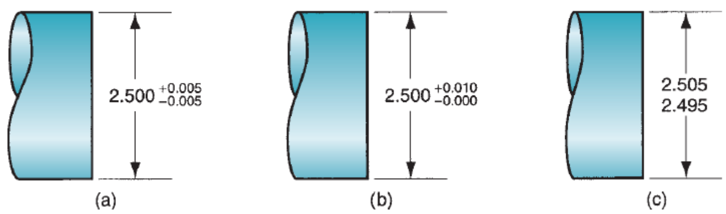
DIMENSIONS, SURFACES, AND THEIR MEASUREMENT

- Dimensions are the linear or angular sizes of a component specified on the part drawing.
- Tolerance is limited variation given in dimension.
- A surface is the exterior boundary of an object with its surroundings, which may be another object, a fluid, or space, or combinations of these.



Three ways to specify tolerance limits for a nominal dimension of 2.500:
(a) bilateral, (b) unilateral, and (c) limit dimensions.

CONVENTIONAL MEASURING INSTRUMENTS AND GAGES

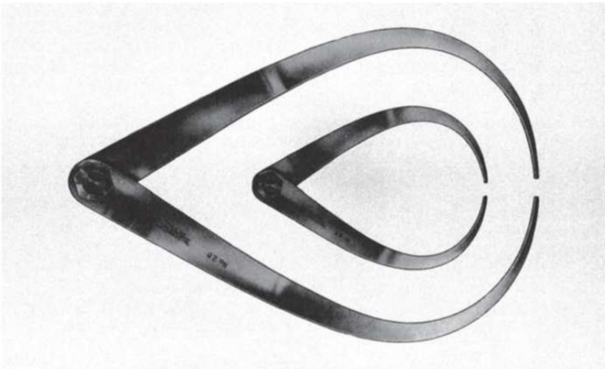
- Measurement is a procedure in which an unknown quantity is compared with a known standard, using an accepted and consistent system of units.
- Two systems of units have evolved in the world: (1) the U.S. customary system (U.S.C.S.), and (2) the International System of Units (or SI), more popularly known as the metric system.
- The most basic of the measuring devices is the rule (made of steel, and often called a steel rule), used to measure linear dimensions.

Definitions of geometric attributes of parts

- Angularity—The extent to which a part feature such as a surface or axis is at a specified angle relative to a reference surface. If the angle = 90, then the attribute is called perpendicularity or squareness.
- Circularity—For a surface of revolution such as a cylinder, circular hole, or cone, circularity is the degree to which all points on the intersection of the surface and a plane perpendicular to the axis of revolution are equidistant from the axis.
- Concentricity—The degree to which any two (or more) part features such as a cylindrical surface and a circular hole have a common axis.
- Cylindricity—The degree to which all points on a surface of revolution such as a cylinder are equidistant from the axis of revolution.
- Flatness—The extent to which all points on a surface lie in a single plane.
- Parallelism—The degree to which all points on a part feature such as a surface, line, or axis are equidistant from a reference plane or line or axis.
- Perpendicularity—The degree to which all points on a part feature such as a surface, line, or axis are 90 from a reference plane or line or axis.
- Roundness—Same as circularity.
- Squareness—Same as perpendicularity.
- Straightness—The degree to which a part feature such as a line or axis is a straight line.

MEASURING INSTRUMENTS FOR LINEAR DIMENSIONS

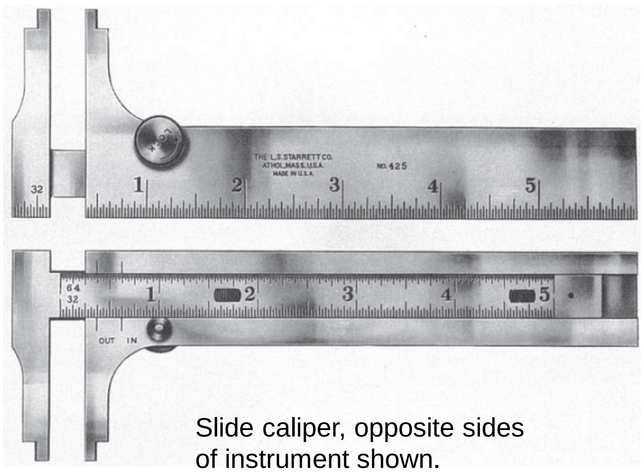
- Calipers are available in either nongraduated or graduated styles.
- Nongraduated caliper (referred to simply as a caliper) consists of two legs joined by a hinge mechanism.



Two sizes of outside calipers.

MEASURING INSTRUMENTS FOR LINEAR DIMENSIONS

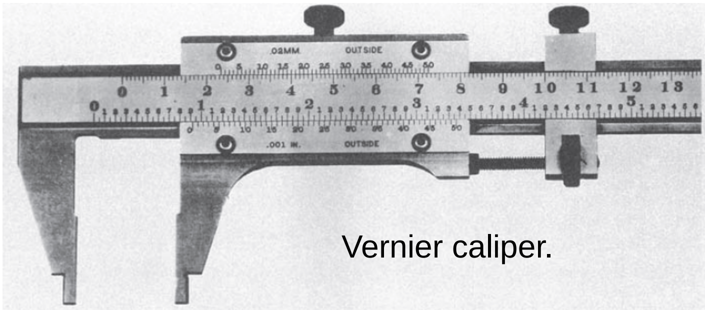
A variety of graduated calipers are available for various measurement purposes. The simplest is the slide caliper, which consists of a steel rule to which two jaws are added, one fixed at the end of the rule and the other movable.



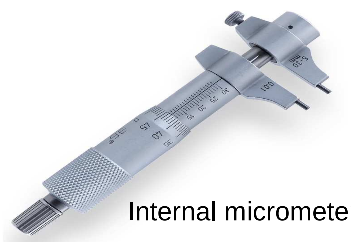
Slide caliper, opposite sides of instrument shown.

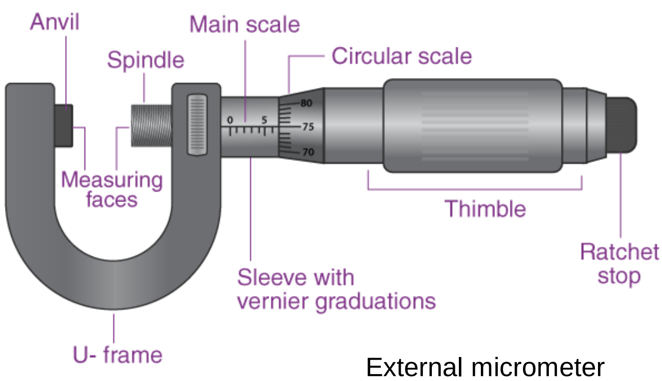
MEASURING INSTRUMENTS FOR LINEAR DIMENSIONS

- A refinement of the slide caliper is the vernier caliper.
- In this device, the movable jaw includes a vernier scale.
- The vernier provides graduations of 0.01mm in the SI (and 0.001 inch in the U.S. customary scale), much more precise than the slide caliper.


Vernier caliper.

- The micrometer is a widely used and very accurate measuring device, the most common form of which consists of a spindle and a C-shaped anvil.
- The spindle is moved relative to the fixed anvil by means of an accurate screw thread.
- Modern micrometers are available with electronic devices that display a digital readout of the measurement.

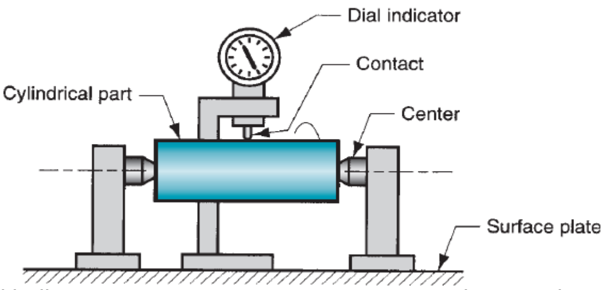

Internal micrometer



External micrometer

COMPARATIVE INSTRUMENTS

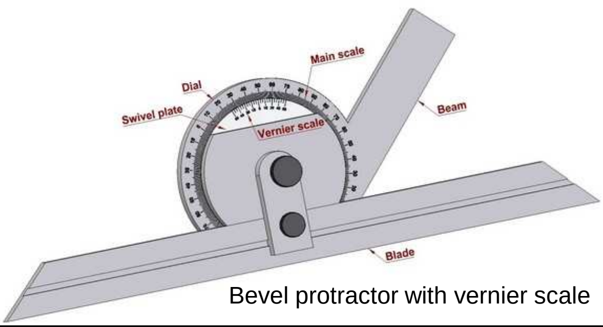
- Comparative instruments are used to make dimensional comparisons between two objects, such as a workpart and a reference surface.
- Mechanical Gages: Dial Indicators Mechanical gages are designed to mechanically magnify the deviation to permit observation.
- The most common instrument in this category is the dial indicator which converts and amplifies the linear movement of a contact pointer into rotation of a dial needle.
- Dial indicators are used in many applications to measure straightness, flatness, parallelism, squareness, roundness, and runout.



Dial indicator setup to measure runout; as part is rotated about its center, variations in outside surface relative to center are indicated on the dial.

ANGULAR MEASUREMENTS

- Angles can be measured using any of several styles of protractor. A simple protractor consists of a blade that pivots relative to a semicircular head that is graduated in angular units (e.g., degrees, radians).
- To use, the blade is rotated to a position corresponding to some part angle to be measured, and the angle is read off the angular scale.
- A bevel protractor consists of two straight blades that pivot relative to each other.



Bevel protractor with vernier scale

SURFACES

- A surface is what one touches when holding an object, such as a manufactured part.
- The designer specifies the part dimensions, relating the various surfaces to each other.
- Surfaces are commercially and technologically important for a number of reasons, different reasons for different applications:

(1) Aesthetic reasons—surfaces that are smooth and free of scratches and blemishes are more likely to give a favorable impression to the customer.

(2) Surfaces affect safety.

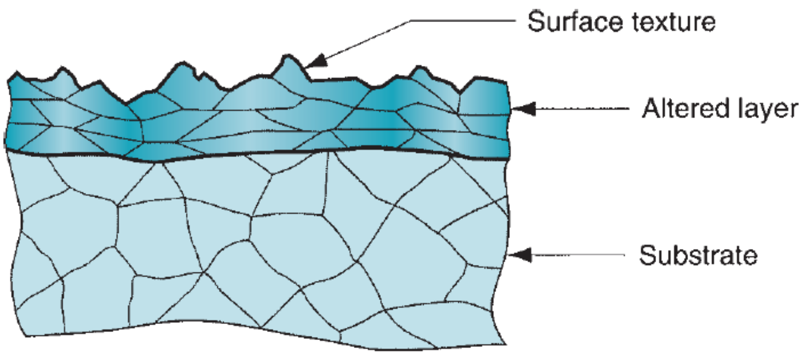
(3) Friction and wear depend on surface characteristics.

(4) Surfaces affect mechanical and physical properties; for example, surface flaws can be points of stress concentration.

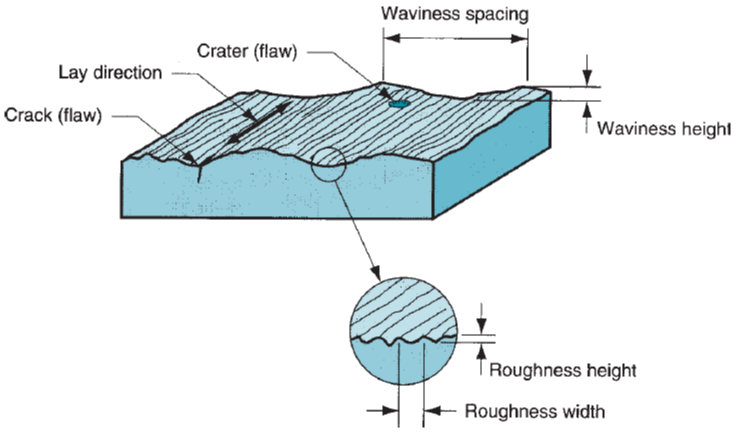
(5) Assembly of parts is affected by their surfaces; for example, the strength of adhesively bonded joints is increased when the surfaces are slightly rough.

(6) Smooth surfaces make better electrical contacts.

- A microscopic view of a part's surface reveals its irregularities and imperfections.



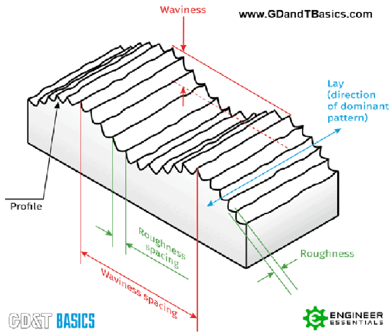
A magnified cross section of a typical metallic part surface.

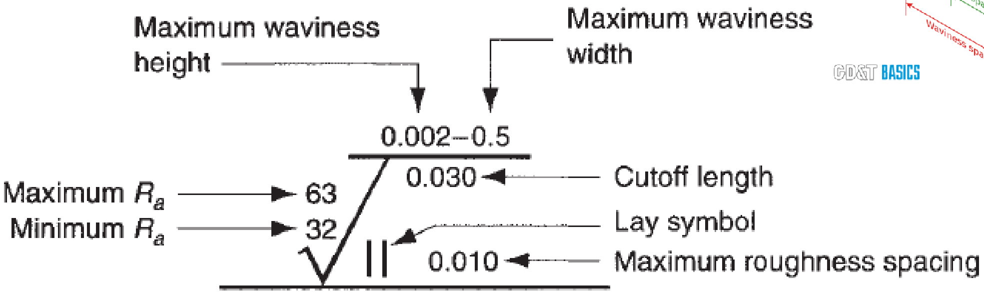


Surface texture features.

Lay symbol	Surface pattern	Description
=		Lay is parallel to line representing surface to which symbol is applied.
⊥		Lay is perpendicular to line representing surface to which symbol is applied.
X		Lay is angular in both directions to line representing surface to which symbol is applied.
C		Lay is circular relative to center of surface to which symbol is applied.
R		Lay is approximately radial relative to the center of the surface to which symbol is applied.
P		Lay is particulate, nondirectional, or protuberant.

- Most of the possible lays a surface can take, togetherwith the symbol used by a designer to specify them.
- Finally, flaws are irregularities that occur occasionally on the surface; these include cracks, scratches, inclusions, and similar defects in the surface.
- Although some of the flaws relate to surface texture, they also affect surface integrity

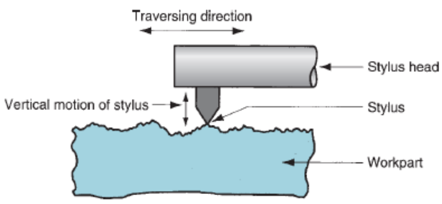




MEASUREMENT OF SURFACE ROUGHNESS

- Standard Test Surfaces - Sets of standard surface finish blocks are available, produced to specified roughness values. To estimate the roughness of a given test specimen, the surface is compared with the standard both visually and by the ‘‘fingernail test.’’ In this test, the user gently scratches the surfaces of the specimen and the standards, judging which standard is closest to the specimen.
- Stylus Instruments - The disadvantage of the fingernail test is its subjectivity. Several stylus-type instruments are commercially available to measure surface roughness—similar to the fingernail test, but more scientific.

An example is the Profilometer. In these electronic devices, a cone-shaped diamond stylus with point radius of about 0.005 mm(0.0002 in) and 90 tip angle is traversed across the test surface at a constant slow speed. As the stylus head is traversed horizontally, it also moves vertically to follow the surface deviations. The vertical movement is converted into an electronic signal that represents the topography of the surface



MEASUREMENT OF SURFACE ROUGHNESS

- Optical Techniques - Most other surface-measuring instruments employ optical techniques to assess roughness.
- These techniques are based on light reflectance from the surface, light scatter or diffusion, and laser technology.
- They are useful in applications where stylus contact with the surface is undesirable.
- Some of the techniques permit very-high-speed operation, thus making 100% inspection feasible.
- However, the optical techniques yield values that do not always correlate well with roughness measurements made by stylus-type instruments.

TABLE 5.3 Forms of energy applied in manufacturing and the resulting possible surface and subsurface alterations that can occur.[a]

Mechanical	Thermal	Chemical	Electrical
Residual stresses in subsurface layer	Metallurgical changes (recrystallization, grain size changes, phase changes at surface)	Intergranular attack	Changes in conductivity and/or magnetism
Cracks—microscopic and macroscopic	Redeposited or resolidified material	Chemical contamination	Craters resulting from short circuits during certain electrical processing techniques
Plastic deformation	Heat-affected zone	Absorption of elements such as H and Cl	
Laps, folds, or seams	Hardness changes	Corrosion, pitting, and etching	
Voids or inclusions		Dissolving of microconstituents	
Hardness variations (e.g., work hardening)		Alloy depletion	

TABLE 5.5 Surface roughness values produced by the various manufacturing processes.[a]

Process	Typical Finish	Roughness Range[b]	Process	Typical Finish	Roughness Range[b]
Casting:			***Abrasive:***		
Die casting	Good	1–2 (30–65)	Grinding	Very good	0.1–2 (5–75)
Investment	Good	1.5–3 (50–100)	Honing	Very good	0.1–1 (4–30)
Sand casting	Poor	12–25 (500–1000)	Lapping	Excellent	0.05–0.5 (2–15)
Metal forming:			Polishing	Excellent	0.1–0.5 (5–15)
Cold rolling	Good	1–3 (25–125)	Superfinish	Excellent	0.02–0.3 (1–10)
Sheet metal draw	Good	1–3 (25–125)	***Nontraditional:***		
Cold extrusion	Good	1–4 (30–150)	Chemical milling	Medium	1.5–5 (50–200)
Hot rolling	Poor	12–25 (500–1000)	Electrochemical	Good	0.2–2 (10–100)
Machining:	Good	0.5–6 (15–250)	Electric discharge	Medium	1.5–15 (50–500)
Boring			Electron beam	Medium	1.5–15 (50–500)
Drilling	Medium	1.5–6 (60–250)	Laser beam	Medium	1.5–15 (50–500)
Milling	Good	1–6 (30–250)	***Thermal:***		
Reaming	Good	1–3 (30–125)	Arc welding	Poor	5–25 (250–1000)
Shaping and planing	Medium	1.5–12 (60–500)	Flame cutting	Poor	12–25 (500–1000)
Sawing	Poor	3–25 (100–1000)	Plasma arc cutting	Poor	12–25 (500–1000)
Turning	Good	0.5–6 (15–250)			

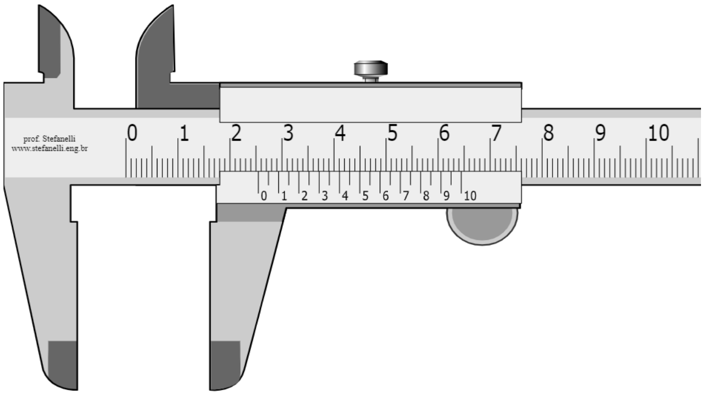
[a]Compiled from [1], [2], and other sources.
[b]Roughness range values are given, μm (μ-in). Roughness can vary significantly for a given process, depending on process parameters.

REVIEW QUESTIONS

1. What is a tolerance? Show the tolerance on the dimension in a technical drawing?
2. What is the difference between a bilateral tolerance and a unilateral tolerance?
3. What are some of the reasons why surfaces are important?
4. What is the caliper used for?
5. How many units of measurement systems are used in the world? Write them down.
6. What is the relationship between inches and millimeters?
7. For what purpose are comparative instruments used?

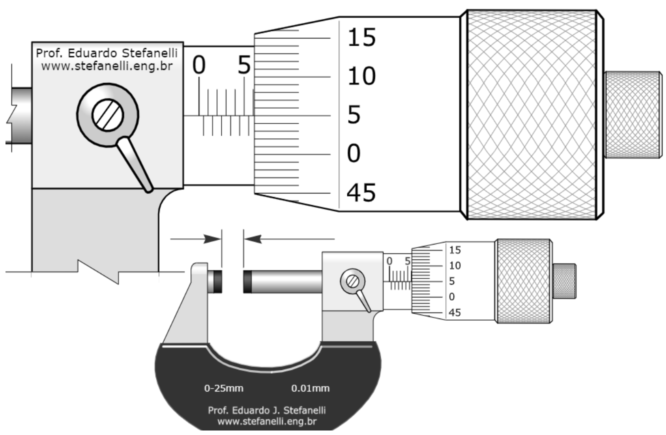
REVIEW QUESTIONS (Cont.)

8. The caliper given below shows how many mm.



REVIEW QUESTIONS (Cont.)

9. The micrometer given below shows how many mm.



REVIEW QUESTIONS (Cont.)

10. What is accuracy in measurement?
11. What is precision in measurement?
12. What is meant by the term graduated measuring device?
13. Define surface texture.
14. How is surface texture distinguished from surface integrity?
15. Within the scope of surface texture, how is roughness distinguished from waviness?
16. Surface roughness is a measurable aspect of surface texture; what does surface roughness mean?