Lec 2: Metrology

1) Manufacturing and measurement
2) Metrology
3) Effect of manufacturing process
4) Measuring instruments
5) Advanced measuring instruments
6) Use of caliper, micrometer, indicator, profile projector, coordinate measure system…

1) Manufacturing & measurement

- Why
  - *To assure of product quality*
  - *To improve productivity*
- Units
  - *metric (SI)*
  - *"standard" (US customary)*
- Types
  - *Contact: mechanical principle, eg.:*
  - *Non-contact: physical principle, eg.:*
- What
  - *dimension*
  - *form/shape*
  - *surface*
- How
  - *100% inspection*
  - *Statistical Quality Control*

2.1 Dimension

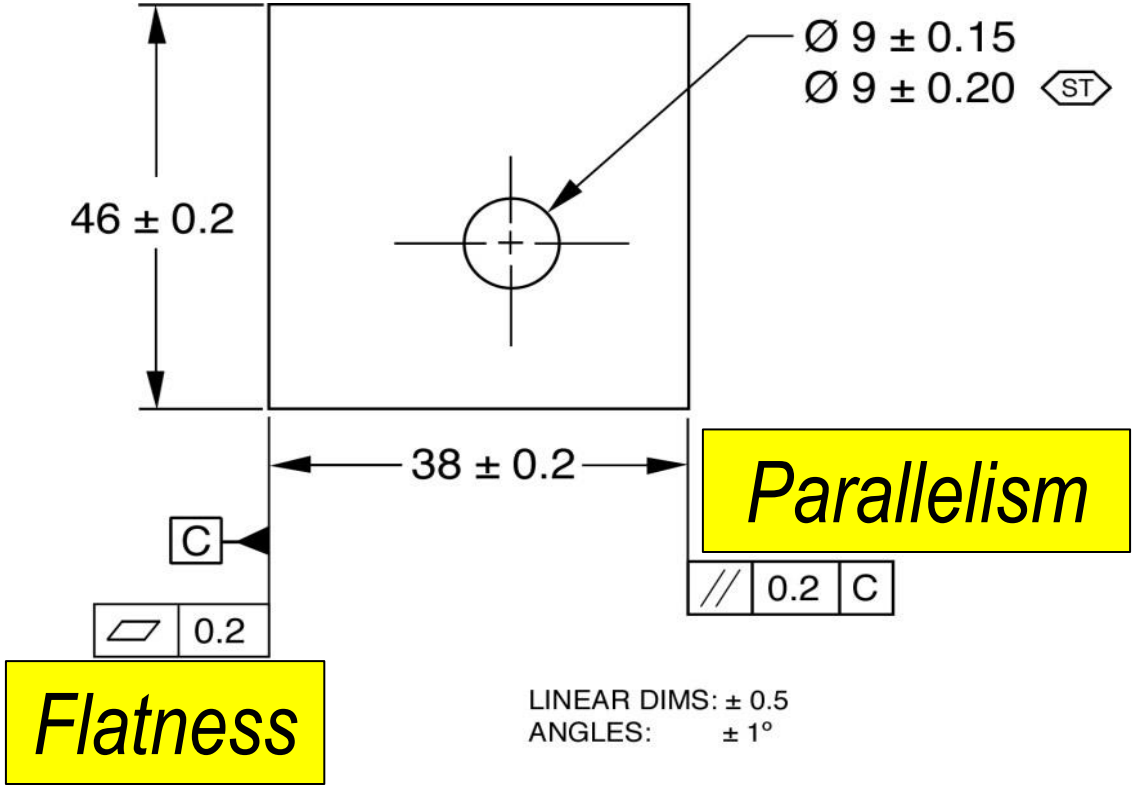
- *Design dimension*: expected dimension
- *Tolerance*: allowable deviation from design dimension
- *Accuracy*: deviation from design dimension
- *Precision*: repeatability of measured data
- *Calibration*: process to correct an instrument
- *Resolution*: smallest measurable quantity

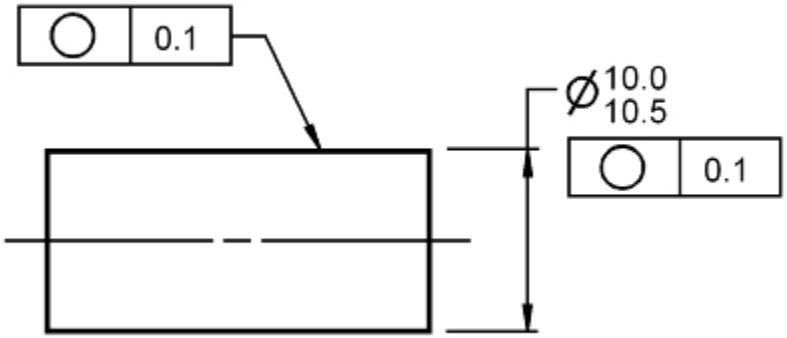
Metrology equipment resolution

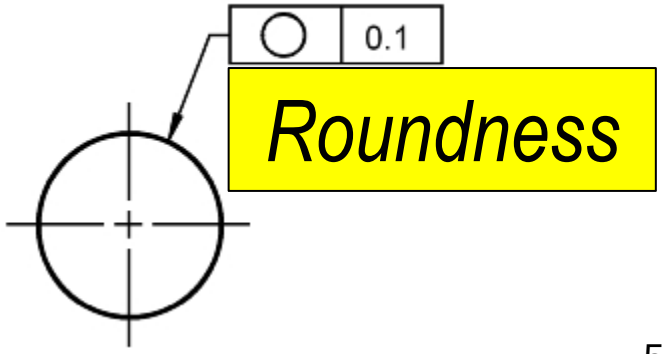
- *Digital: the smallest increment*

- *Analog: half of the smallest graduation values*

2.2 Form & shape





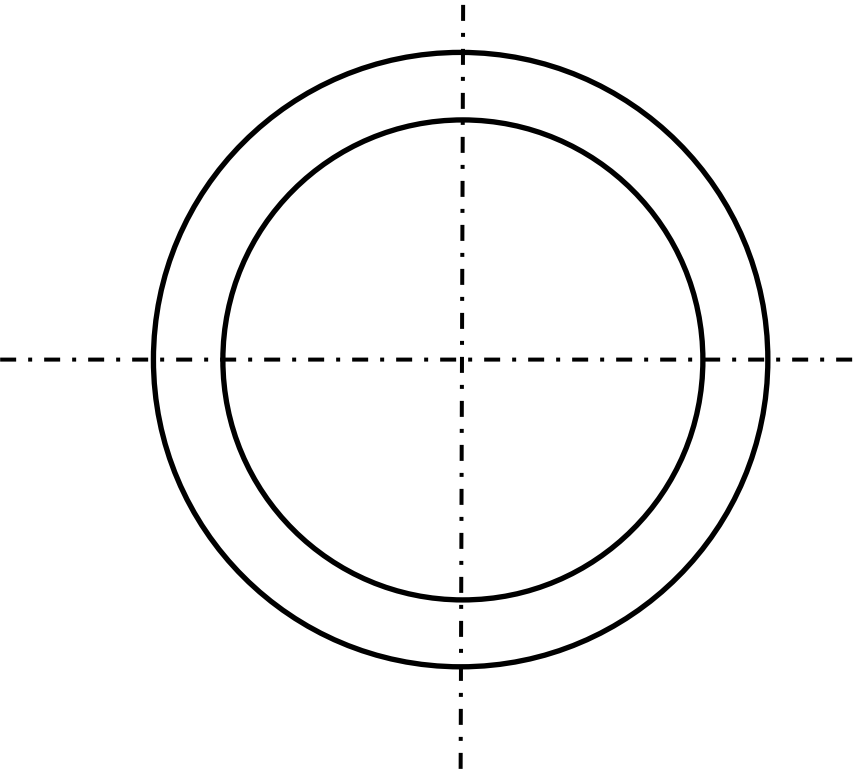


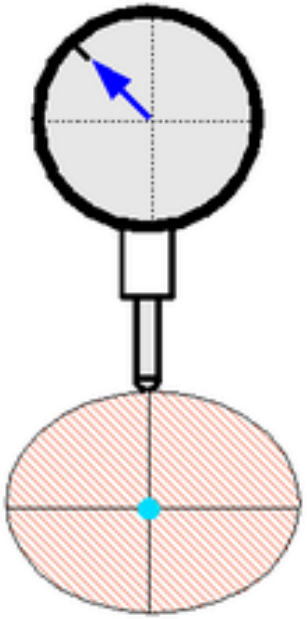
2.2. Measure form & shape

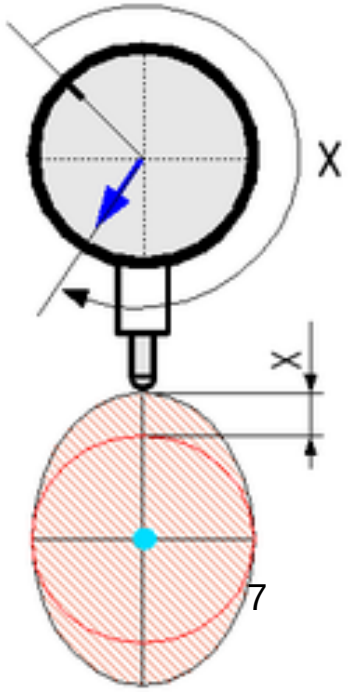
Feature	Symbol	Description
Angularity		Tolerance zone of all surfaces/axes from an ideal plane positioning at an angle to the reference.
Conicity (conical taper)		Extension of angularity for 3D part
Circularity (roundness)		2D tolerance zone of profiles deviated from an ideal circle.
Sphericity		Extension of roundness for 3D part
Concentricity		Tolerance zone of a centerline from a reference axis
Cylindricity		Total circularity along an axis
Flatness (planarity)		Tolerance zone of all points from an ideal plane
Parallelism		Tolerance zone from a plane that is at an equal distance to the reference plane
Perpendicularity (squareness)		angularity at 90°
Straightness		Tolerance zone of all points deviated from an ideal line
Line profile		2D tolerance zone of all lines/curves deviated from an ideal profile.
Surface profile		3D tolerance zone of all surfaces deviated from an ideal surface.
Circular run-out		Tolerance zone of points (run-out) about a rotating axis
Total run-out		Tolerance zone of surfaces (total run-out) about a rotating axis
Symmetry		Tolerance zone within which all median points of a feature must lie. The zone is symmetric about a datum axis
Positional tolerance		Zone within which the point (such as hole center) must be located

Form & shape

Roundness of a “round surface”



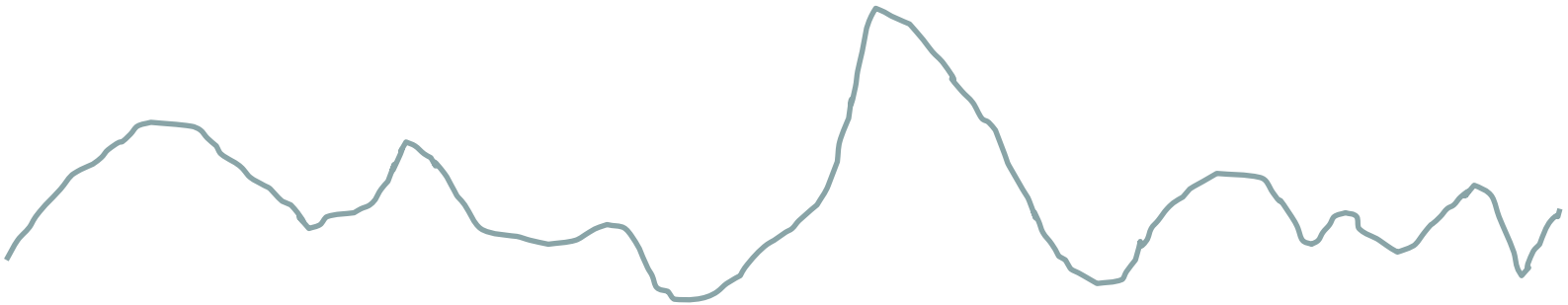




fr.wikipedia.org

2.3 Surface

Surface roughness / finish

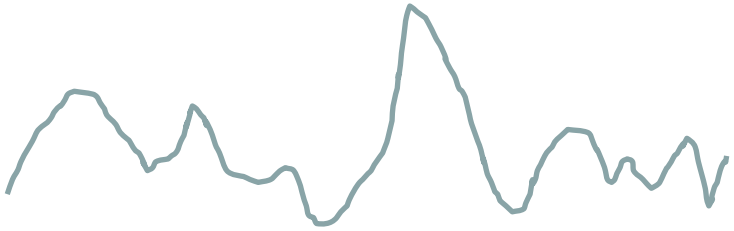


$$R_a = \frac{|y_1| + |y_2| + \cdots + |y_n|}{n}$$

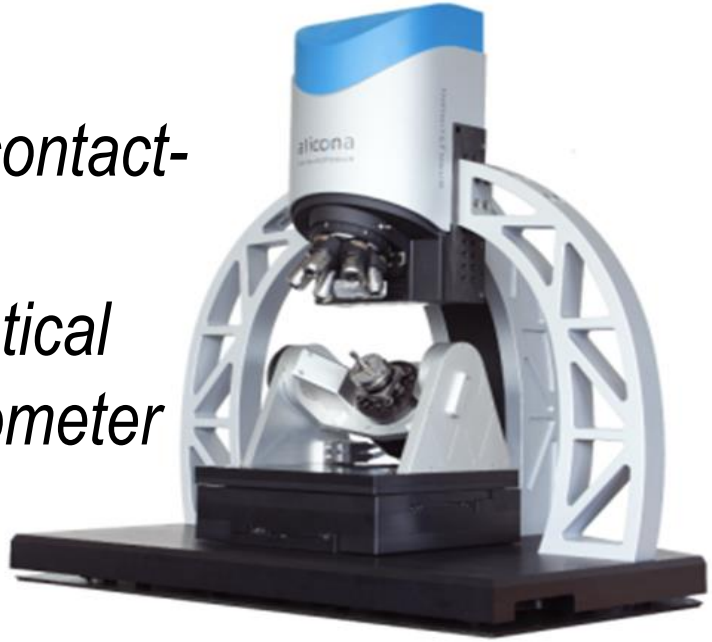
Other measurement of roughness: R_t, R_q, R_z, R_p, R_v…

2.3 Surface

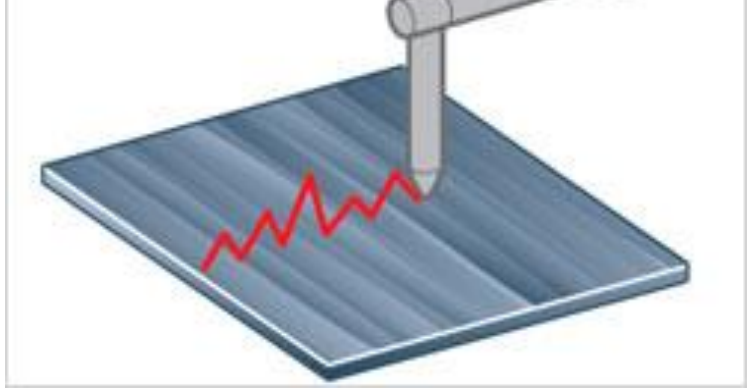
Instrument for surface roughness measurement



[www.alicona.com]

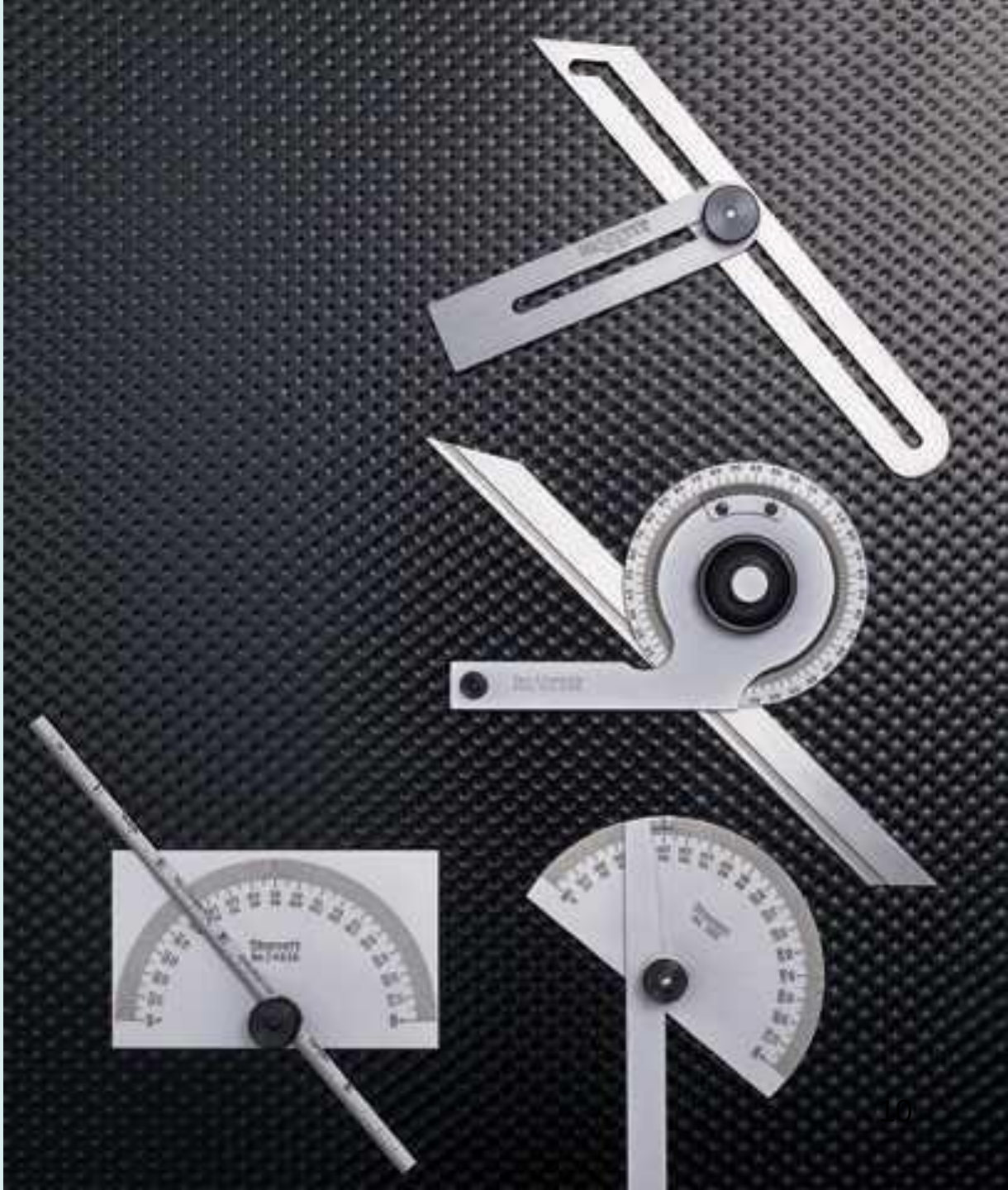


Non-contact-type 3D optical profilometer



Contact-type profilometer

Contact type: protractor



Source:
http://www.starrett.com/

Contact type: caliper

Dial caliper

Vernier caliper

Source: http://www.starrett.com/

Contact type: height gage

Source: http://www.starrett.com/

Contact type: indicator

Source: http://www.starrett.com/

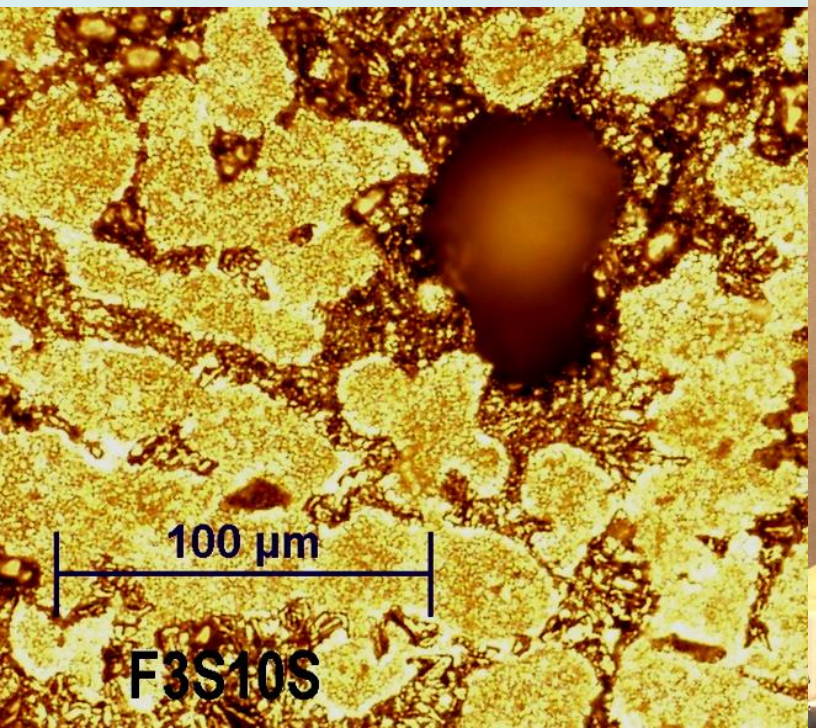
Contact type: micrometer

Source: http://www.starrett.com/

Non-contact type: optical comparator (profile projector)

Source: http://mitutoyo.com

Non-contact type: measuring microscope



Non-contact type: profile laser scanner

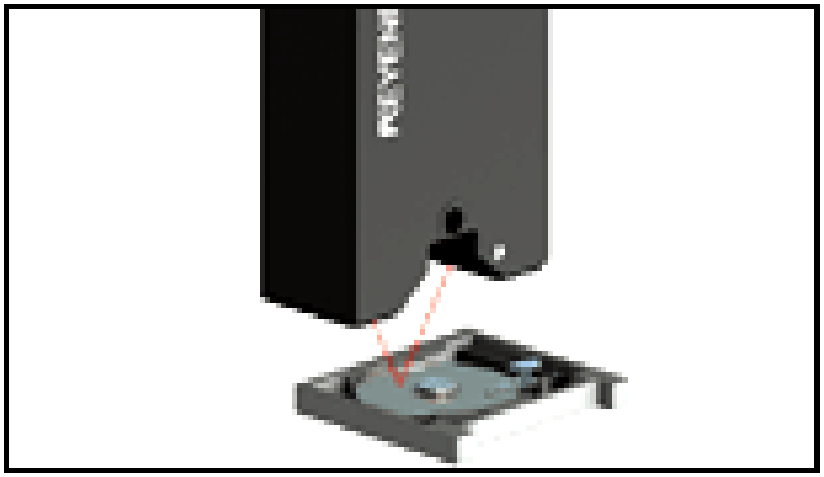
Contact type: coordinate measuring machine (CMM)

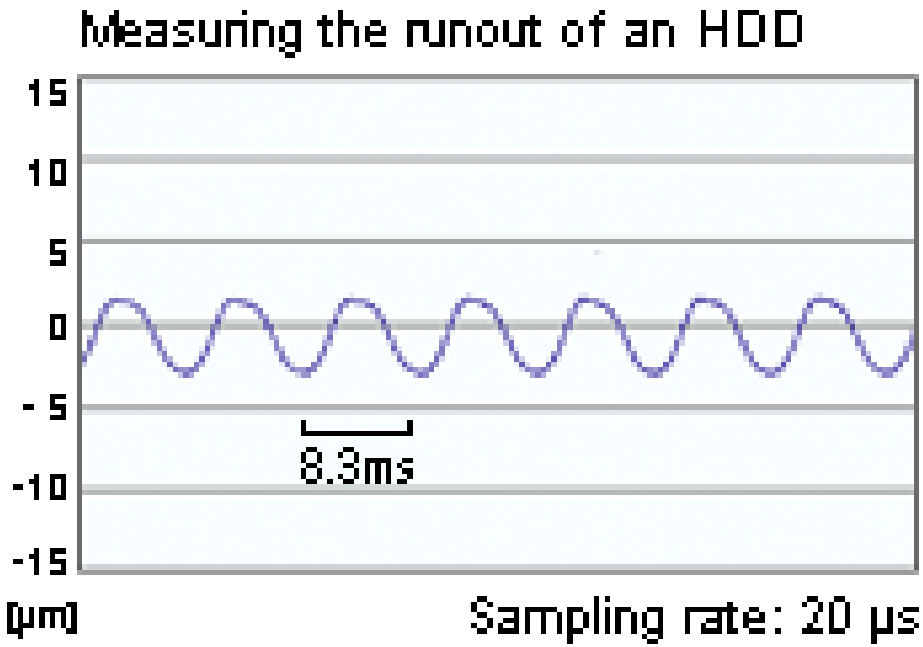
http://www.mitutoyo.com

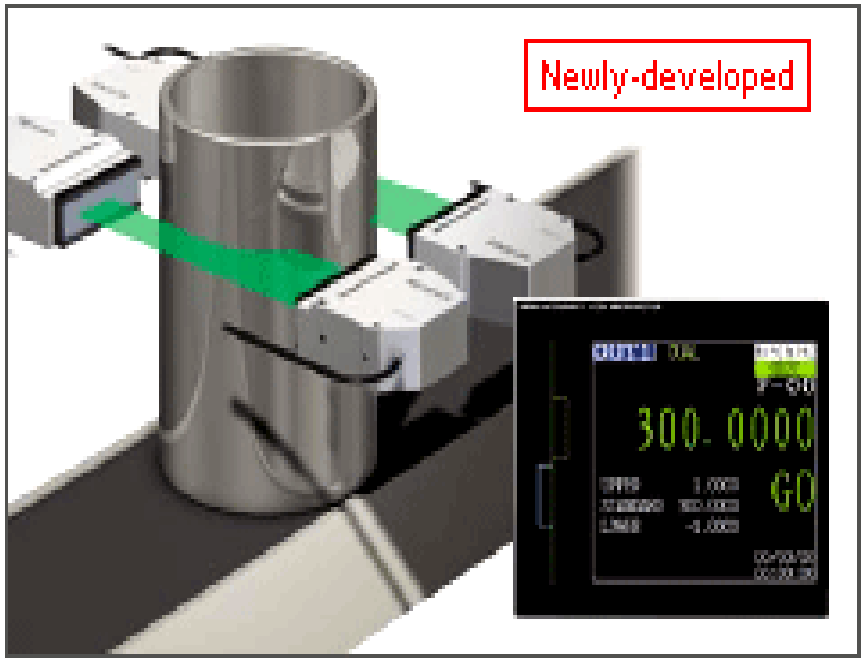
Contact type: form measurement

Source: http://www.taylor-hobson.com/

Non-contact type: laser sensor

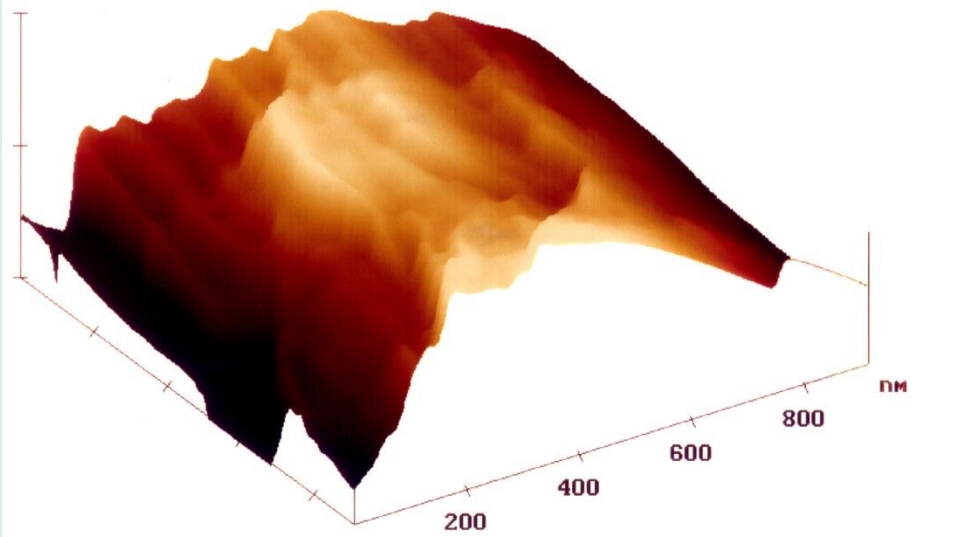


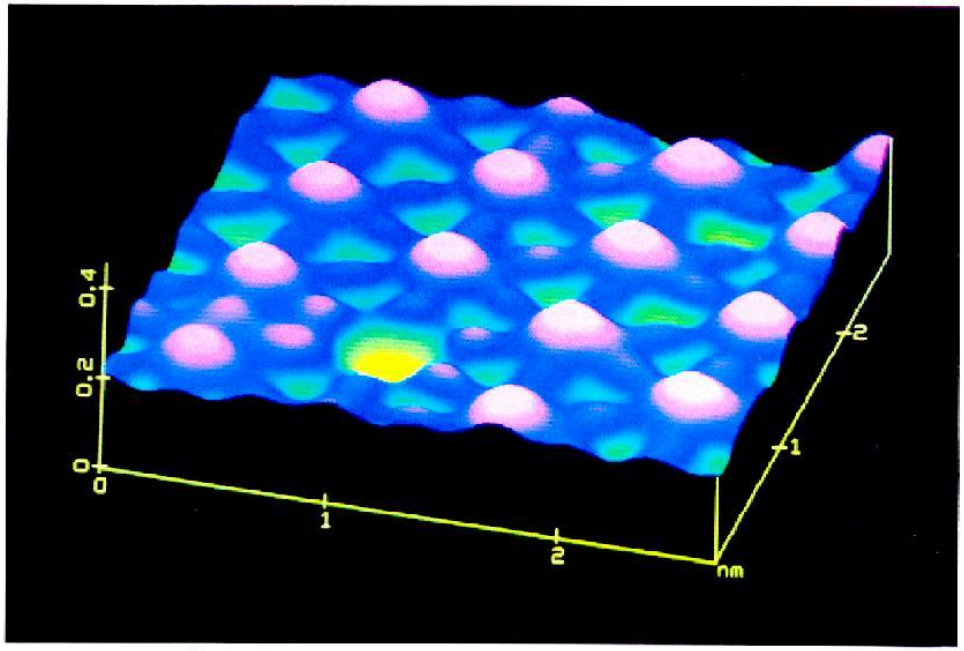




Source: www.keyence.com

Semi-contact type: Scanning probe microscopy





Iodine atoms in a 3x3 array adsorbed on platinum. Data from: Dr. Bruce Schardt, Purdue University.

Contact type: surface profile measurement (profilometer)

Source: http://www.mitutoyo.com/

Equipment

Contact type: Profilometer

[www.processinstruments.ca]

Equipment

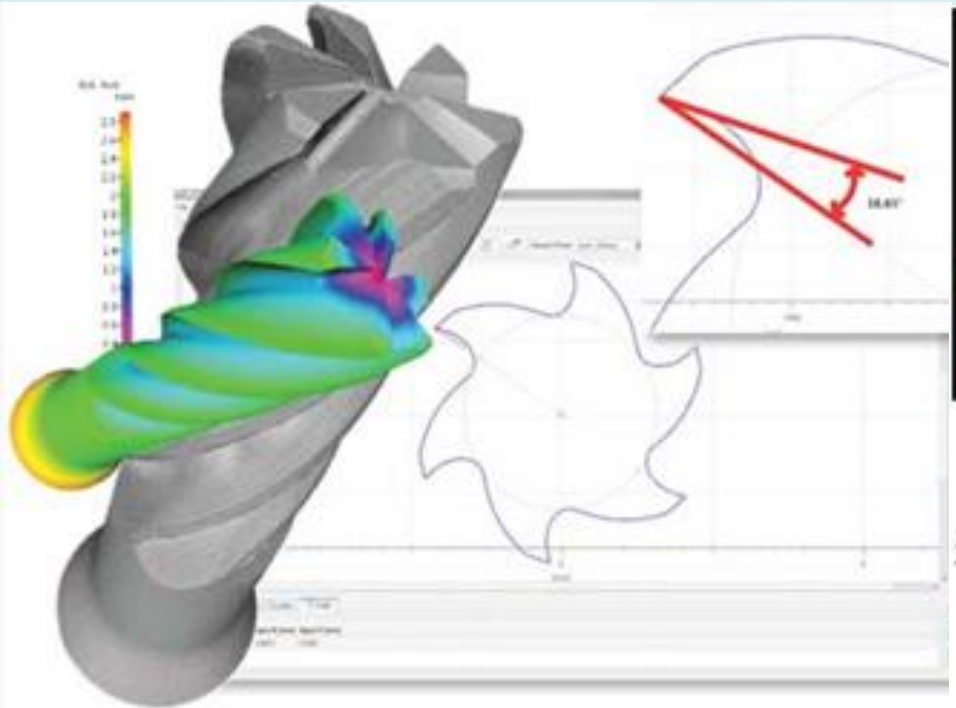
Noncontact type: interferometer

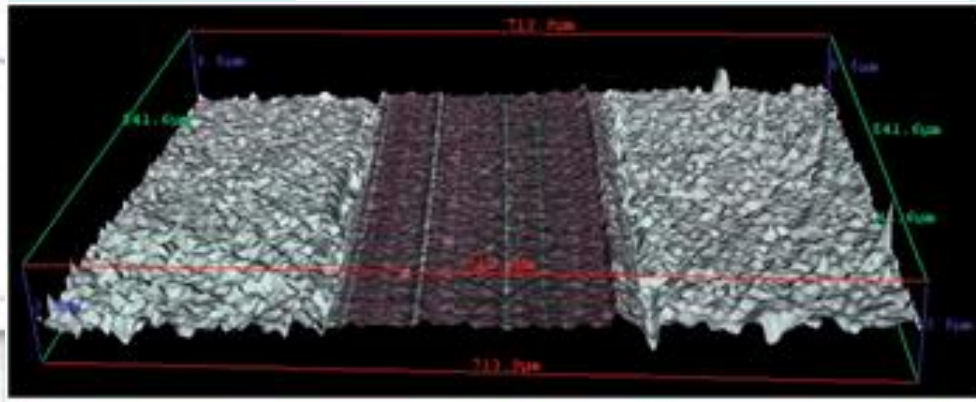
Source:
http://www.zygo.com/?/met/profilers/newview7000/

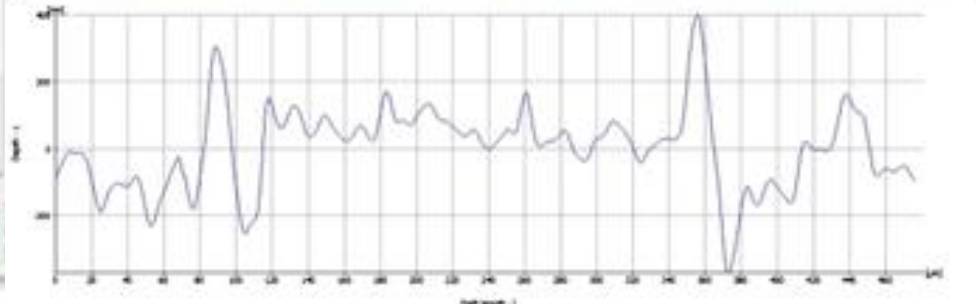
Equipment

Noncontact type: optical 3D profiler

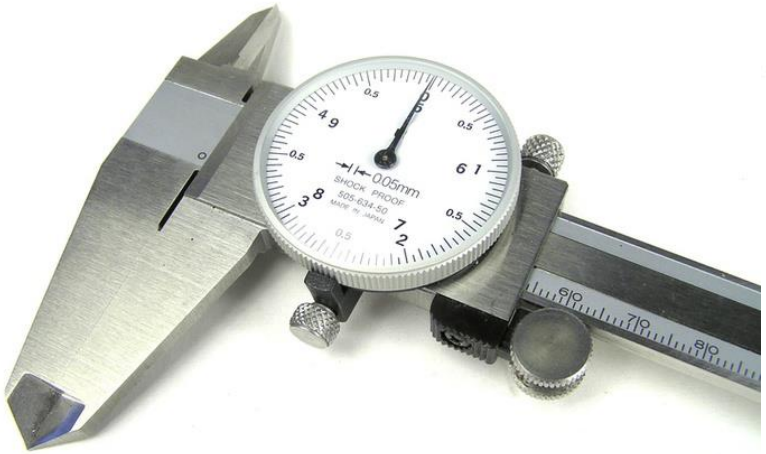
[www.alicona.com]



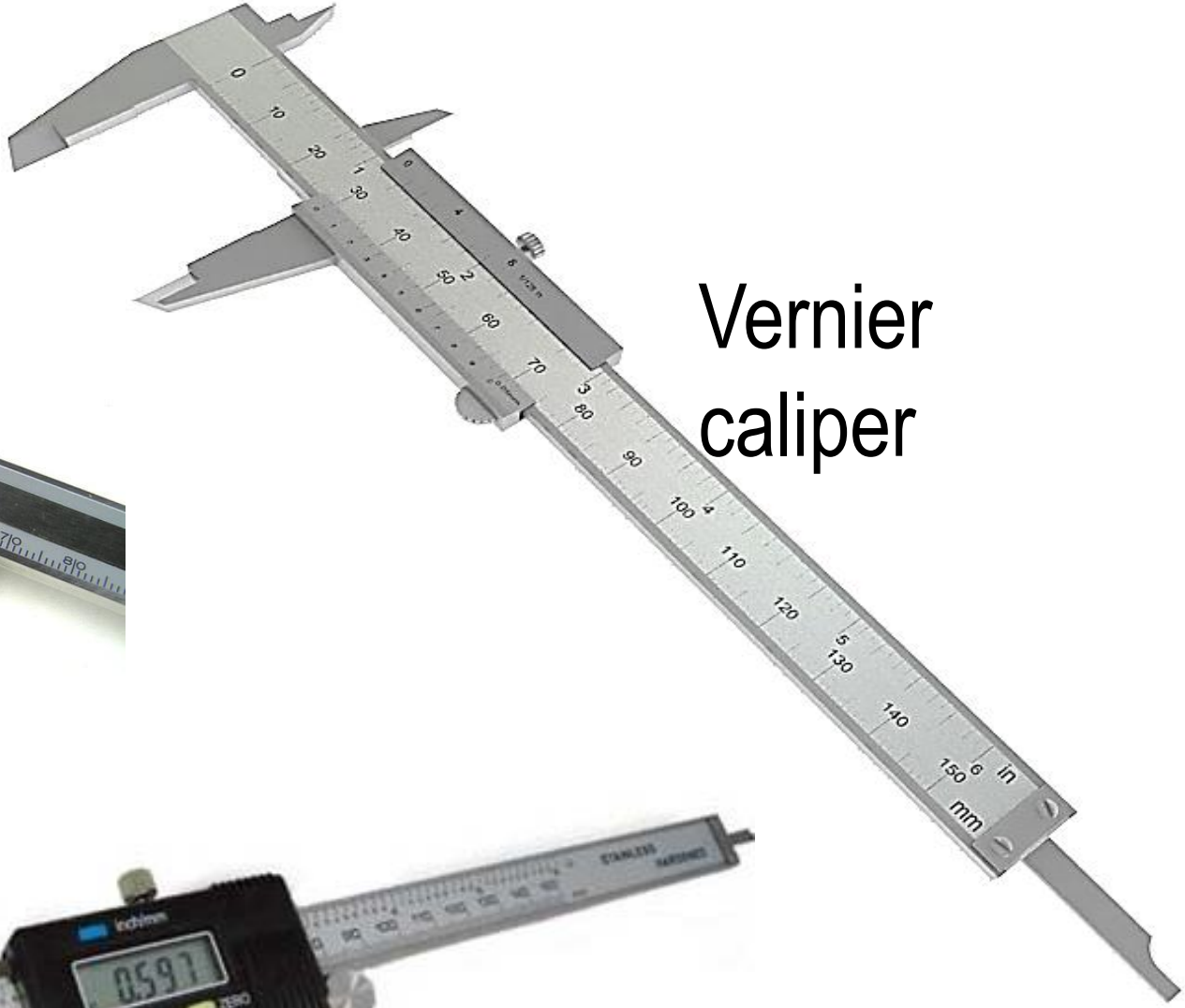




6. Caliper

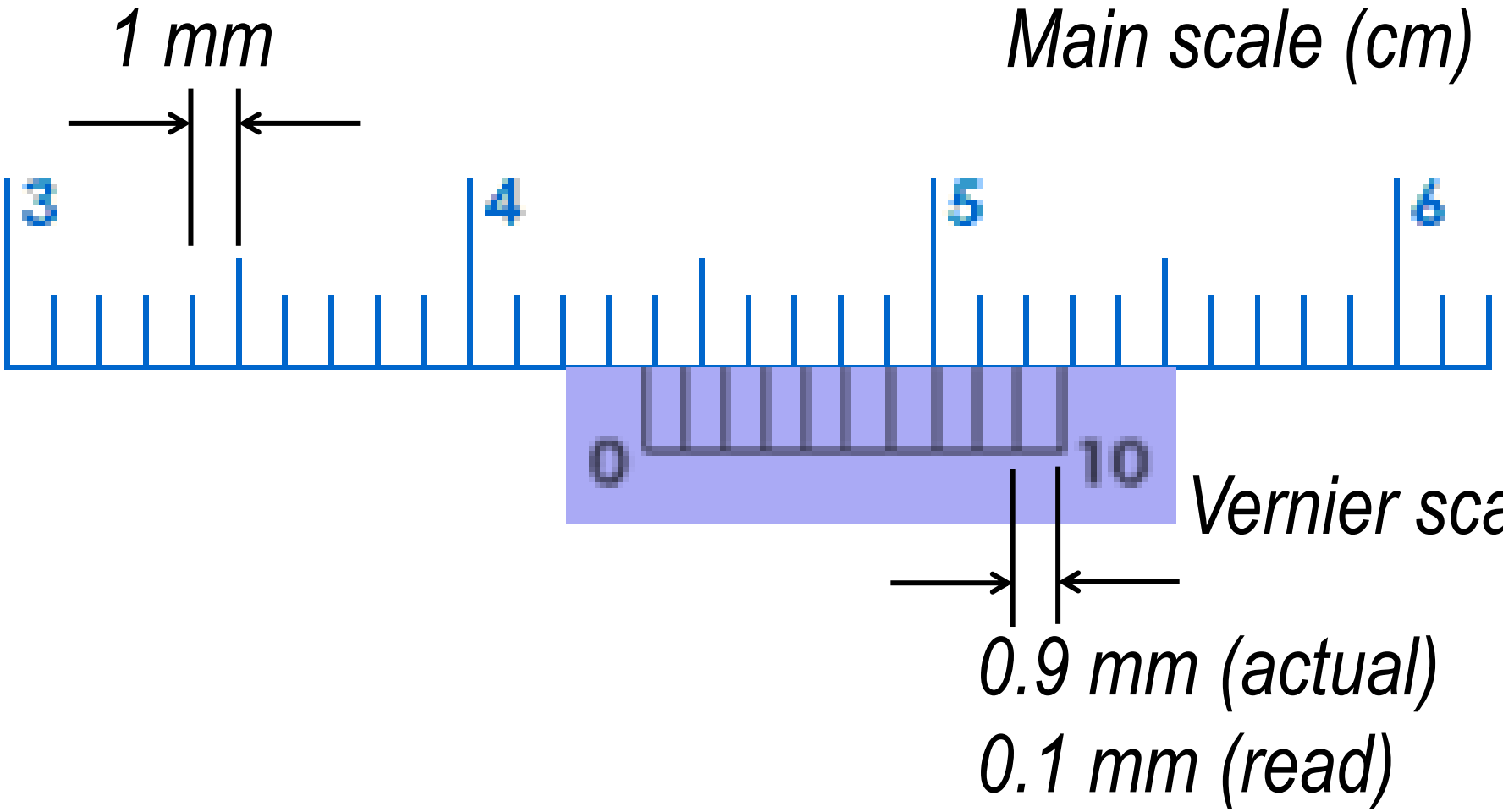


Dial caliper

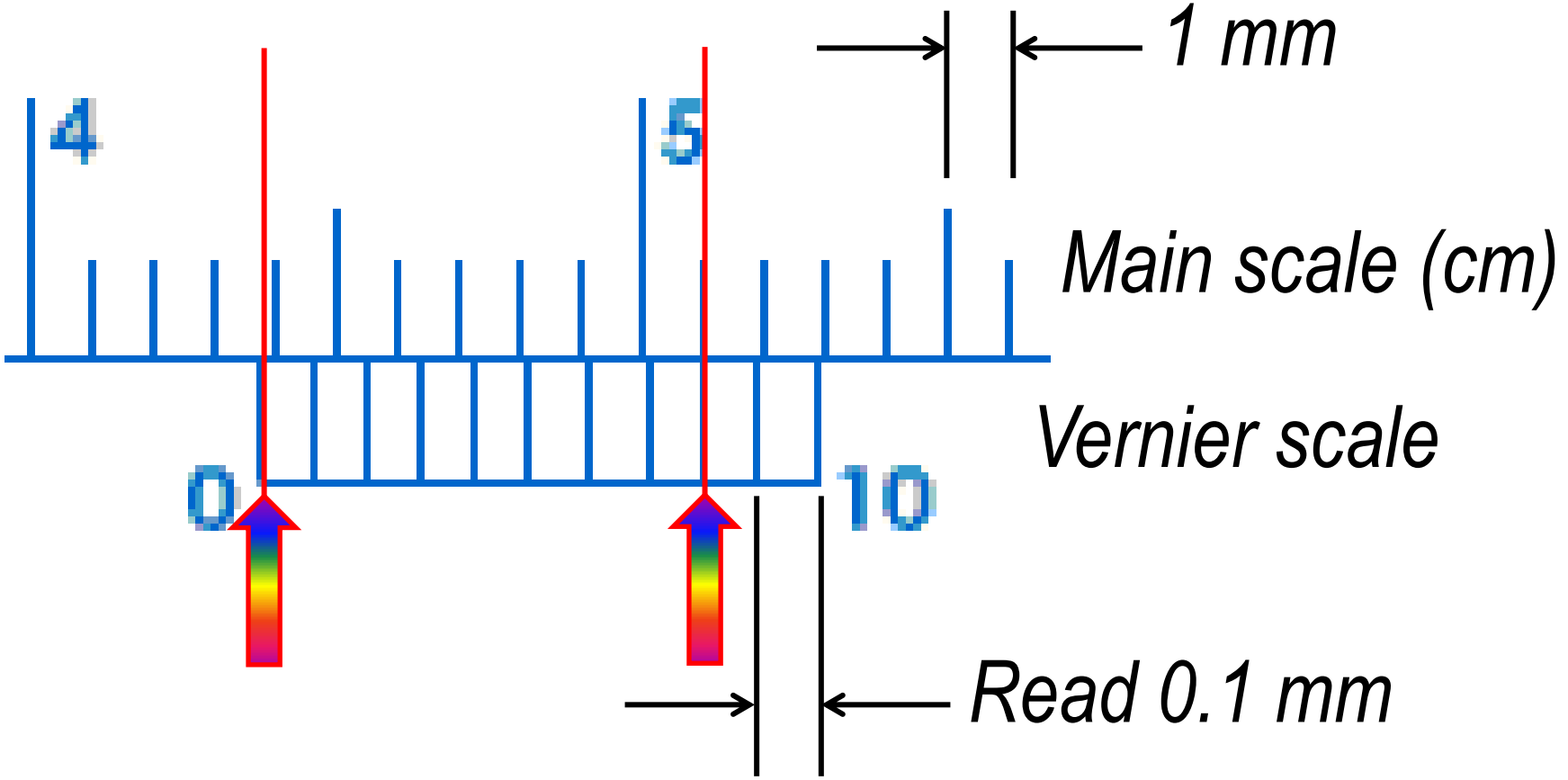


Vernier caliper

Digital caliper


1 mm
Main scale (cm)
3
4
5
6
0
10
Vernier scale
0.9 mm (actual)
0.1 mm (read)

Vernier scale reading

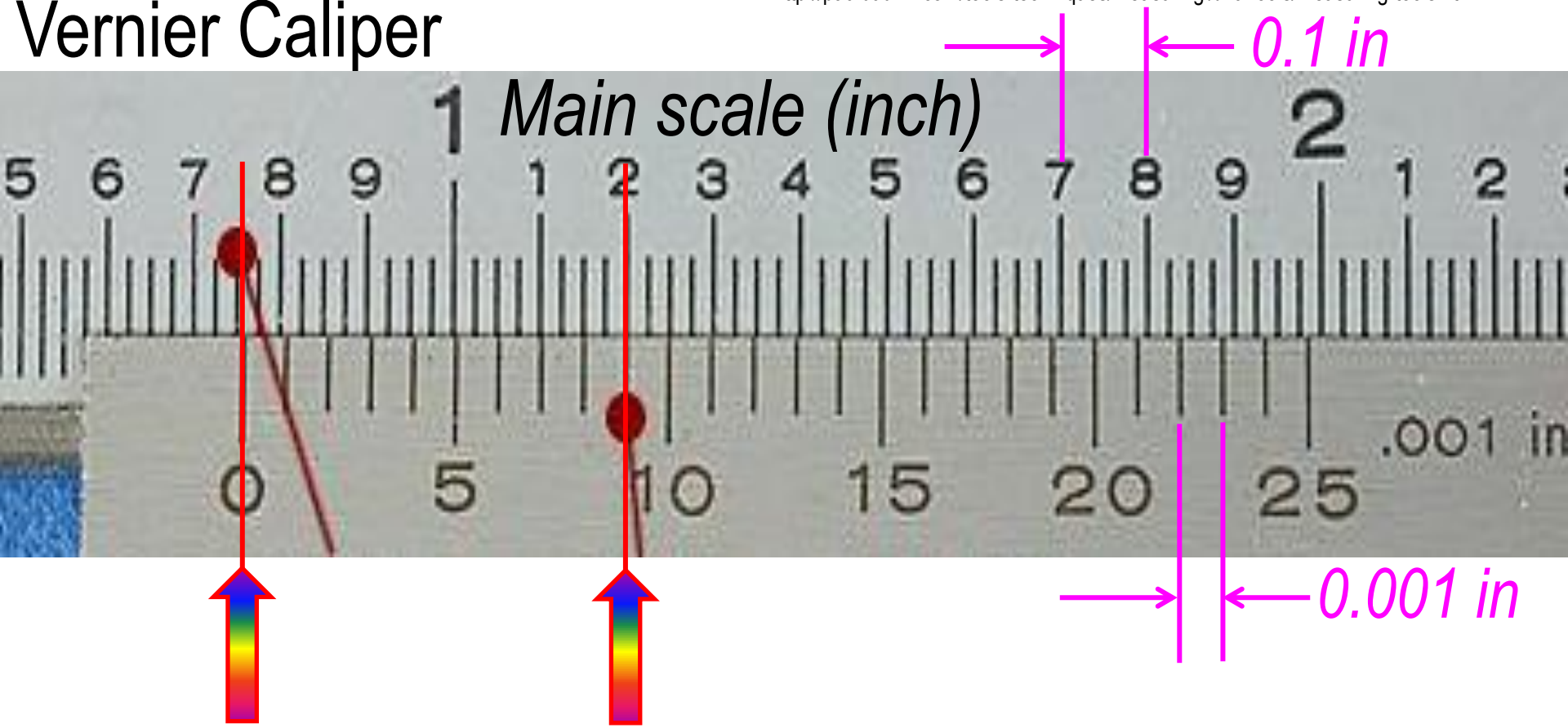


43.0 + 8(0.1) = 43.8 mm

Reading: _____ mm (1 decimal digit)

Vernier Caliper

http://paulbudzik.com/tools-techniques/Measuring%20Tools/measuring-tools.html

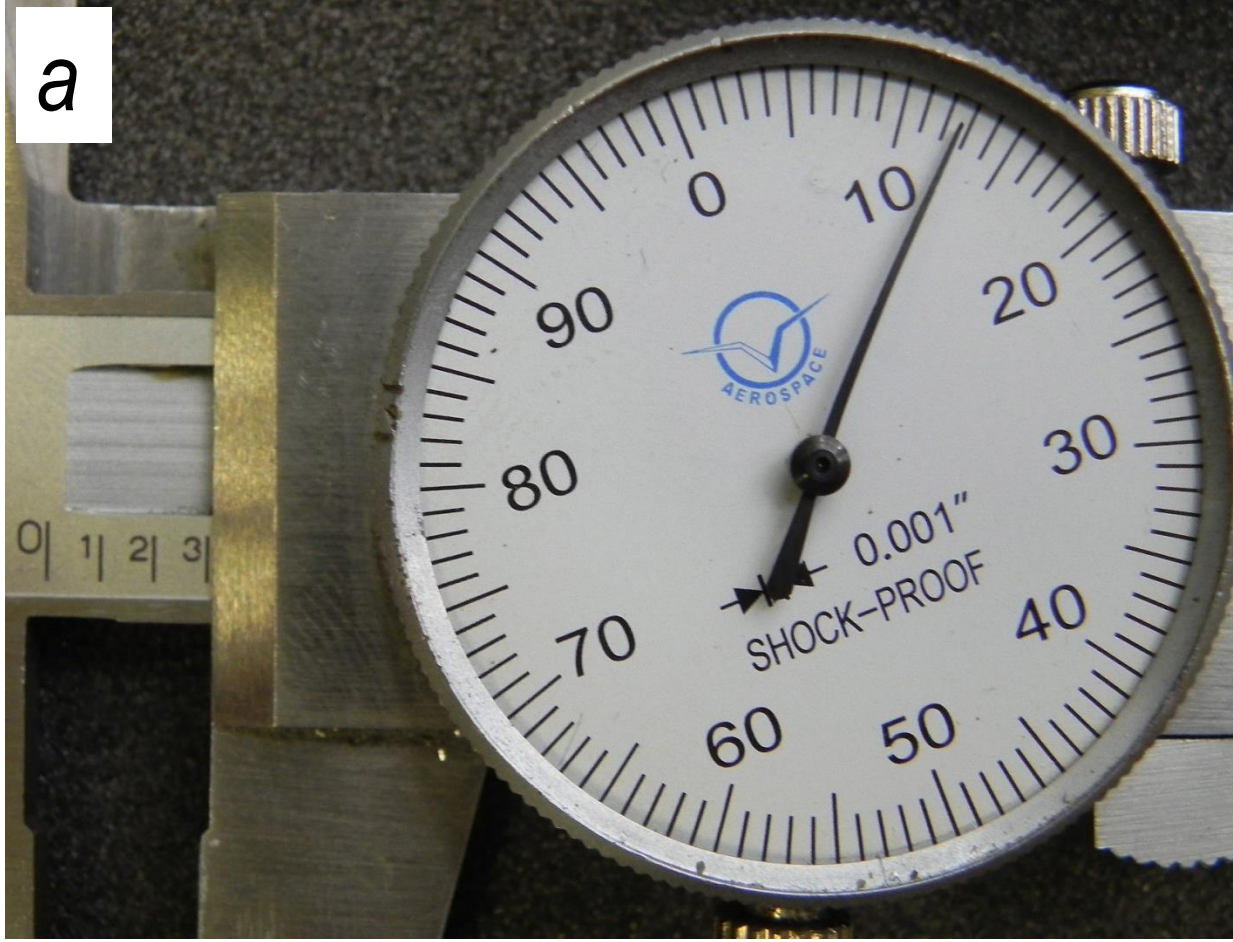


0.700 + 2(0.025) + 9(0.001) = 0.759 in

Reading: _____ in (3 decimal digits)

Dial Caliper

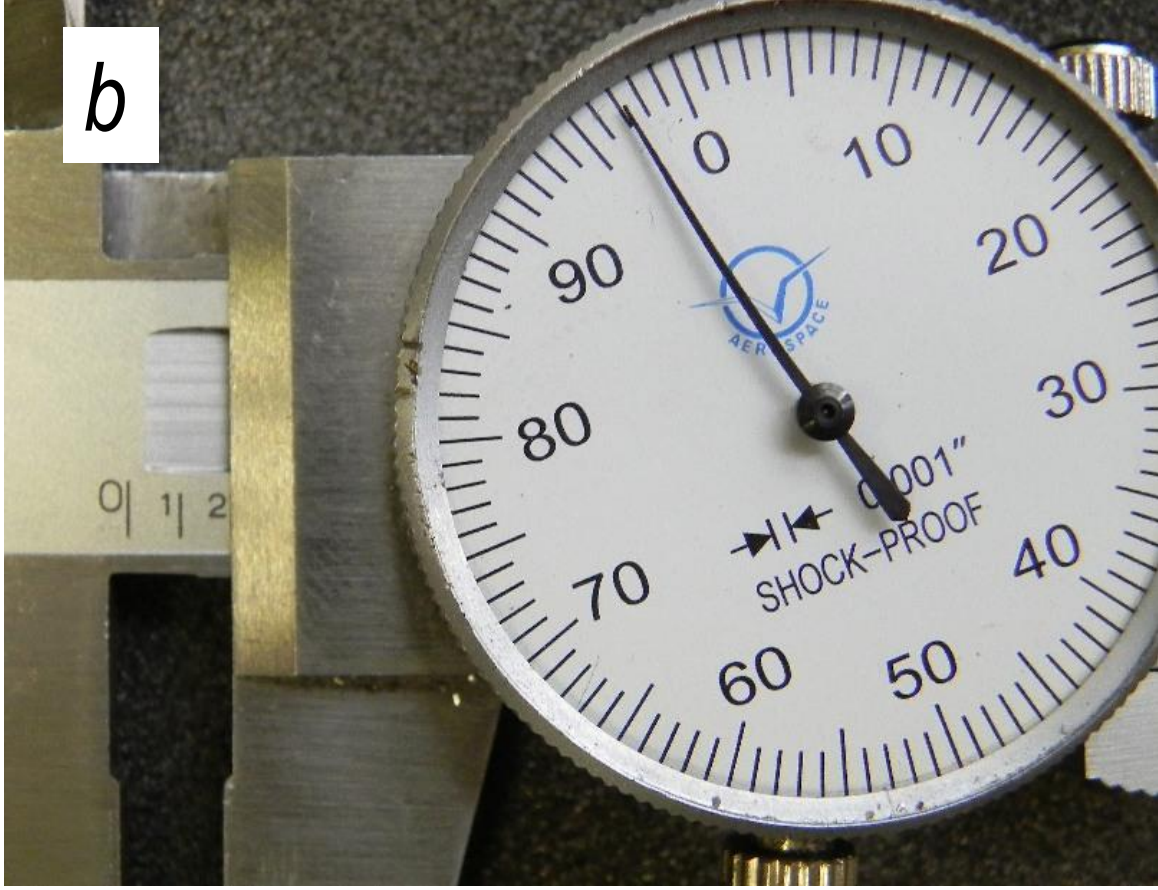
3(0.1) = 0.3000
12(0.001) = 0.0120
0.5(0.001)=0.0005



Reading: 0.3125 inch (4 decimal digits)

Dial caliper

1(0.1) = 0.1000
97(0.001) = 0.0970

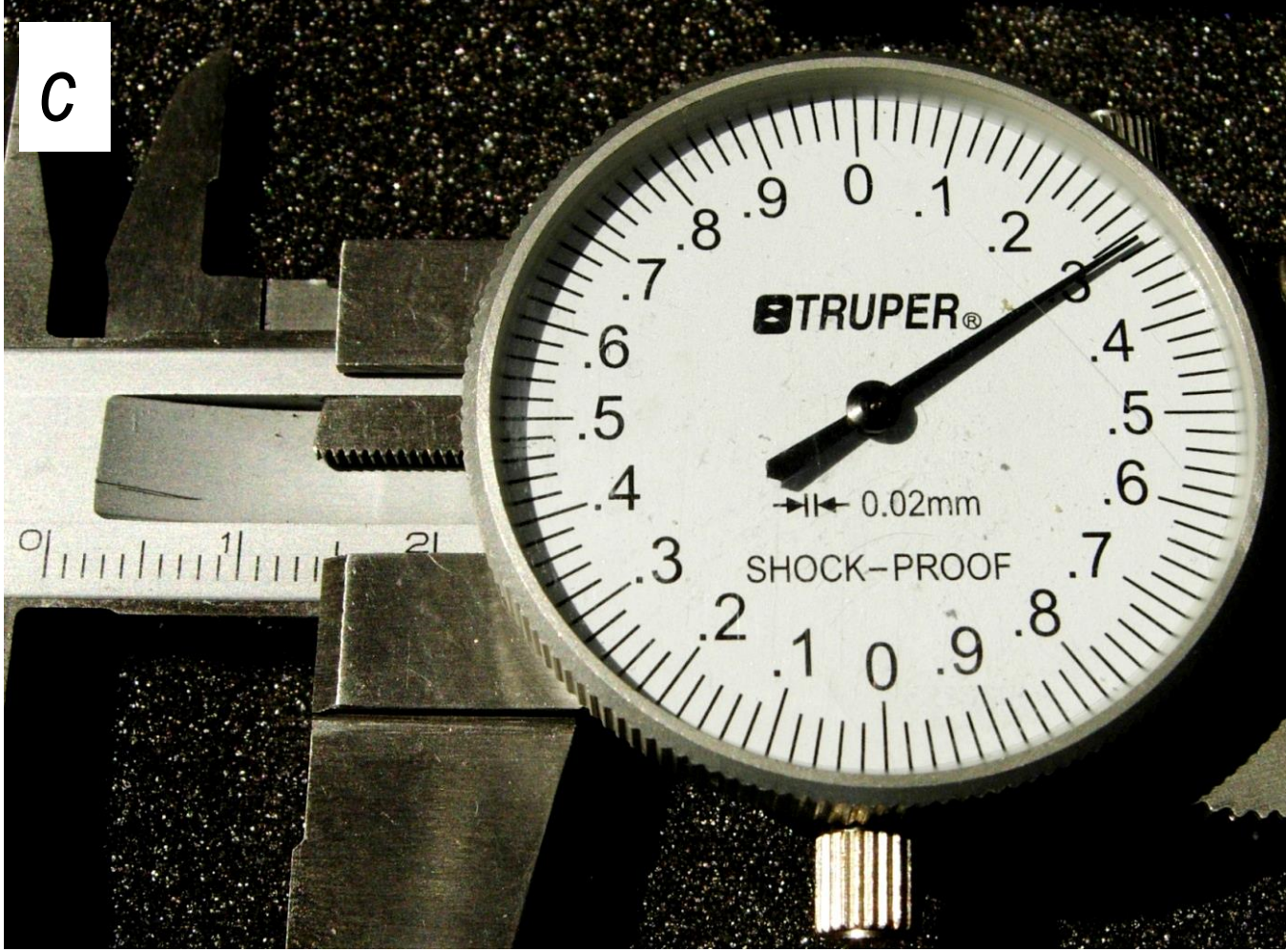


Reading: 0.1970 inch (4 decimal digits)

Dial caliper

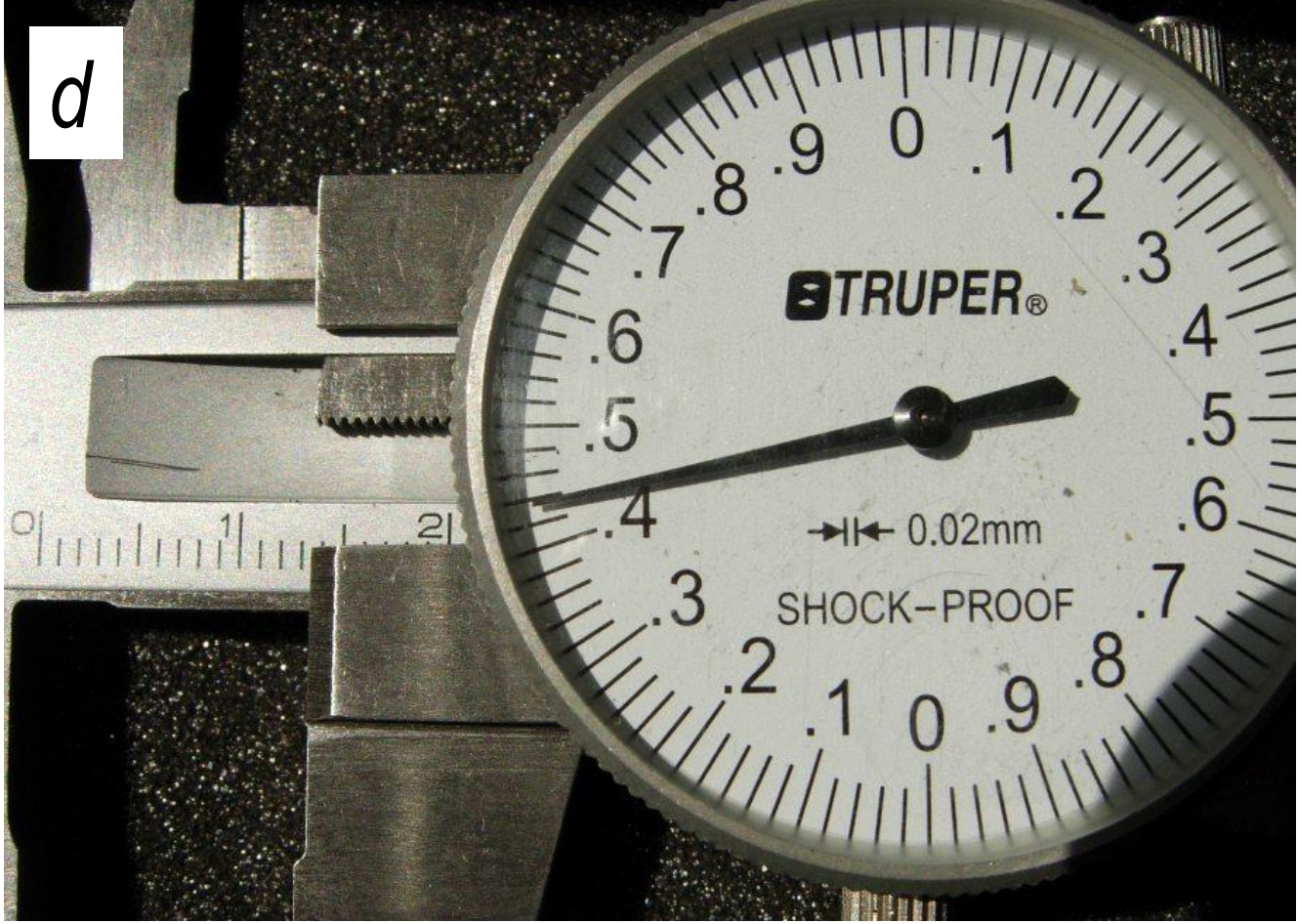
14(1)=14.00
15(0.02)= 0.30
0.5(0.02)=0.01

14.31



Reading: _____*14.31*_____ *mm (2 decimal digits)*

Dial caliper



13(1) =13.00

21(0.02)=0.42

0.5(0.02)=0.01

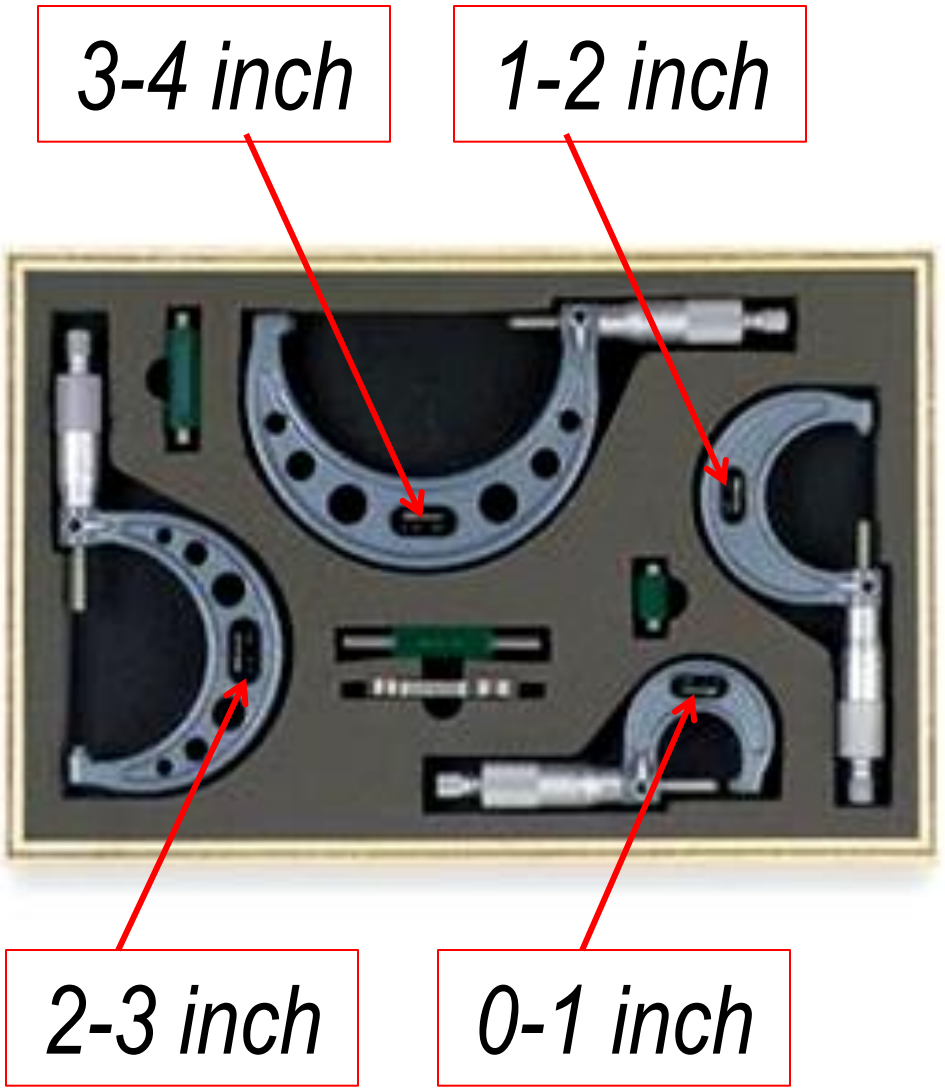
13.43

Reading: 13.43 mm (2 decimal digits)

7. Micrometer

www.mitutoyo.com

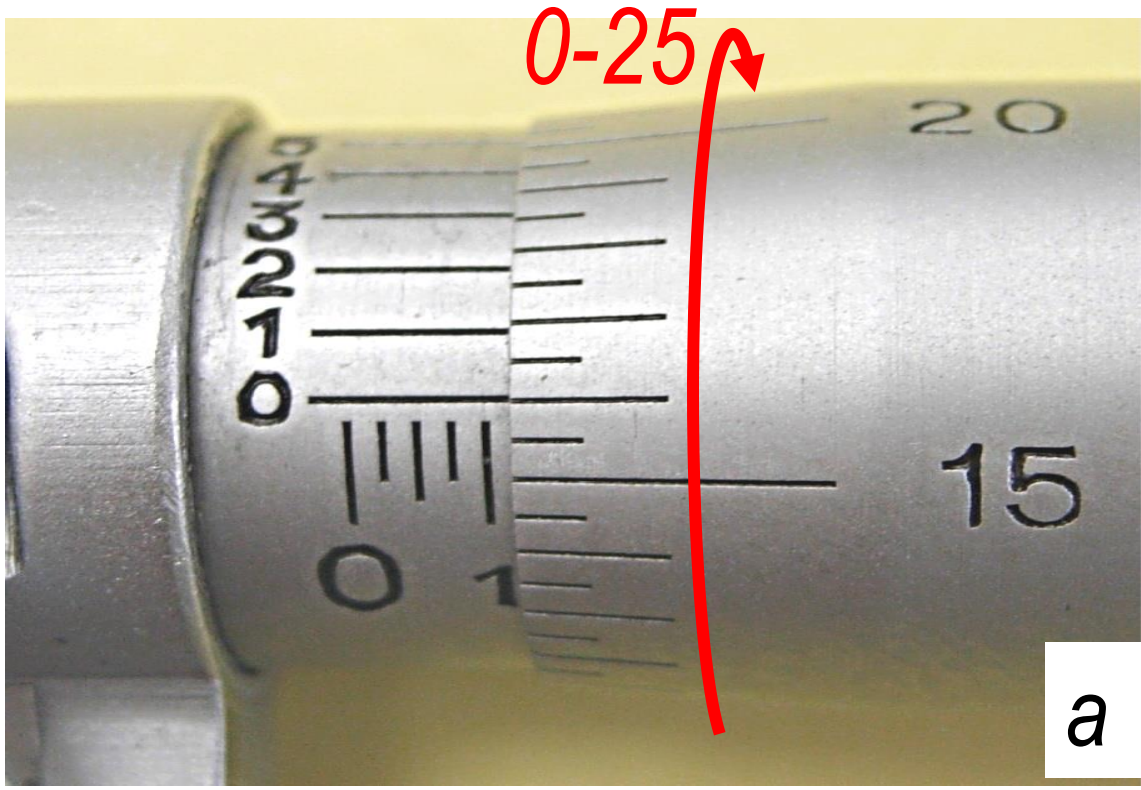
Micrometer set for different ranges



Micrometer

Min range = 3.0000
4(0.025) = 0.1000
16(0.001) = 0.0160

3.1160



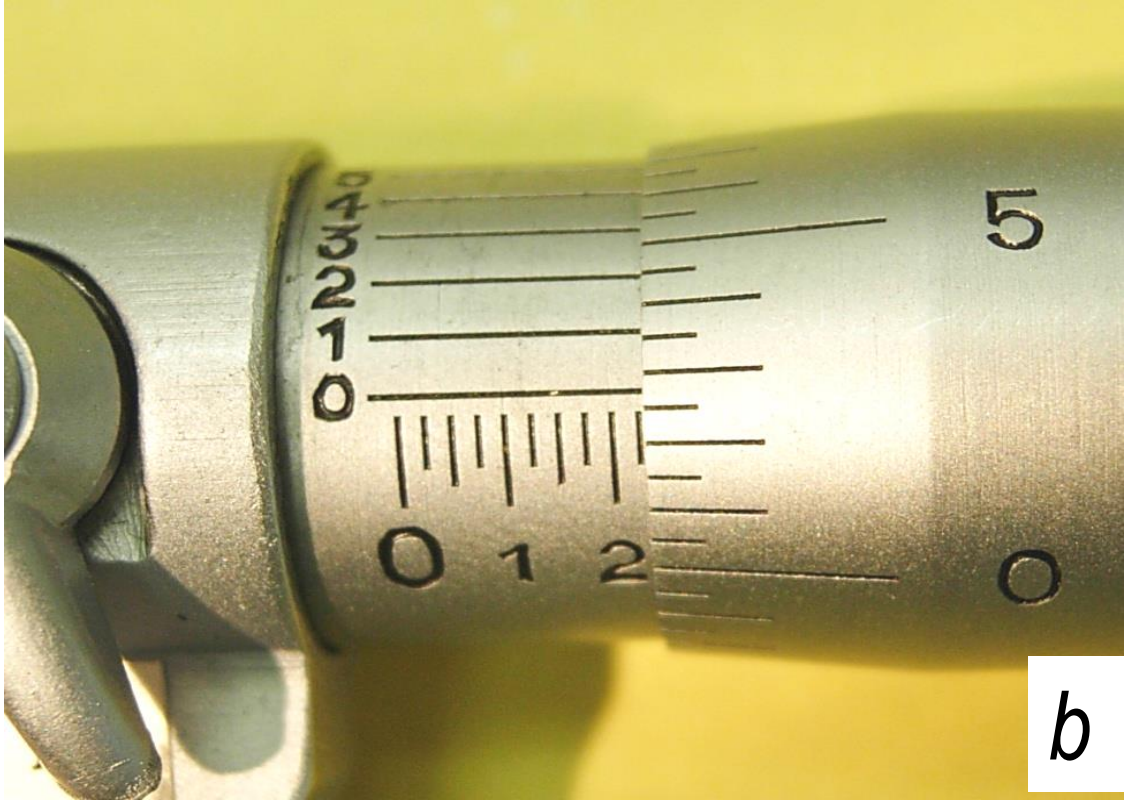
Range: 3-4 inch

Reading: 3.1160 inch (4 decimal digits)

Micrometer

Min range = 4.0000
2(0.1) = 0.2000
1(0.025) = 0.0250
2.5(0.001) = 0.0025
2(0.0001) = 0.0002

4.2277



b

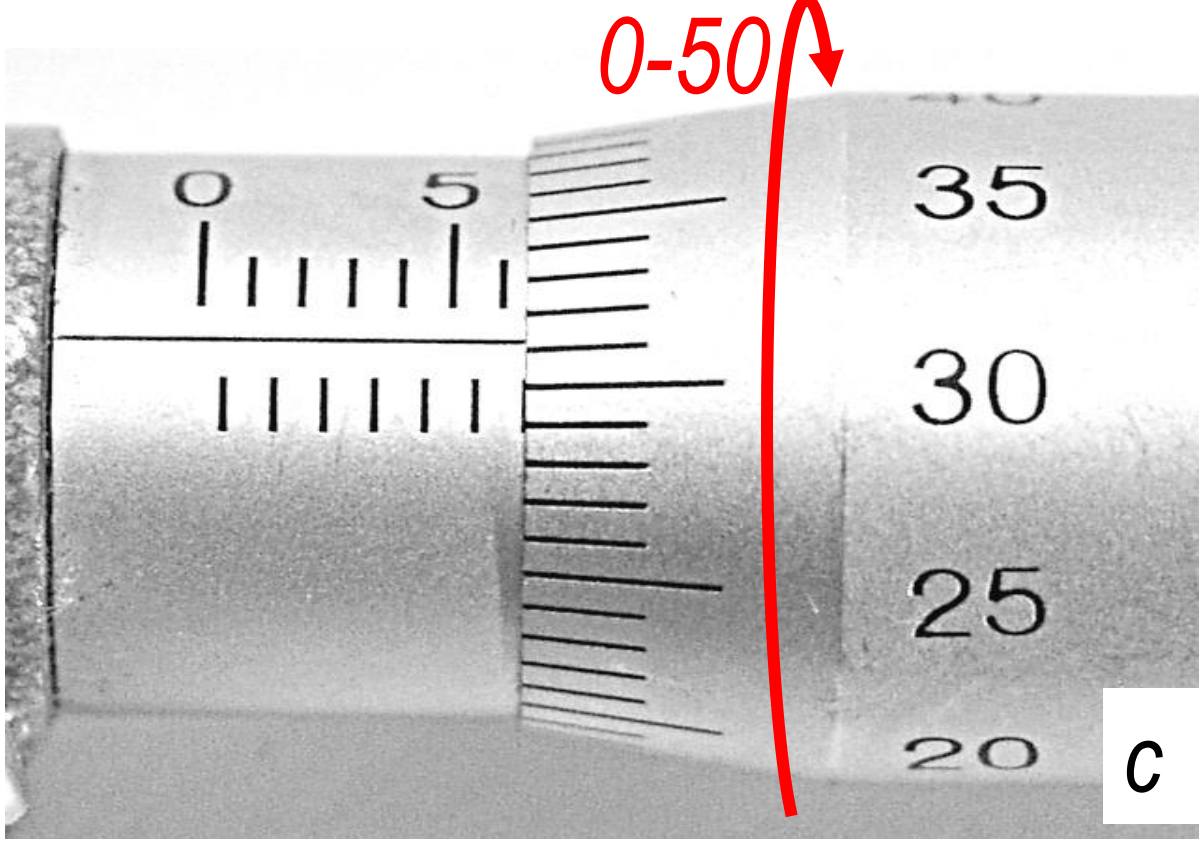
Range: 4-5 inch

Reading: 4.2277 inch (4 decimal digits)

Metric micrometer

Min range = 25.000
6(1) = 6.000
31.2(0.01) = 0.312

31.312



Range: 25-50 mm

Reading: 31.312 mm (3 decimal digits)

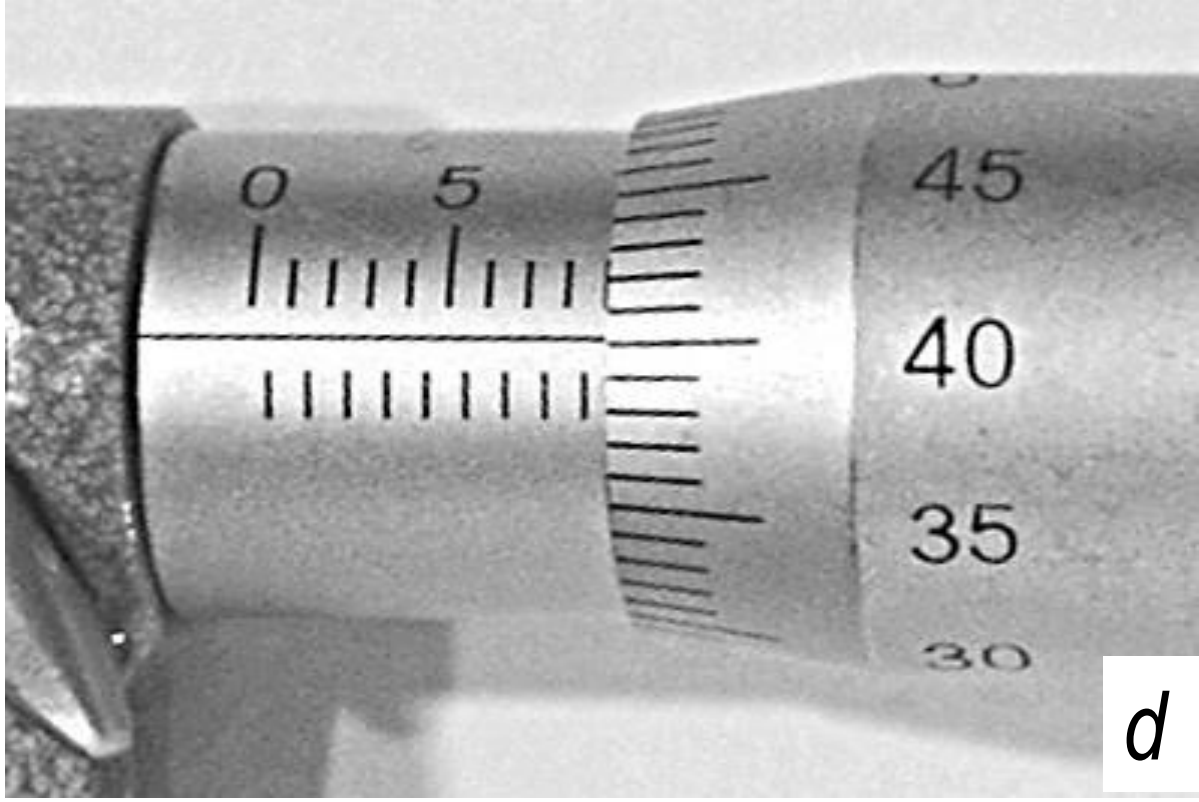
Metric micrometer

Min range = 50.000

8.5(1) = 8.500

40.1(0.01) = 0.401

58.901



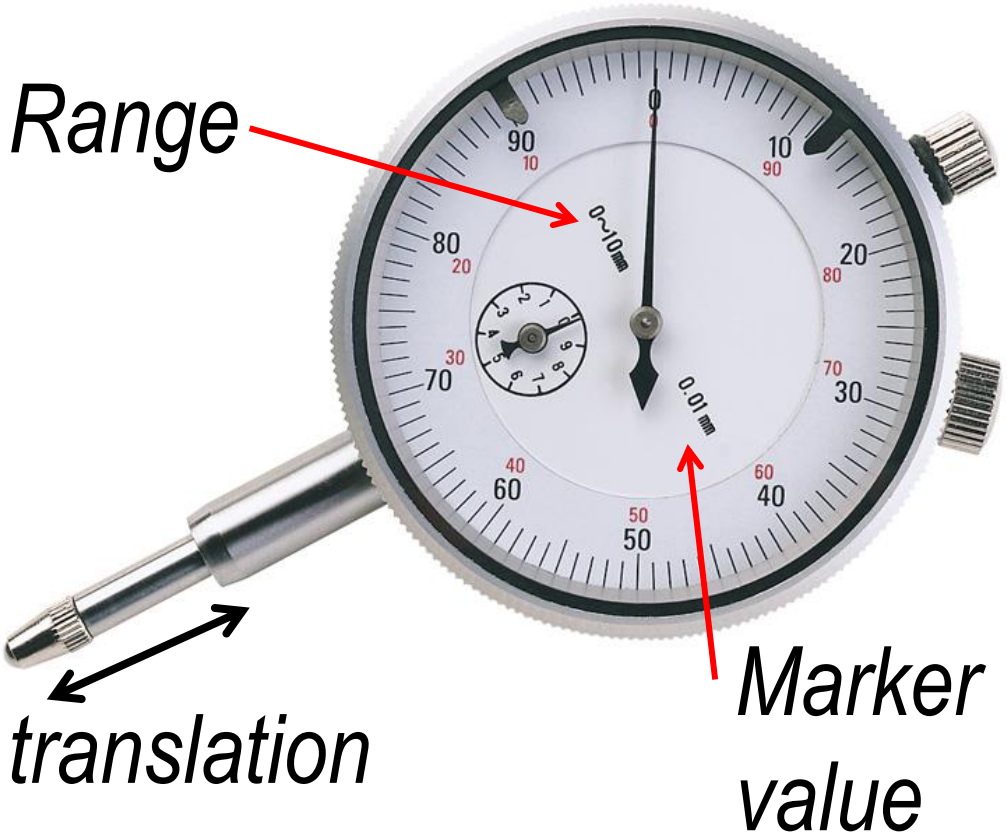
d

Range: 50 -75mm

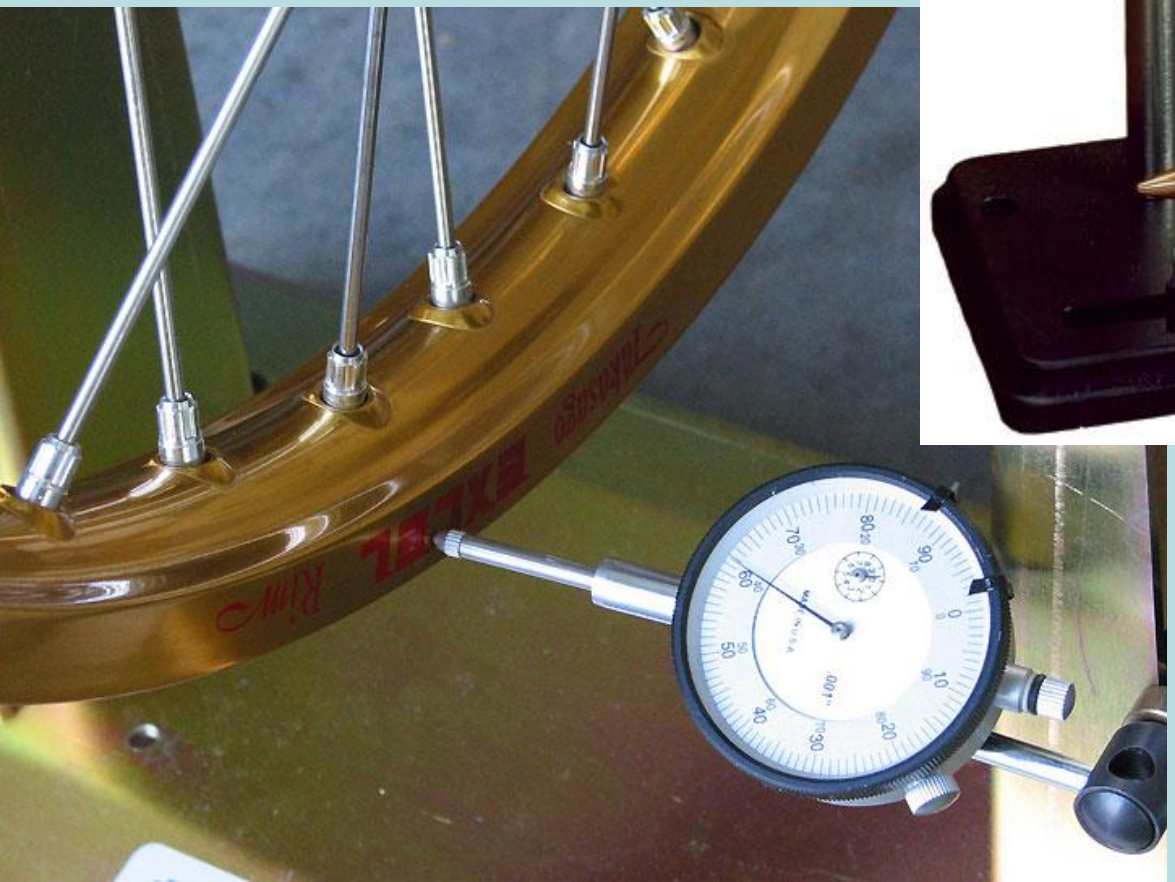
Reading: 58.901 mm (3 decimal digits)

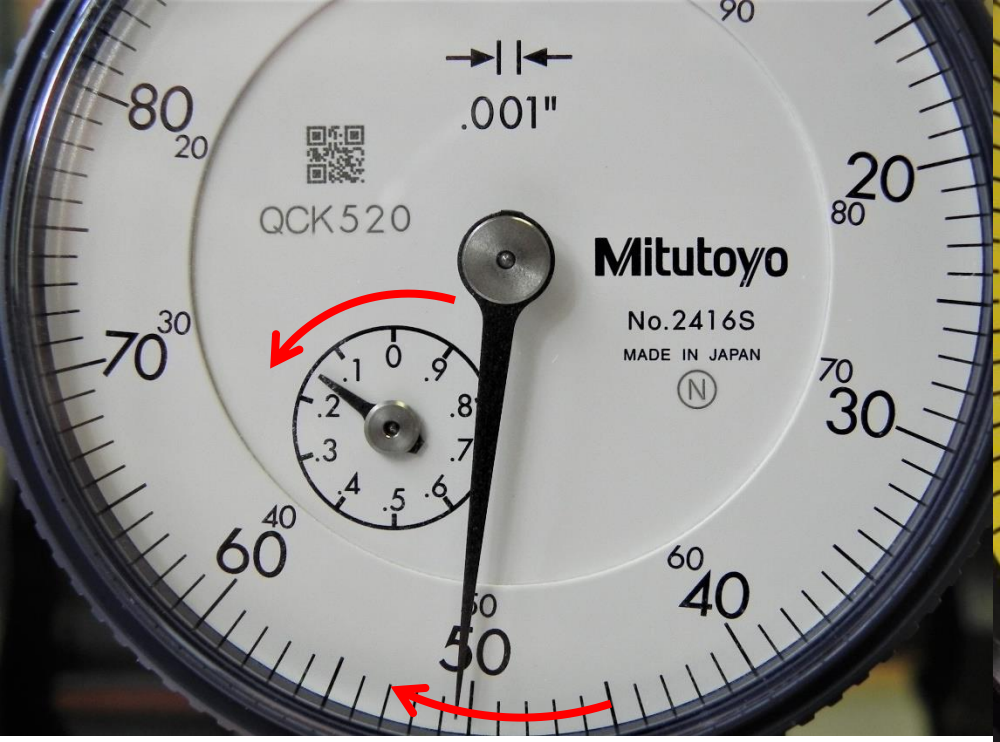
8. Indicators

- Amplify small displacement (linear or rotation)
- Measure dimensional change or form variation



Indicator applications





Mitutoyo indicator with long and short hands rotate in different directions

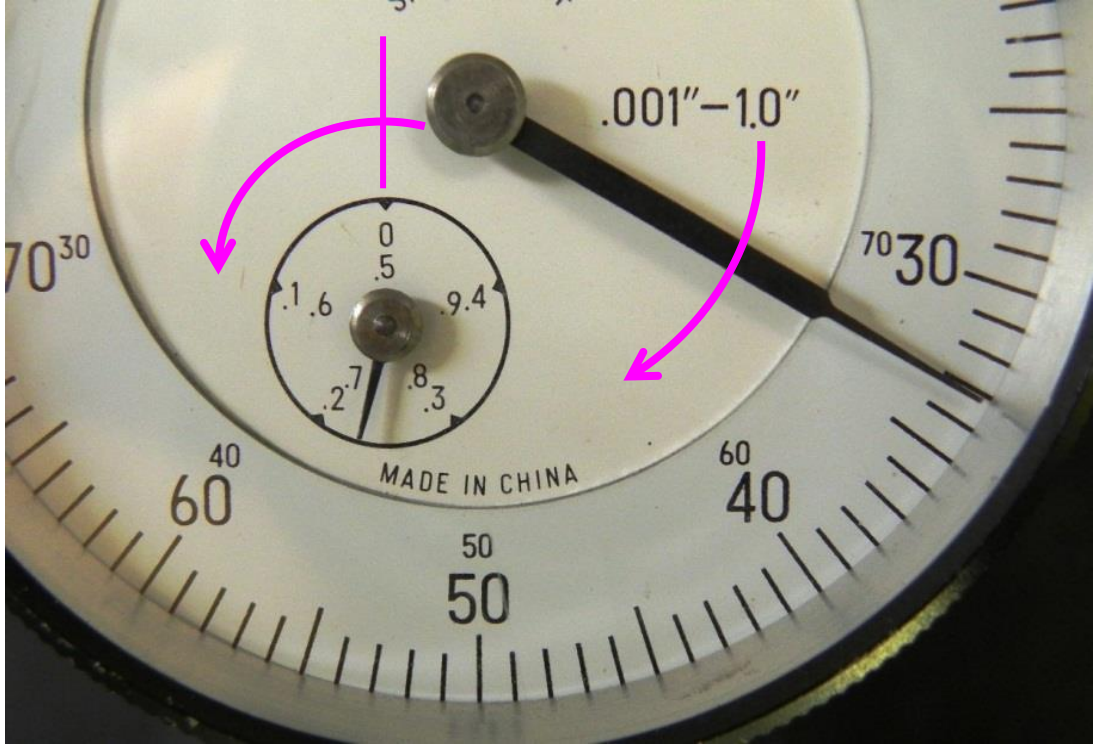
MHC indicator with long and short hands rotate in same directions

Instruction to read a dial indicator

https://www.youtube.com/watch?v=0KbMTKq4SLk

Indicator

- Assume rotation directions
- Range: 0-1 inch
- Marker: 0.001 inch
- Read small dial then large dial



2(0.1) = 0.2000

33(0.001) = 0.0330

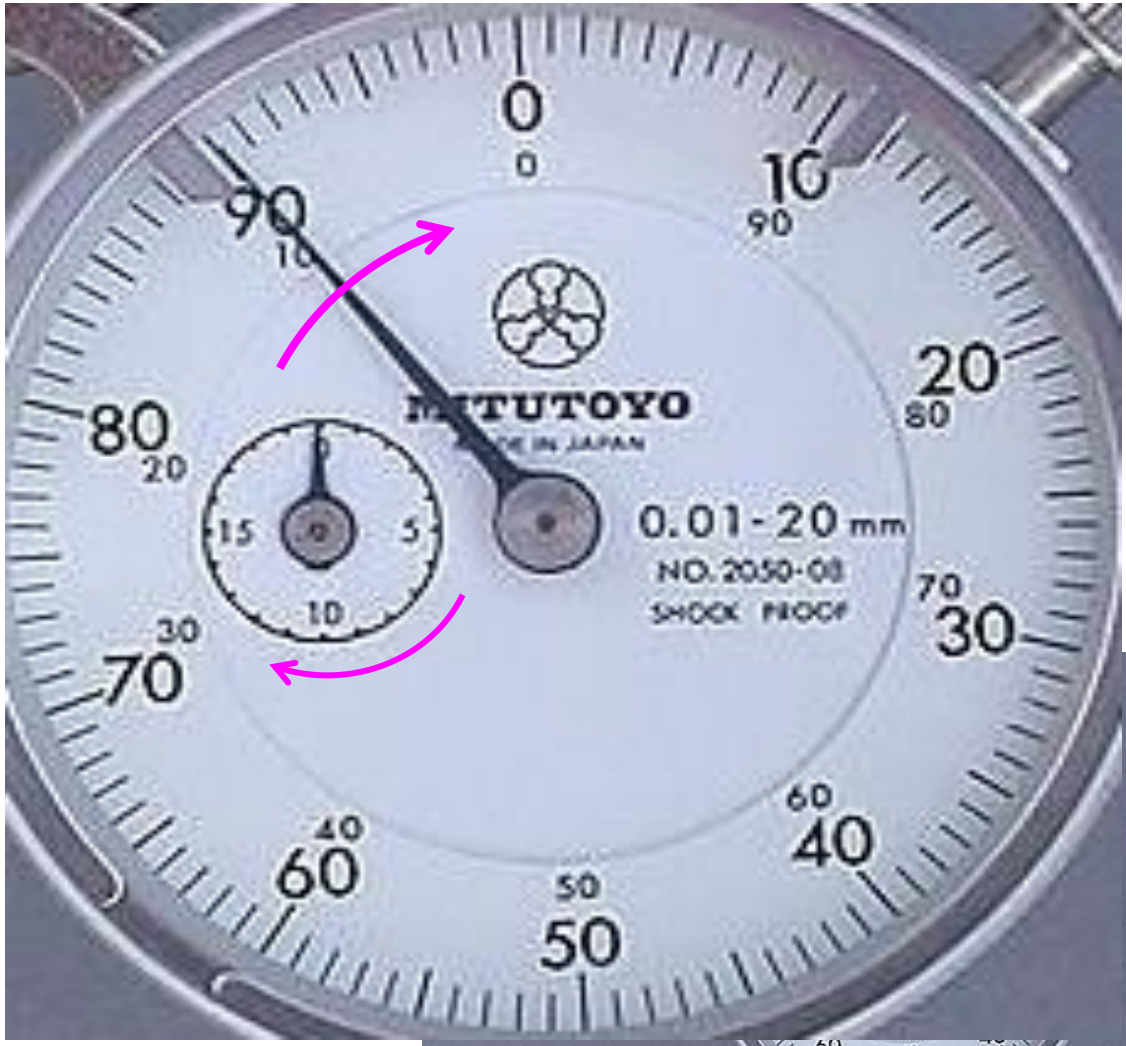
0.2330

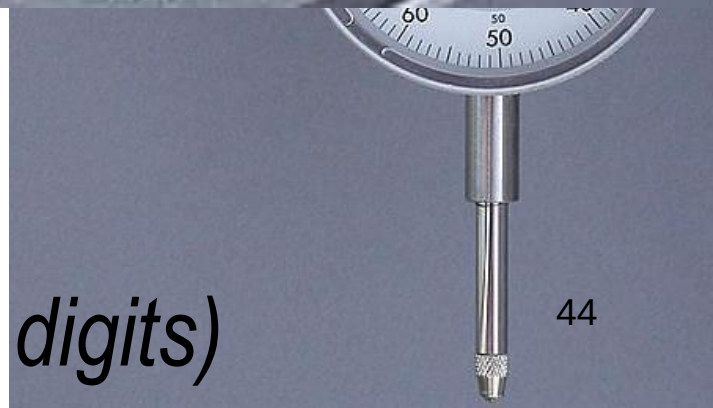
Reading: *0.2330 inch* *(4 decimal digits)*

Indicator

- Assume rotation directions
- Range: 0-20 mm
- Marker: 0.01 mm
- Read small dial then large dial

19(1) = 19.000
90(0.01) = 0.900
19.900

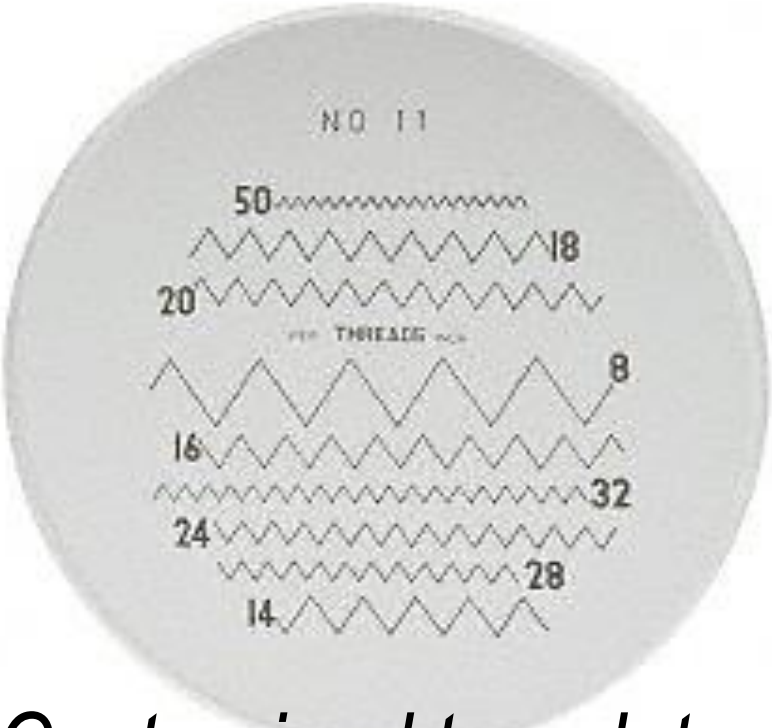




Reading: 19.900 mm (3 decimal digits)

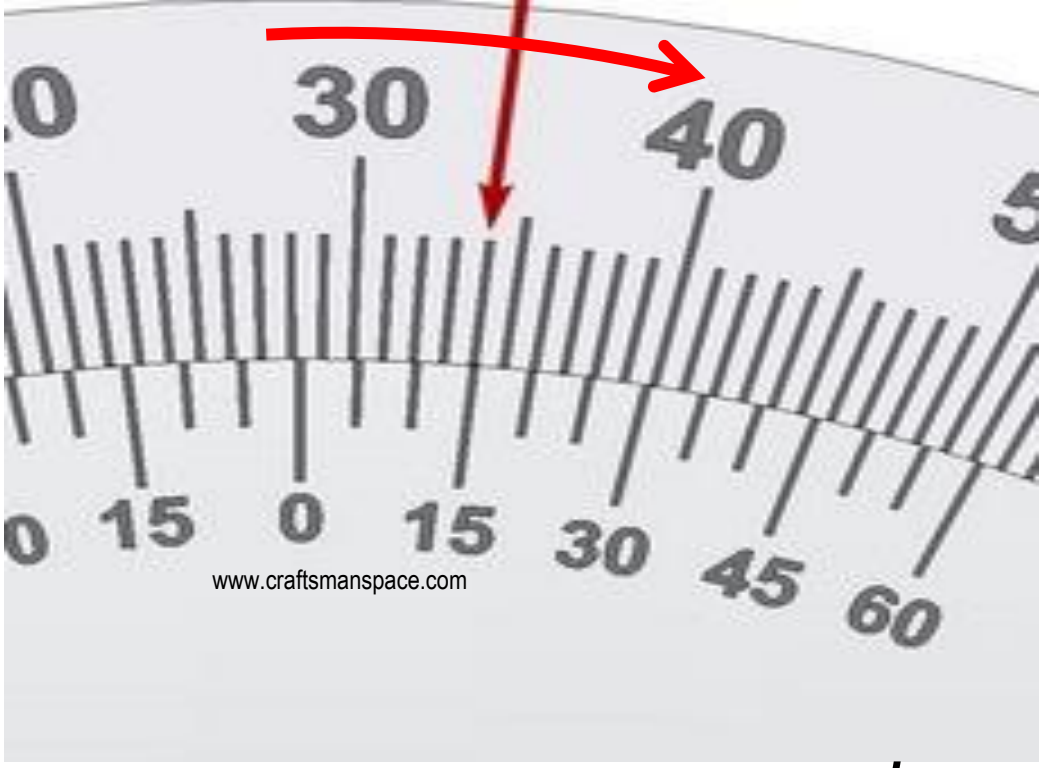
9. Profile projector (optical comparator)

- Magnify image
- Analyze shadow
- Calculate true



Customized template

Angle measurement



Angle measurement and conversion

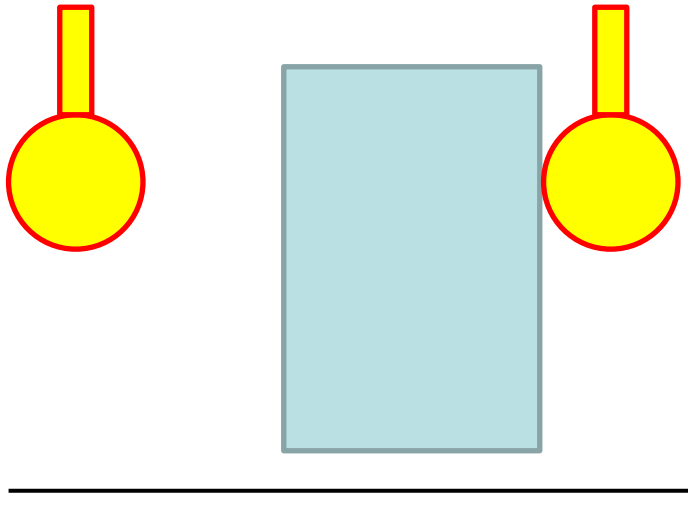
1° = 60 minutes = 3600 seconds

28°15 min

28 + 15/60 = 28.25°

10. Coordinate measuring machine (CMM)

- Use precise probes with known dimensions
- Provide coordinate of each point
- Calculate dimension and form



Portable CMM

www.canadianmetalworking.com/