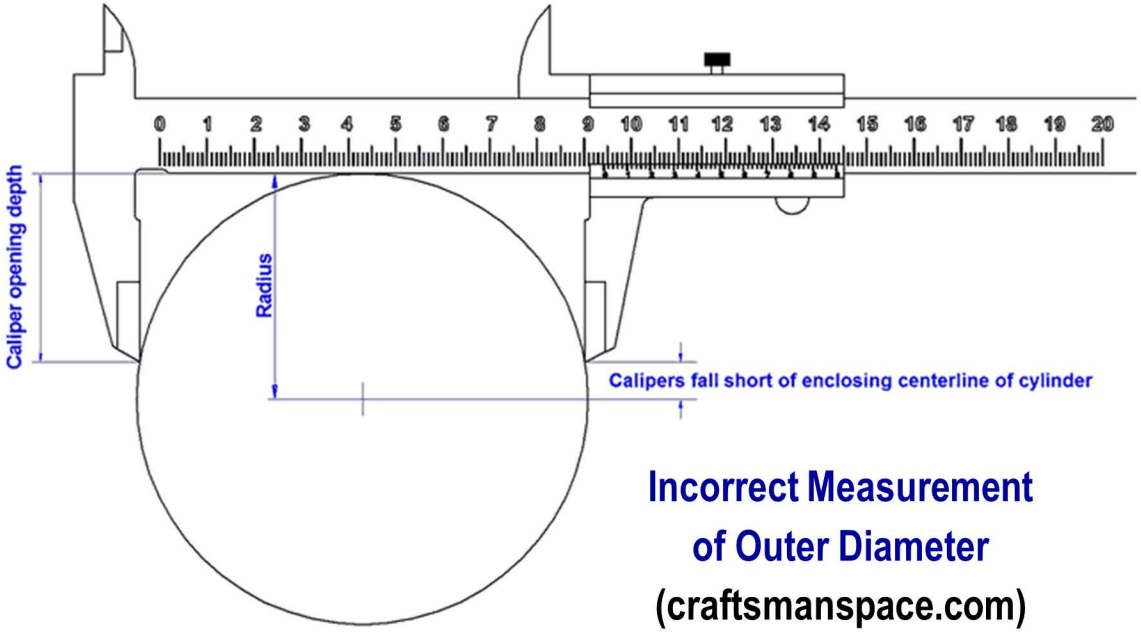
## How to read Vernier Caliper:

- Read graduation on **main scale** just before the vernier scale starts (i.e. **13th graduation** which gives **13 mm**)
- Read graduation on **vernier scale** where the lines of graduations on main and vernier scales perfectly match (i.e. **21st graduation** which gives 21 * 1/50 = **0.42 mm**)
- Sum those readings (i.e. 13 + 0.42 = **13.42 mm**)





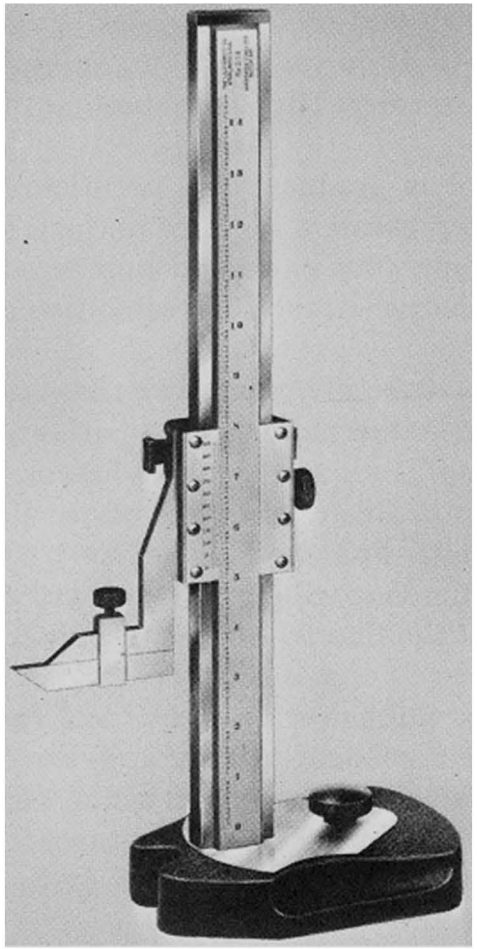
Typical Measurements
(craftsmanspace.com)




Incorrect Measurement
of Outer Diameter
(craftsmanspace.com)


## Graduated Linear Measurements: Vernier Height Gauges

For use in toolrooms, workshops, inspection departments to **mark-off heights** and **locate center distances.**



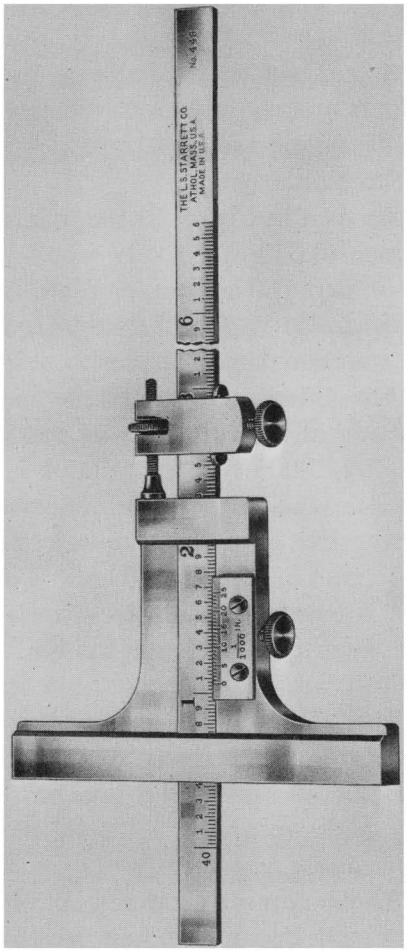
Standard Height Gauge

Dial Height Gauge

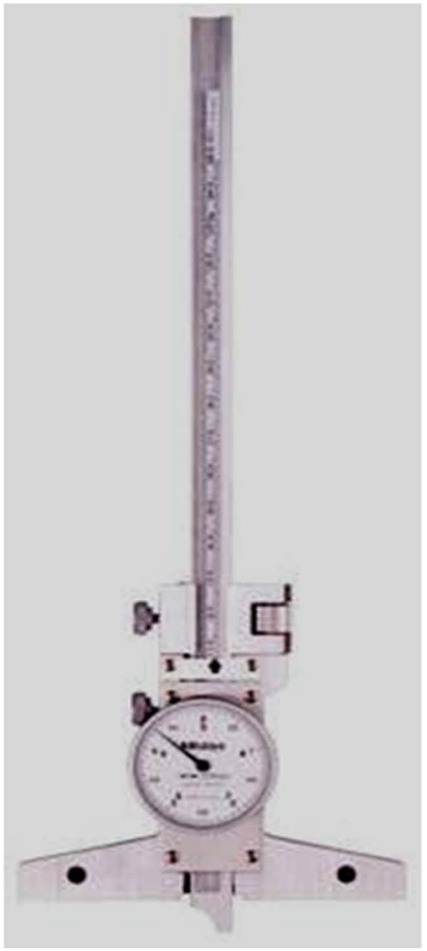
Digital Height Gauge

## Graduated Linear Measurements: Vernier Depth Gauges

For use in toolrooms, workshops, inspection departments to **measure depth of holes, slots, recesses, etc.**



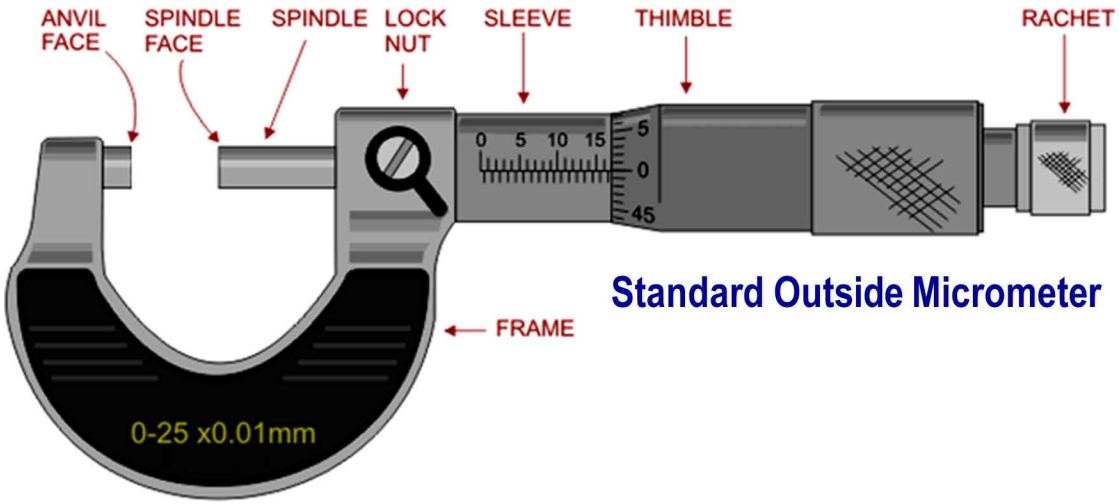

Standard Depth Gauge



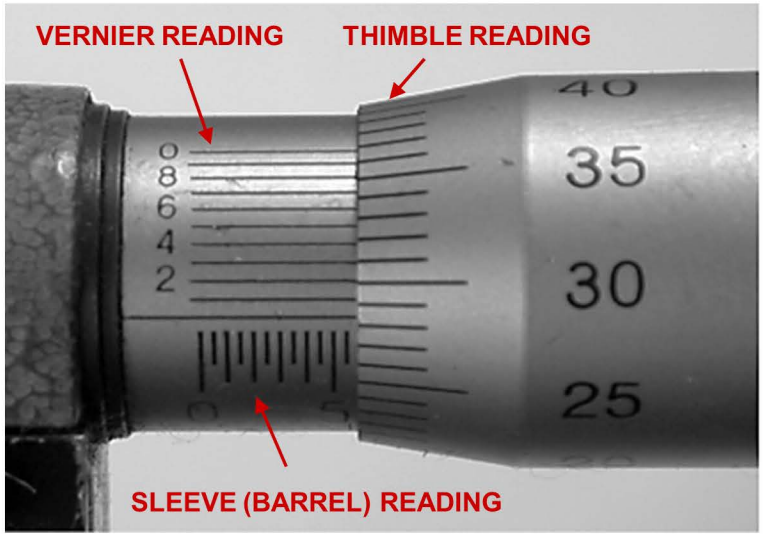
Dial Depth Gauge


Digital Depth Gauge

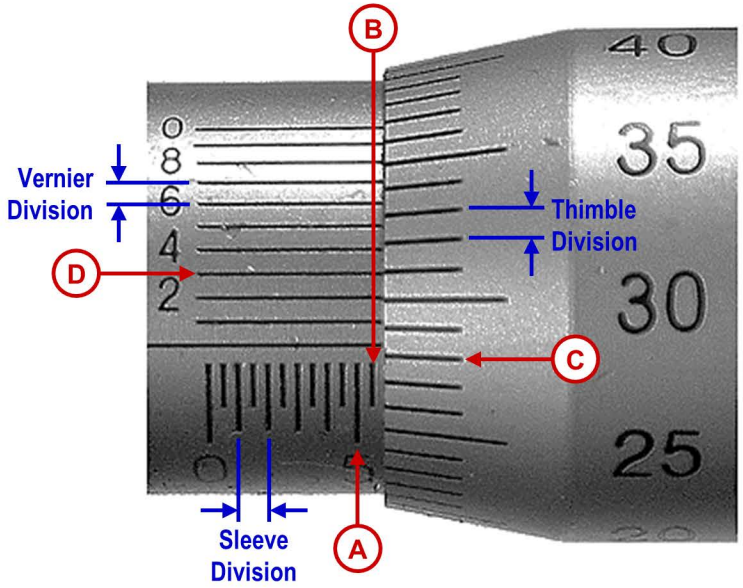
## Graduated Linear Measurements: Micrometers




Standard Outside Micrometer




Vernier Micrometer




### How to read Vernier Micrometer:

**Sleeve division:** 1 mm (main) & 1/2 mm (sub)

**Thimble division:** 1/50 of sleeve sub-div. = 1/100 mm

**Vernier division** = 1/10 of thimble div. = 1/1000 mm

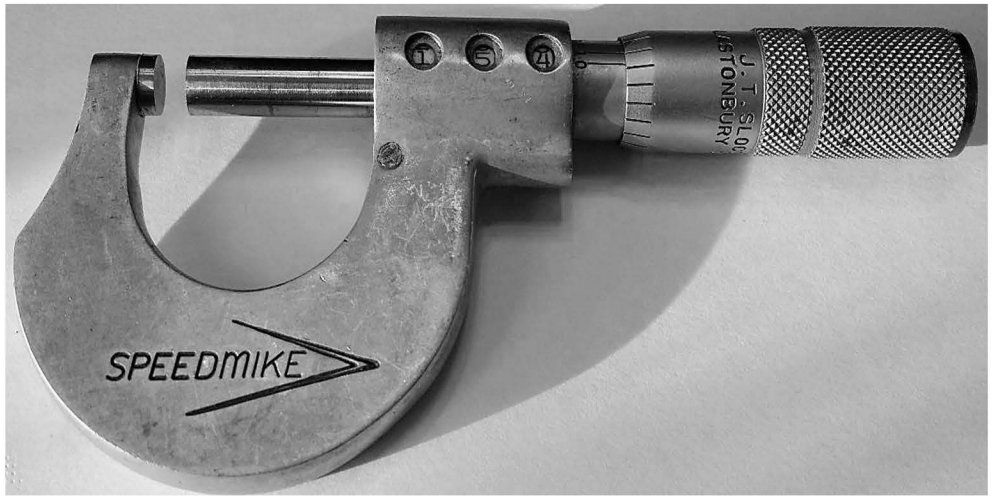
**A** → The highest figure: **5 unit** * (sleeve main div.) = **5 mm**

**B** → The half-figures: **1 unit** * (sleeve sub-div.) = **0.5 mm**

**C** → The highest figure: **28 unit** * (thimble div.) = **0.28 mm**

**D** → The matching figure: **3 unit** * (vernier div.) = **0.003 mm**

**FINAL READING: A + B + C + D = 5.783 mm**




Direct Reading Micrometer

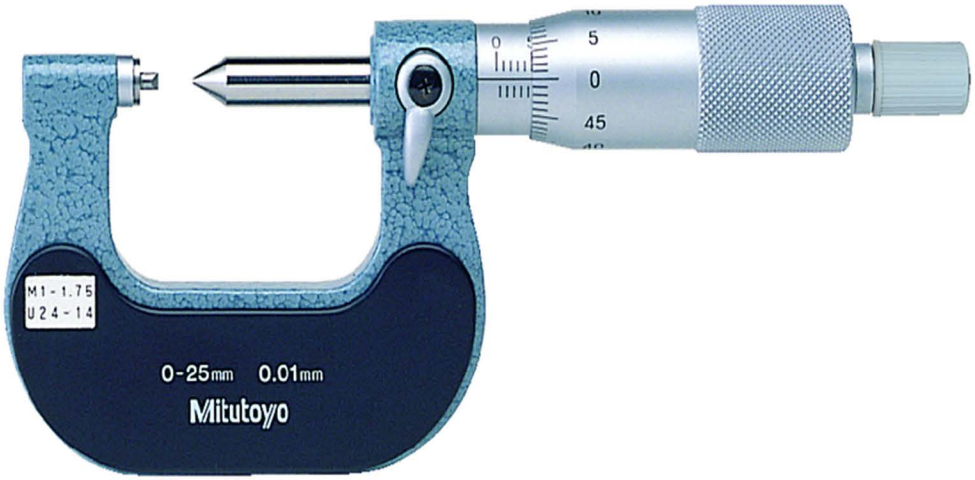

Bench Micrometer


Dial Micrometer


Digital Micrometer


V-Anvil Micrometer

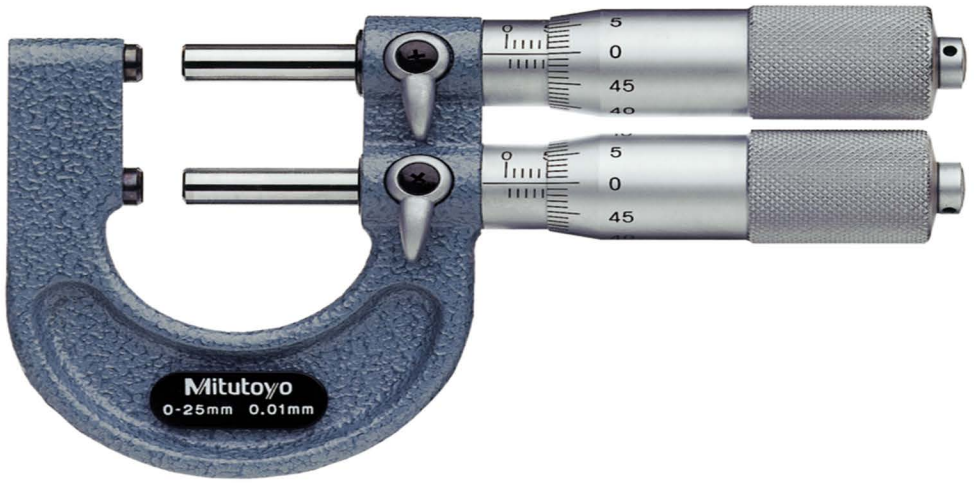

Flat-Anvil Micrometer




Screw Thread (Pitch Diameter) Micrometer

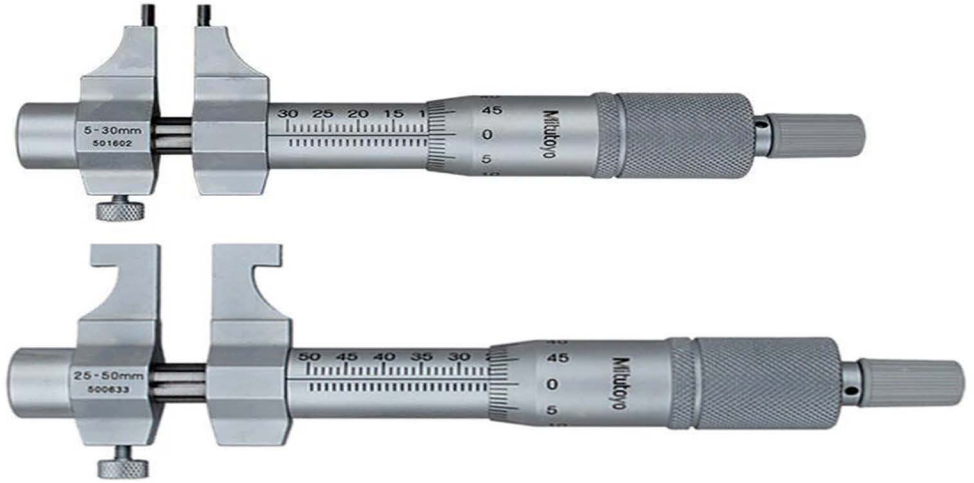

Tube Thickness Micrometer


Blade Micrometer

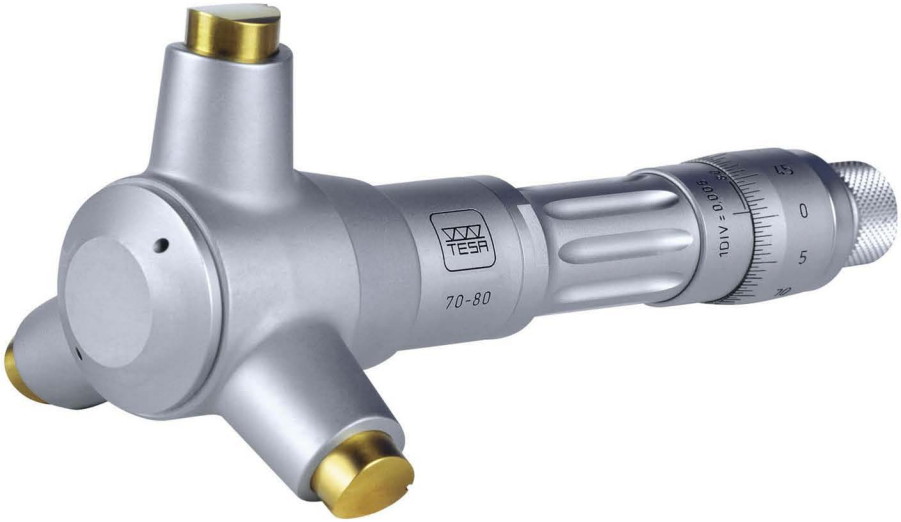



Limit (Snap Gauge) Micrometer


Spherical-Face (Ball) Micrometer



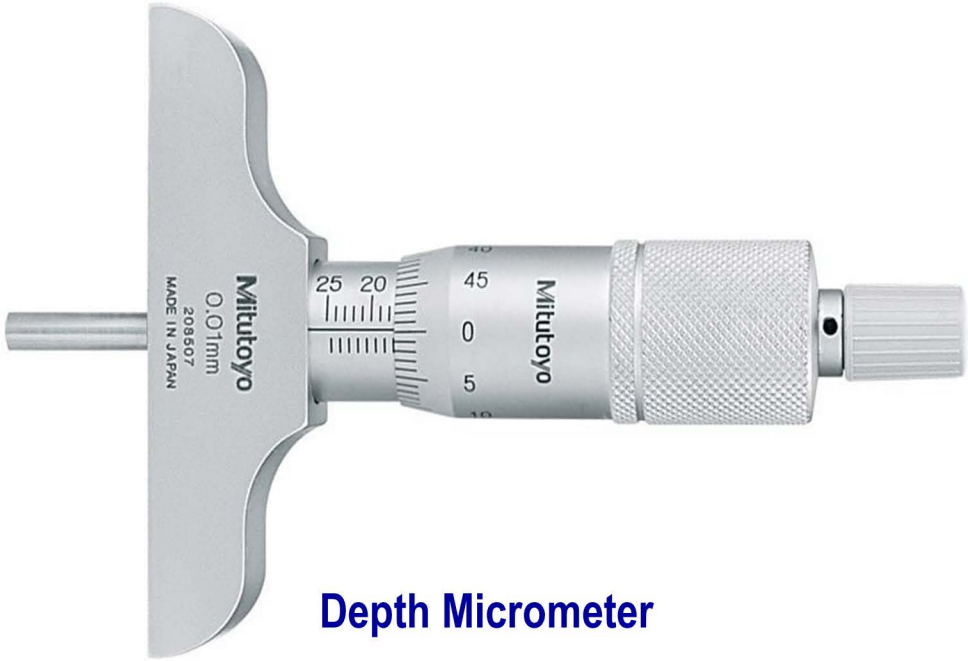

Inside Micrometer





3-Point Bore Micrometers


Differential Screw Micrometer

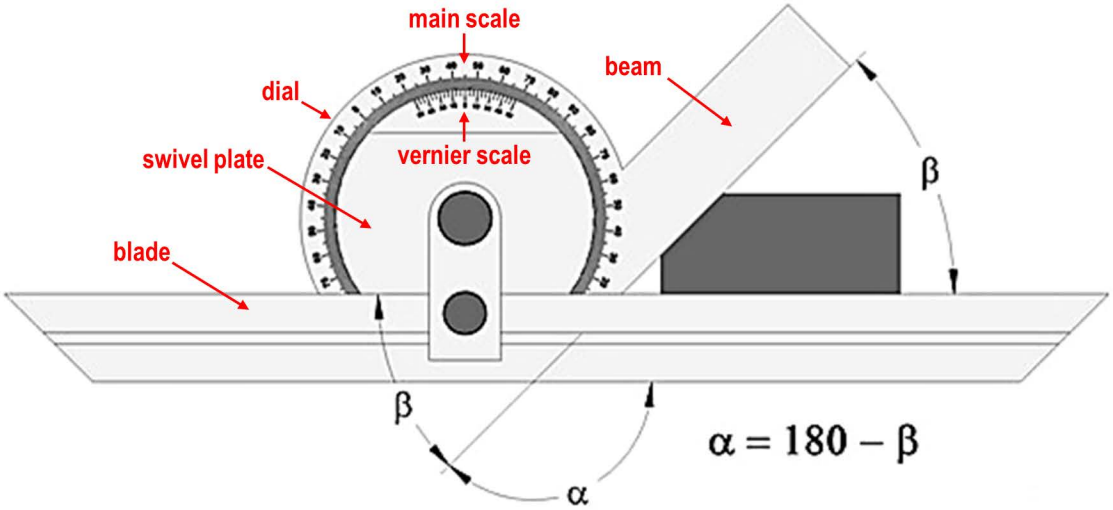


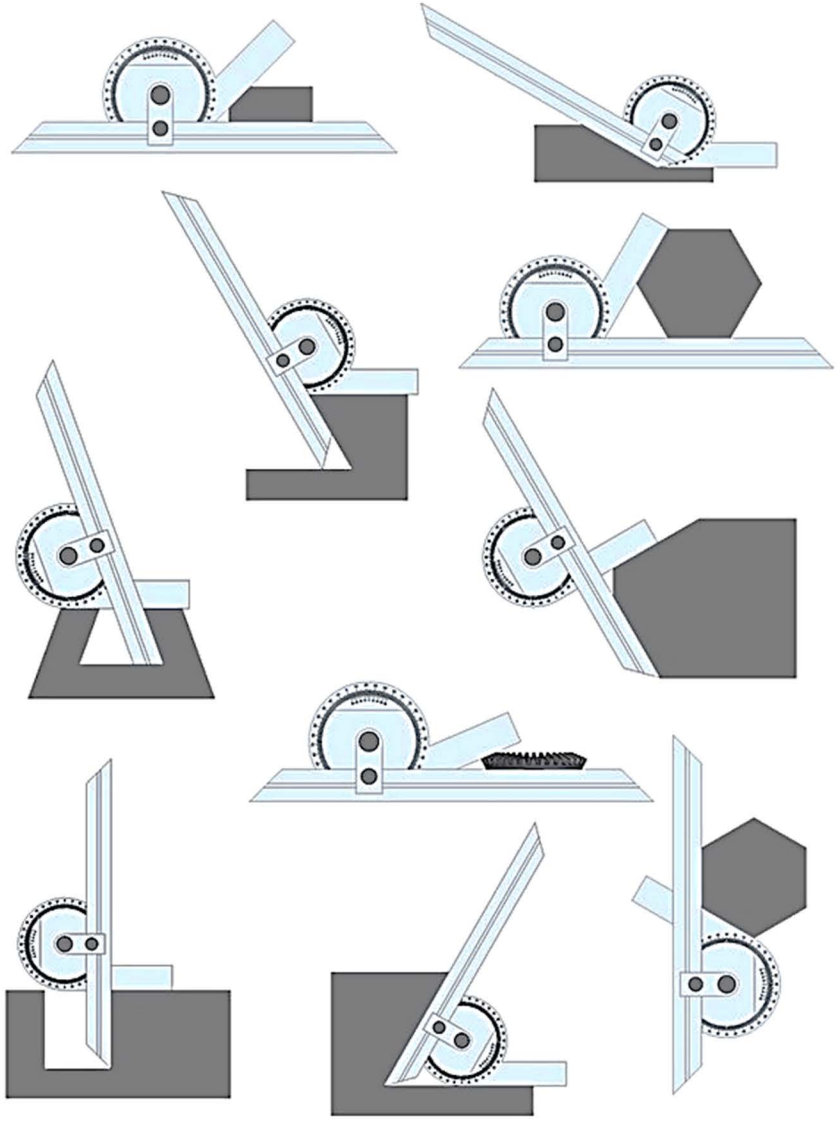

Depth Micrometer

Bore Gauge Micrometer Set

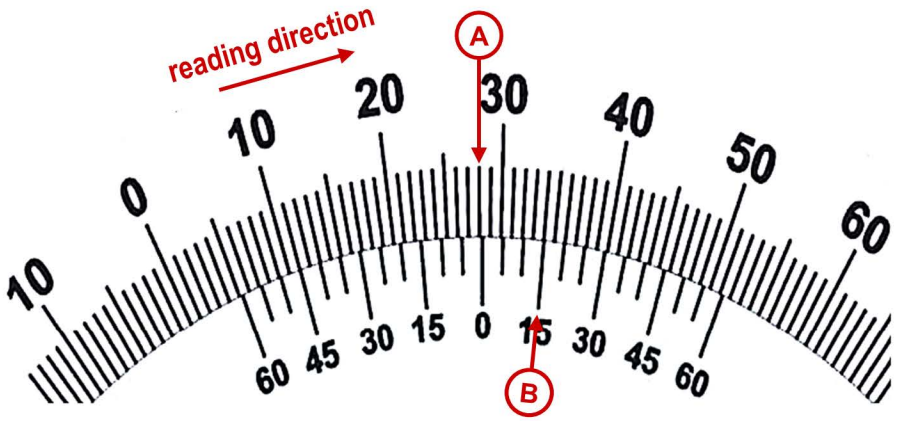
# Graduated Angular Measurements: Protractors


Universal Bevel Protractor (4 quarters of 90°)



Typical Measurements (craftsmanspace.com)




## How to read Vernier Protractor (1):

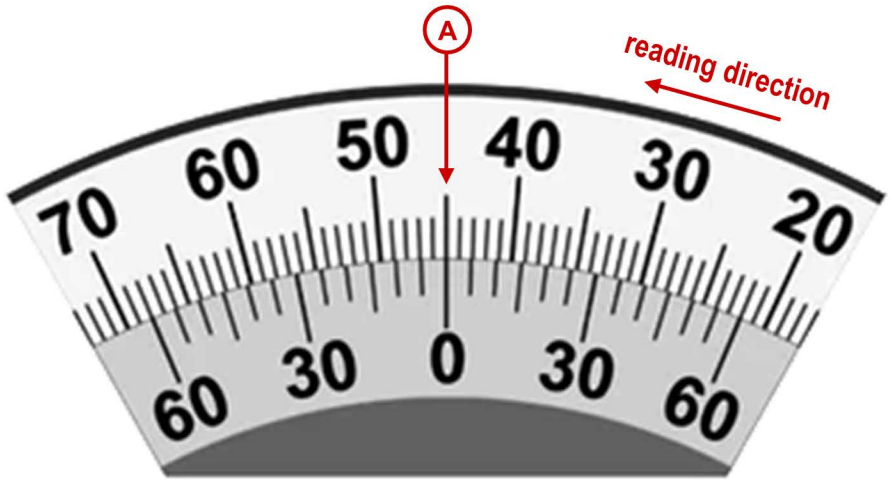
**Main division:** 1° ( 60′ )

**Vernier division:** = 1/12 of main div. ≈ 0.0833° ( 5′ )

**A** ⟶ The highest figure: **28 unit** * (main div.) = **28°**

**B** ⟶ The matching figure: **3 unit** * (vernier div.) = **0.25°** ( 15′ )

**FINAL READING: A + B = 28.25° ( 28° 15′ )**




## How to read Vernier Protractor (2):

**Main division:** 1° ( 60′ )

**Vernier division:** = 1/12 of main div. ≈ 0.0833° ( 5′ )

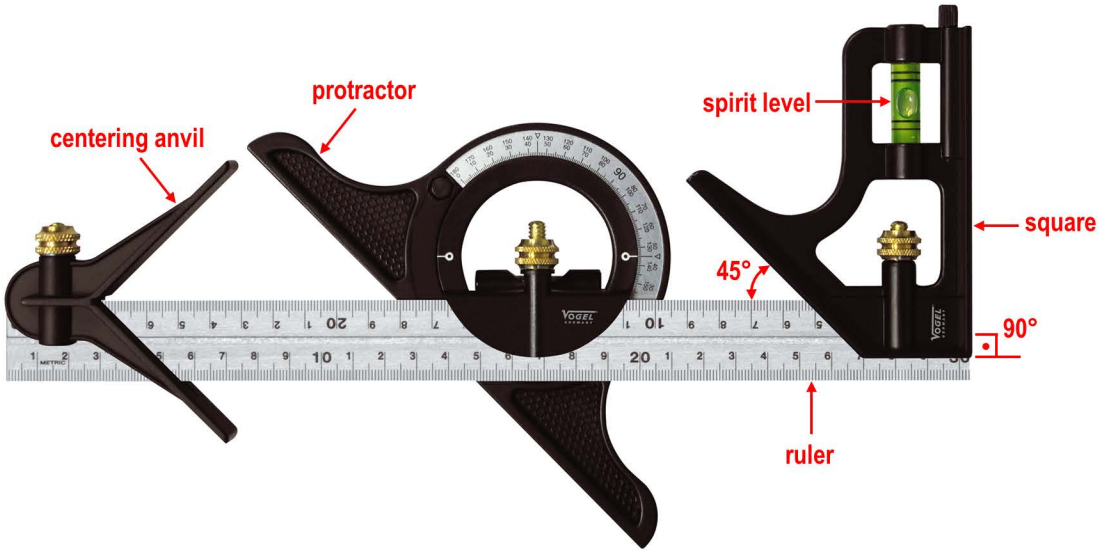
**A** ⟶ The highest figure: **45 unit** * (main div.) = **45°**

**FINAL READING: 45°**

## Special-Purpose Graduated Tools
## (Measurement & Inspection)


Magnetic Spirit Level (Analog)


Magnetic Spirit Level (Digital)



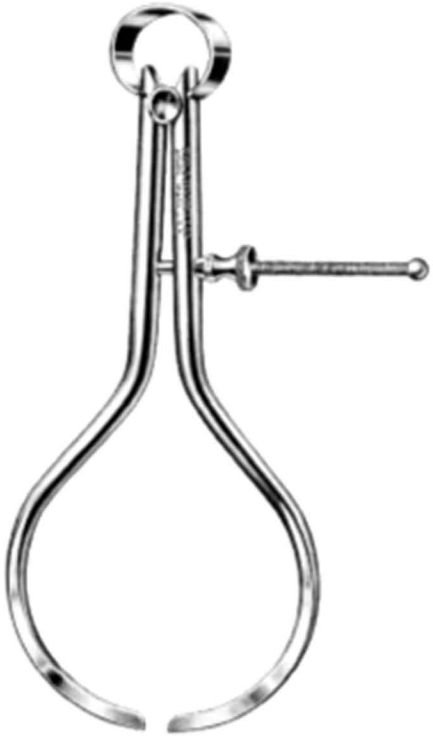

Combination Set (Protractor, Spirit Level, Square, Ruler, V-Anvil)


Dial Test Indicator with Magnetic Stand

## Non-Graduated Linear Measurements: Calipers

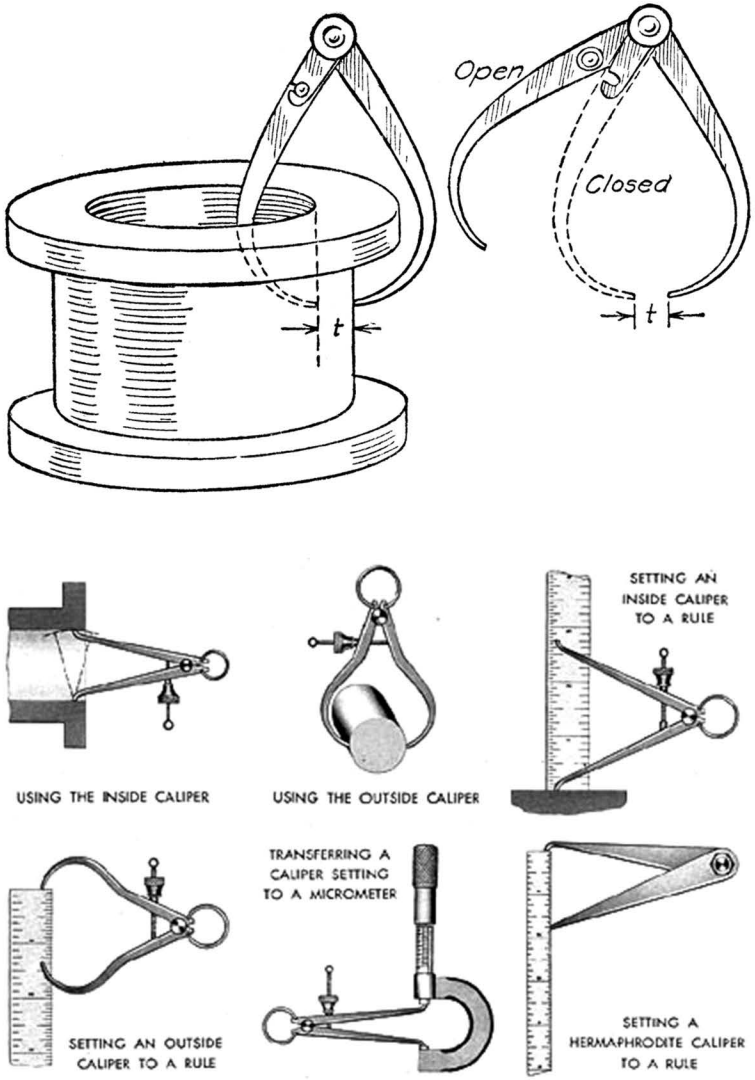
- Having **fine adjustment screw** and **quick-adjusting spring nut**.
- The measurement is **transferred to a graduated measuring tool**.
- **Accuracy of measurement** depends on the inherent skill of users.

Caliper for internal measurements



Caliper for external measurements

Caliper used as divider

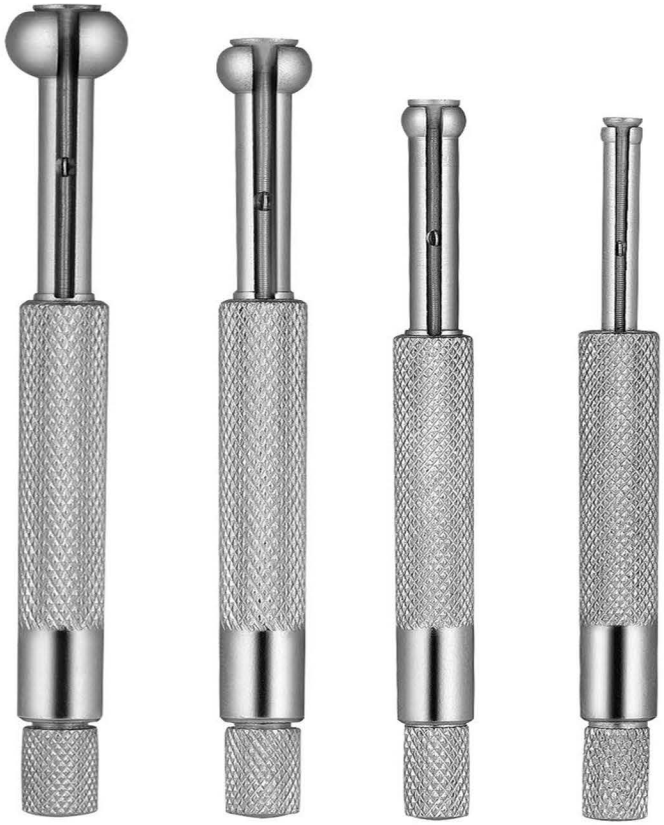



Typical Measurements

## Non-Graduated Linear Measurements:

### Small-Hole Gauges

With **an expanding ball head** adjusted to size **by a knurled knob** to provide accurate "feel" for checking small holes & slots.



## Non-Graduated Linear Measurements:

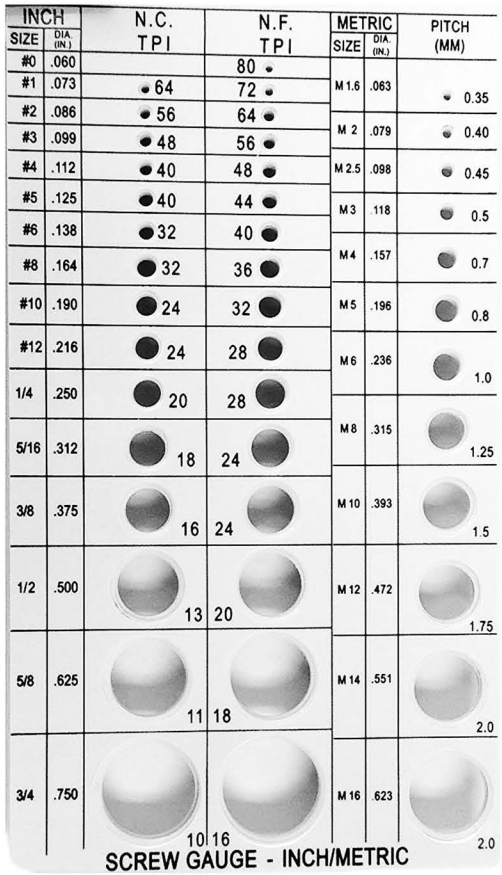
### Telescopic Gauges

Consist of **an expanding head with two plunger-contacts** locked simultaneously for checking dimensions of grooves & slots.

## Non-Graduated Linear Measurements:

## Gauges (Tap, Drill, Screw)

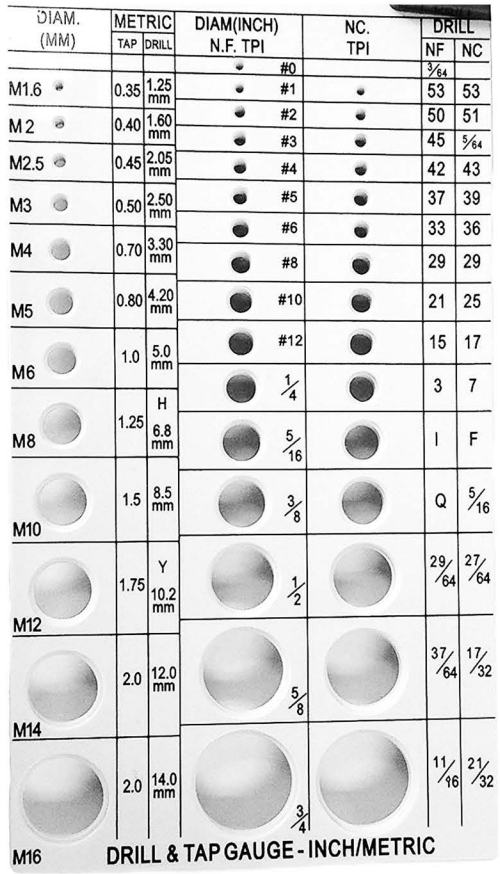
Flat rectangular steel plate (double-sided) with **holes according to sizes (drill, tap, screw)**.



| INCH SIZE | DIA (IN.) | N.C. TPI | N.F. TPI |
|---|---|---|---|
| #0 | .060 | | 80 |
| #1 | .073 | 64 | 72 |
| #2 | .086 | 56 | 64 |
| #3 | .099 | 48 | 56 |
| #4 | .112 | 40 | 48 |
| #5 | .125 | 40 | 44 |
| #6 | .138 | 32 | 40 |
| #8 | .164 | 32 | 36 |
| #10 | .190 | 24 | 32 |
| #12 | .216 | 24 | 28 |
| 1/4 | .250 | 20 | 28 |
| 5/16 | .312 | 18 | 24 |
| 3/8 | .375 | 16 | 24 |
| 1/2 | .500 | 13 | 20 |
| 5/8 | .625 | 11 | 18 |
| 3/4 | .750 | 10 | 16 |

| METRIC SIZE | DIA. (IN.) | PITCH (MM) |
|---|---|---|
| M1.6 | .063 | 0.35 |
| M2 | .079 | 0.40 |
| M2.5 | .098 | 0.45 |
| M3 | .118 | 0.5 |
| M4 | .157 | 0.7 |
| M5 | .196 | 0.8 |
| M6 | .236 | 1.0 |
| M8 | .315 | 1.25 |
| M10 | .393 | 1.5 |
| M12 | .472 | 1.75 |
| M14 | .551 | 2.0 |
| M16 | .623 | 2.0 |

SCREW GAUGE - INCH/METRIC



| DIAM. (MM) | METRIC TAP | METRIC DRILL |
|---|---|---|
| M1.6 | 0.35 | 1.25 mm |
| M2 | 0.40 | 1.60 mm |
| M2.5 | 0.45 | 2.05 mm |
| M3 | 0.50 | 2.50 mm |
| M4 | 0.70 | 3.30 mm |
| M5 | 0.80 | 4.20 mm |
| M6 | 1.0 | 5.0 mm |
| M8 | 1.25 | H 6.8 mm |
| M10 | 1.5 | 8.5 mm |
| M12 | 1.75 | Y 10.2 mm |
| M14 | 2.0 | 12.0 mm |
| M16 | 2.0 | 14.0 mm |

| DIAM(INCH) N.F. TPI | NC. TPI | DRILL NF | DRILL NC |
|---|---|---|---|
| #0 | | 3/64 | |
| #1 | | 53 | 53 |
| #2 | | 50 | 51 |
| #3 | | 45 | 5/64 |
| #4 | | 42 | 43 |
| #5 | | 37 | 39 |
| #6 | | 33 | 36 |
| #8 | | 29 | 29 |
| #10 | | 21 | 25 |
| #12 | | 15 | 17 |
| 1/4 | | 3 | 7 |
| 5/16 | | I | F |
| 3/8 | | Q | 5/16 |
| 1/2 | | 29/64 | 27/64 |
| 5/8 | | 37/64 | 17/32 |
| 3/4 | | 11/16 | 21/32 |

DRILL & TAP GAUGE - INCH/METRIC

## Non-Graduated Linear Measurements:

## Screw Pitch Gauges

A metal case consisting of leaves with teeth corresponding to definite pitch **for matching the teeth with the thread on work**.

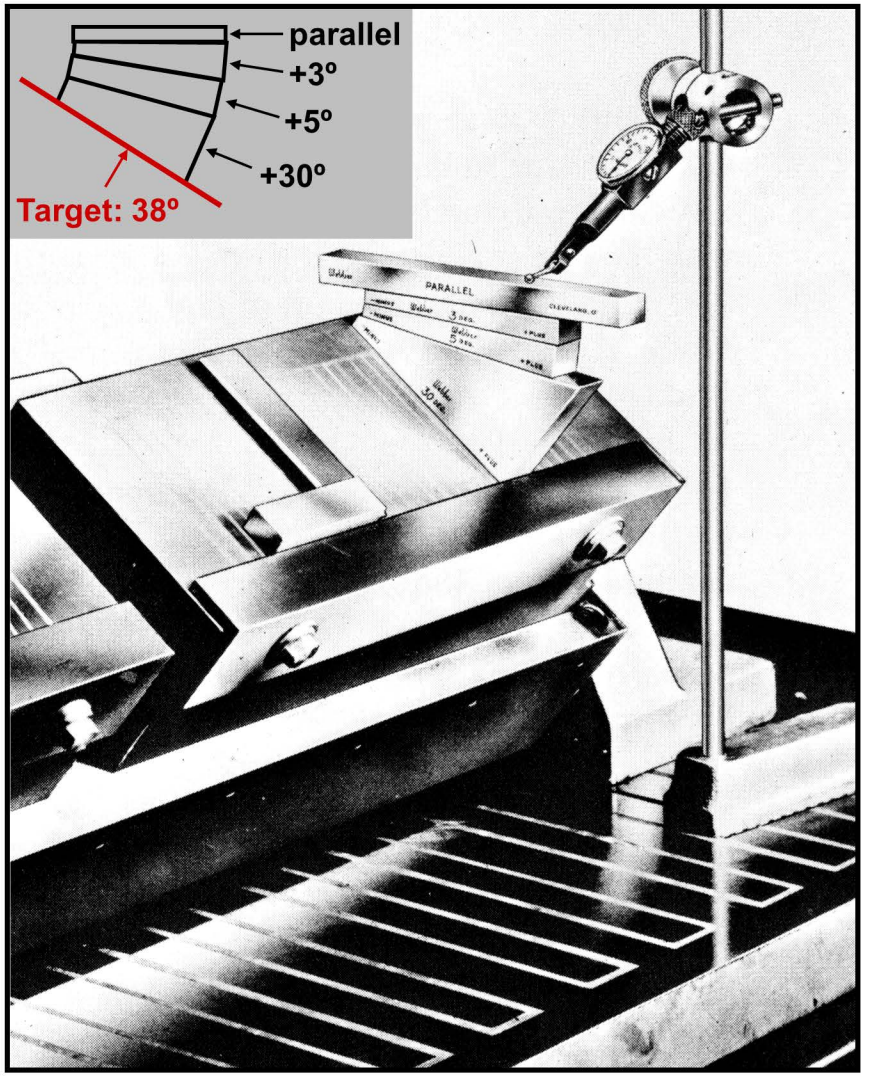

## Non-Graduated Linear Measurements:

## Radius Gauges

A metal case consisting of leaves with radius **for checking convex/concave radii**.

## Non-Graduated Linear Measurements:
## Rectangle Gauge Blocks

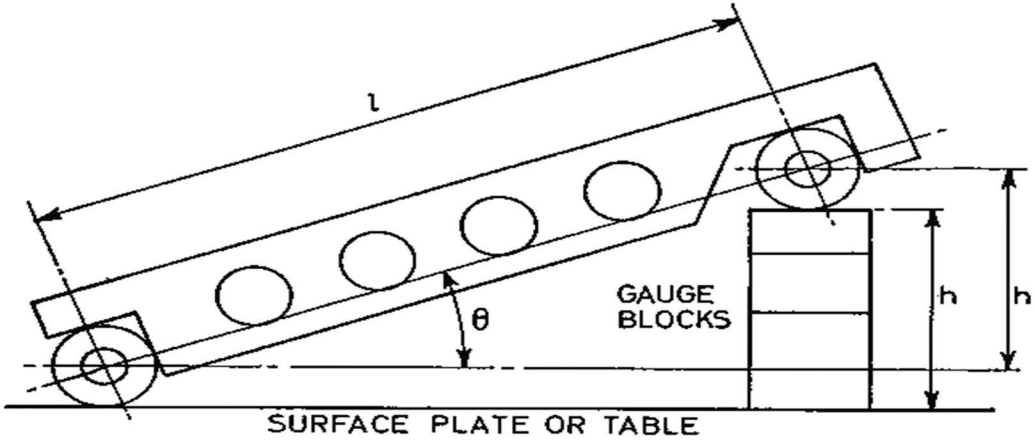

## Non-Graduated Angular Measurements:
## Angle Gauge Blocks


Setting of a revolving magnetic chuck using angle gauge blocks

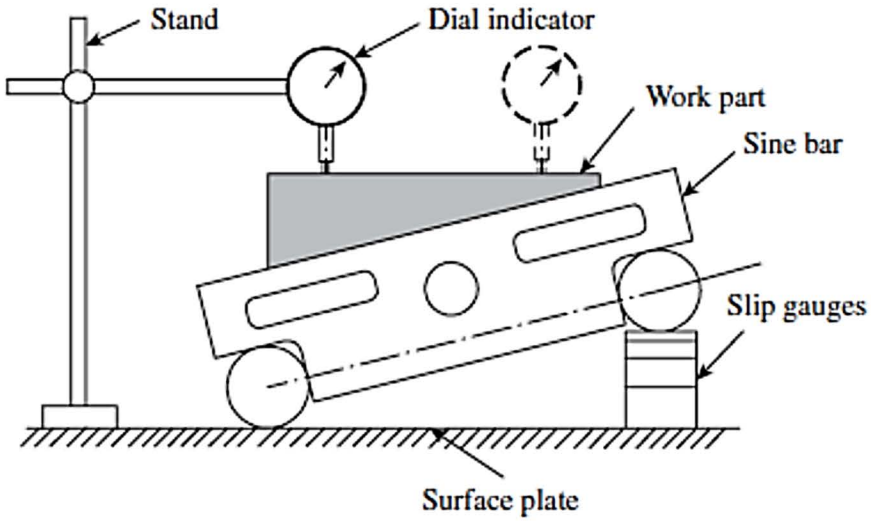
## Non-Graduated Angular Measurements: Sine Bar

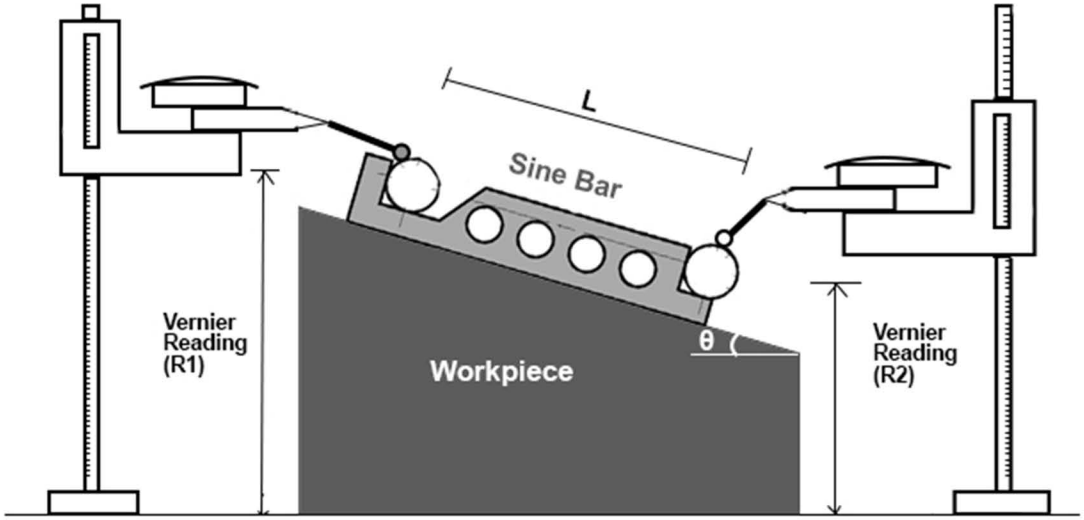





### How to use Sine Bar:

- Suppose that we want to set **the angle of 14º 12′** using **10 mm sine bar**.
- This means that: **L = 10 mm** and **θ = 14.2º**
- The required height: **H = L * sinθ ≈ 2.453 mm**
- So, **the combination of gauge blocks** providing this height must be used to set such angle.




**Measuring the angle (small part)**

$$\sin\theta = H / L$$

**Measuring the angle (large part)**

$$\sin\theta = (H_1 - H_2) / L$$

## Limitations of Sine Bar:

- The setting of height obtained by the sine bar is **limited by available divisions of gauge blocks**. This causes errors that may be negligible or quite significant in some cases.
- Due to nature trigonometry; **at larger angles, it is susceptible to errors in the length of sine bar** as well as the corresponding height to be set by gauge blocks.