

GUJARAT TECHNOLOGICAL UNIVERSITY

BE-4 SEMESTER – MID TERM – S26 – ANSWER BANK

Subject Name & Code:

MECHANICAL MEASUREMENT AND METROLOGY- BE04000181

Mid Sem Exam Answer Bank

(1) Differentiate following terms: 1) Accuracy and Precision, 2) Systematic and random errors

1) Accuracy vs. Precision

Feature	Accuracy	Precision
Definition	It is the degree of closeness of a measured value to the true or actual value of the quantity.	It is the degree of repeatability or consistency of a set of measurements. It indicates how close the measurements are to each other.
Key Concept	Correctness of the measurement.	Reproducibility of the measurement.
Analogy (Target)	Hitting the bullseye (center) of the target.	All shots hitting the same spot , even if it is not the center.
Dependence	Depends on systematic errors . High accuracy means low systematic error.	Depends on random errors . High precision means low random error.
Example	A weighing scale consistently shows 1 kg for a known 1 kg standard.	A scale shows 1.05 kg repeatedly for the same 1 kg standard, but the readings are all consistent with each other.

2) Systematic vs. Random Errors

Feature	Systematic Errors	Random Errors
Definition	Errors that consistently occur in the same direction (either positive or negative) and are reproducible.	Errors that cause random scattering of measurements around the mean value, varying in both magnitude and direction.
Cause	Faults in the instrument (calibration error), environmental conditions (zero shift), or observational habits (parallax).	Fluctuations in friction, variations in readings by an observer, or unpredictable environmental changes.
Nature	Reproducible and constant . Can be eliminated once the cause is identified.	Non-reproducible and random . Cannot be eliminated but can be reduced by taking

Feature	Systematic Errors	Random Errors
		multiple readings and using statistical analysis (e.g., mean).
Effect on Data	Shifts the mean of the measurements away from the true value, affecting accuracy .	Affects the spread or distribution of the measurements, affecting precision .
Example	A zero error in a vernier caliper (always reads 0.1 mm when fully closed).	Slight variations in reading a scale due to minute changes in eye position.

(2) Define metrology and list the objectives of metrology.

Definition:

Metrology is the science of **measurement**. It encompasses all theoretical and practical aspects of measurement, regardless of the uncertainty of measurement and field of application. In engineering, it specifically deals with the measurement of length, angles, and other quantities to ensure standardization and quality.

Objectives of Metrology:

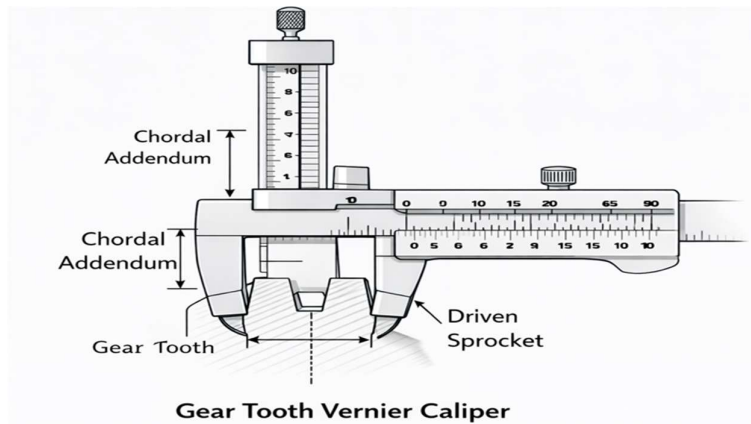
The main objectives are to ensure that components are manufactured according to the design specifications and to maintain quality. The key objectives include:

- **To ensure product standardization and interchangeability:** Metrology helps in manufacturing parts that can be assembled with mating parts from different batches or manufacturers without any need for fitting.
- **To evaluate the newly developed product:** It is used to inspect prototypes and ensure they meet the design requirements before mass production begins.
- **To determine the accuracy of measuring instruments:** Metrology provides methods for calibrating instruments to ensure they are giving correct readings.
- **To establish the validity of measurement:** It helps in minimizing the cost of rejection and rework by detecting errors early in the manufacturing process.
- **To correlate and coordinate measurement standards:** It links the measurements made in an industry workshop to national and international standards (e.g., the **International System of Units (SI)**).
- **To optimize the measurement process:** It aims to achieve maximum accuracy and reliability of measurement at a minimum cost.

(3) How to measure chordal thickness using gear tooth vernier caliper? Explain in detail.

The **gear tooth vernier caliper** is a specialized instrument used to measure the **chordal thickness** of a gear tooth. It has two perpendicular vernier scales: one vertical for setting the **chordal addendum** (height) and one horizontal for measuring the **chordal thickness** at that height.

Diagram:



Gear Tooth Vernier Caliper

Step-by-Step Measurement Procedure:

1. **Calculate the Theoretical Values:** First, calculate the theoretical **chordal addendum (h)** and **chordal thickness (t)** using the gear's specifications (Number of teeth N , Module m , and Pressure Angle ϕ). The formulas are derived from the geometry of the involute tooth:
 - Pitch Circle Diameter (D) = $m \times N$
 - **Chordal Thickness (t_c)** = $N \times m \times \sin\left(\frac{90^\circ}{N}\right)$
 - **Chordal Addendum (h_c)** = $m \times \left[1 + \frac{N}{2} \times \left(1 - \cos\left(\frac{90^\circ}{N}\right)\right)\right]$
2. **Set the Vertical Scale:** Adjust the vertical vernier scale of the gear tooth caliper to the calculated **chordal addendum (h_c)** value and lock it in place.
3. **Place the Caliper on the Tooth:** Place the **anvil** (the fixed jaw of the vertical scale) firmly on the **top (tip)** of the gear tooth to be measured. Ensure the caliper is held square and true to the tooth flank.
4. **Adjust the Horizontal Jaws:** While holding the caliper steady with the vertical jaw touching the tooth tip, gently slide the horizontal jaws until they make light, firm contact with the **two flanks** of the gear tooth. The contact should be made at the level where the vertical scale is set.
5. **Take the Reading:** Lock the horizontal scale and read the measurement from the horizontal vernier scale. This is the actual **chordal thickness** of the gear tooth.
6. **Interpret the Result:** Compare the measured value with the theoretical value calculated in step 1. The difference indicates the manufacturing accuracy of the gear tooth thickness. The actual value is always slightly less than the theoretical value to provide necessary backlash.

(4) Briefly explain about plug gauge and ring gauge.

Plug gauges and ring gauges are **limit gauges** used for checking the dimensional accuracy of holes and shafts. They are not measuring instruments but **comparison tools** that determine whether a component's size is within the specified tolerance limits (Go and No-Go).

1. Plug Gauge

- **Purpose:** Used to check the **straightness, roundness, and size of holes** (internal diameters).
- **Construction:** It is typically a double-ended or single-ended cylindrical gauge.
 - **Go End (Go Plug):** Designed to the **minimum** limit of the hole size (L.L.). It should **fit** into the hole easily under its own weight or light pressure. This verifies that the hole is not smaller than the allowed minimum.
 - **No-Go End (No-Go Plug):** Designed to the **maximum** limit of the hole size

(U.L.). It should **NOT** enter the hole. If it does, it indicates the hole is oversize and has been rejected.

- **Use:** A "GO" and "NO-GO" result confirms the hole is within the specified tolerance zone.

Diagram:

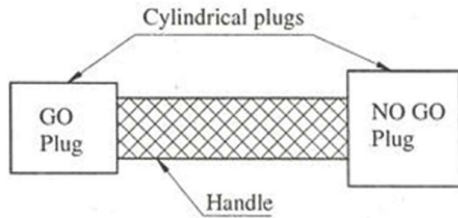


Fig.1.40 – Double ended plug gauge

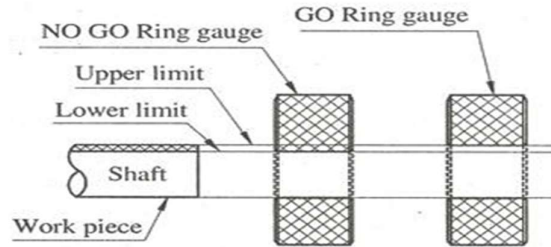


Fig.1.43 – Ring Gauges

2. Ring Gauge

- **Purpose:** Used to check the **straightness, roundness, and size of external shafts** (external diameters).
- **Construction:** They are also usually double-ended (or marked on the same ring).
 - **Go Ring (Go):** Machined to the **maximum** limit of the shaft size. The good shaft must **pass through** the "GO" ring gauge. This ensures the shaft is not thicker than the allowed maximum.
 - **No-Go Ring (No-Go):** Machined to the **minimum** limit of the shaft size. The shaft should **NOT** pass through the "NO-GO" ring. If it does, the shaft is undersize and is rejected.

(5) Explain three wire methods for measuring effective diameter of screw thread with neat sketch.

The **three-wire method** is the most accurate and direct method for measuring the **effective (pitch) diameter** of a screw thread. It uses three precision-ground wires of equal diameter.

Principle:

The wires are placed in the grooves of the thread on opposite sides, allowing the measurement over the wires (M) to be taken with a micrometer. By knowing the wire diameter (d_w), the pitch (p), and the thread angle (θ), the effective diameter (E) can be accurately calculated.

Diagram:

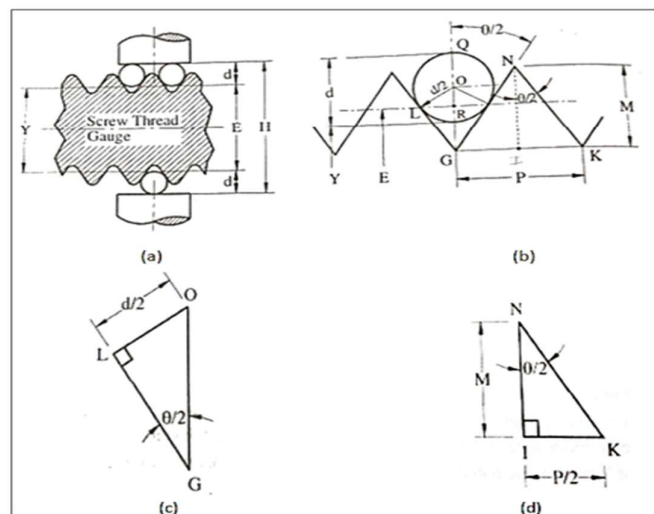


Fig.3.10 - Three-wire method

Procedure:

1. **Select Wire Size:** Choose wires of a suitable diameter (d_w) so they contact the thread flanks at or near the **pitch line** (where the groove width equals half the pitch). The best size wire is calculated as $d_w = \frac{p}{2} \sec\left(\frac{\theta}{2}\right)$.
2. **Place the Wires:** Place two wires in the grooves on one side of the thread and the third wire in a groove directly opposite them on the other side (or use a stand with two wires on one side and one on top).
3. **Measure over Wires:** Use a **micrometer** to measure the distance over the outer surfaces of the three wires. Record this value as M .
4. **Calculate Effective Diameter:** The effective diameter (E) is calculated using the following formula (for a metric thread with $\theta = 60^\circ$):
 - $E = M - 3d_w + 0.866025p$
 - Where:
 - E = Effective (Pitch) Diameter
 - M = Measurement over the wires
 - d_w = Diameter of the wires used
 - p = Pitch of the thread

(6) Explain about addendum and dedendum of gear.

These are fundamental terms related to the tooth profile of a gear.

1. Addendum (h_a)

- **Definition:** It is the **radial distance** between the **pitch circle** and the **top (tip) of the tooth**.
- **Location:** Measured from the pitch circle outward to the addendum (tip) circle.
- **Function:** It determines the **height of the tooth above the pitch circle**. The addendum of one gear fits into the dedendum of the mating gear.
- **Standard Value:** In a standard gear system, the addendum is typically equal to the **module (m)** of the gear. So, $h_a = 1 \times m$.

2. Dedendum (h_f)

- **Definition:** It is the **radial distance** between the **pitch circle** and the **bottom of the tooth (root circle)**.
- **Location:** Measured from the pitch circle inward to the root circle.
- **Function:** It provides the **depth of the tooth below the pitch circle**. This depth includes the addendum of the mating gear plus a small clearance to prevent the tip of one tooth from hitting the bottom of the mating tooth space.
- **Standard Value:** In a standard system, the dedendum is greater than the addendum. It is typically $h_f = 1.157 \times m$ or $h_f = 1.25 \times m$, which accounts for the tooth height plus a small bottom clearance.

(7) What are the various methods of measurement? Explain them with examples.

Measurement methods are classified based on how the measurement is obtained. The main types are:

1. Direct Method:

- **Definition:** The value of the quantity to be measured is obtained **directly** by comparing it with a standard (an instrument calibrated in those units).
- **Explanation:** The measuring instrument directly displays the dimension. It's the simplest form of measurement.
- **Example:** Measuring the length of a rod using a **steel rule** or a **vernier caliper**. Measuring the diameter of a shaft with a **micrometer**.

2. Indirect Method:

- **Definition:** The value of the quantity is obtained by measuring **other related parameters** and then calculating the desired value using a known mathematical relationship.
- **Explanation:** The measurand itself is not directly compared; its value is derived.
- **Example:** Measuring the **effective diameter of a thread** using the three-wire method (measuring 'M' and calculating 'E'). Measuring the **area of a triangle** by measuring its base and height.

3. Absolute (or Fundamental) Method:

- **Definition:** Measuring the unknown quantity directly in terms of **fundamental units** of measurement (like mass, length, time).
- **Explanation:** The measurement is based on the basic definition of the unit.
- **Example:** Measuring the length of a bar by comparing it directly with the standard **meter scale**. Determining mass using a **physical balance** with standard weights.

4. Comparative (or Secondary) Method:

- **Definition:** The value of the unknown quantity is determined by comparing it with a **known value (standard)** of the same quantity.
- **Explanation:** The instrument indicates the **difference** between the unknown and the standard, not the absolute value.
- **Example:** Using a **dial indicator** to check the runout of a shaft. The indicator shows how much the surface deviates from a perfect circle. Using **Johansson slip gauges** to set a comparator and then checking the workpiece.

(8) Give the classification of instruments for pressure measurement.

Classification of Pressure Measuring Devices

- The different instruments/devices used for the measurement of pressure can be classified as follows:
 1. Gravitation-type manometers
 2. Mechanical displacement-type manometers:
 - (a) Ring balance
 - (b) Bell-type
 3. Elastic pressure transducers:
 - (a) Bourdon tube pressure gauges
 - (b) Diaphragm-type gauges
 - (c) Bellow gauges
 4. Electrical pressure transducers:
 - (a) Resistance-type pressure transducer
 - (b) Potentiometer devices
 - (c) Inductive-type transducer
 - (d) Capacitive-type transducer
 - (e) Piezoelectric pressure transducer
 - (f) Bridgman gauges
 5. Low-pressure measurement gauges:
 - (a) McLeod gauges
 - (b) Pirani or thermal conductivity gauges
 - (c) Ionization gauges
 6. Engine indicator (for varying pressure measurements)

(9) Explain any one method used for force measurement.

Method: Proving Ring

The **proving ring** is a classic and accurate method for measuring force, primarily used as a **calibration standard** for testing machines.

Diagram:

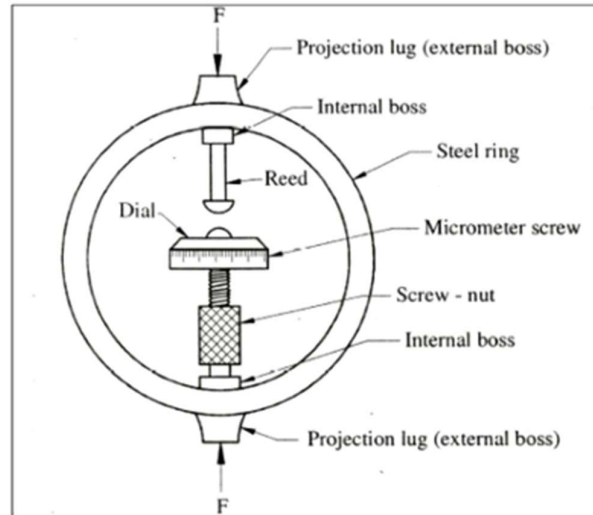


Fig.5.7 - Proving ring

Principle:

It works on the principle of **elastic deformation**. When a force (tensile or compressive) is applied across the diameter of a precision-machined steel ring, the ring deforms slightly. The amount of deformation (change in diameter) is directly proportional to the applied force within the elastic limit of the material.

Construction:

- It consists of a **high-quality steel ring** of a rectangular or circular cross-section.
- A **micrometer screw unit** and a **vibrating reed** (or a LVDT/ strain gauge in modern versions) are mounted on a central boss or arm, across the diameter perpendicular to the force application axis.
- The micrometer measures the change in this diameter.

Working/Measurement Process:

1. **Initial Zero Setting:** With no load applied, the micrometer is adjusted until it just makes contact with the anvil or until the **vibrating reed** just begins to "wink" or vibrate (indicating contact). The initial micrometer reading is noted.
2. **Application of Force:** The unknown force is applied to the proving ring along its loading axis (top and bottom).
3. **Deformation:** The ring deflects (flattens slightly under compression, or elongates under tension). This causes the diameter on which the micrometer is mounted to change.
4. **Final Reading:** The micrometer is readjusted to re-establish contact with the anvil (indicated again by the vibrating reed). The new reading is noted.
5. **Calculation of Force:** The difference between the final and initial readings gives the deflection (δ) of the ring. Using a **calibration chart** provided with the proving ring (which plots Force vs. Deflection), the force corresponding to the measured deflection is directly read.
 - $F = k \times \delta$, where k is the spring constant of the ring.

(10) Give the classifications of threads. Explain the common errors in threads.

Part A: Classifications of Screw Threads

Screw threads can be classified based on several factors:

1. Based on the Shape of the Thread (Profile):

- **V-Thread (Sharp V):** Thread profile is a sharp 'V'. Used for light-duty applications.
- **Whitworth Thread:** British standard with a rounded root and crest. Angle is 55° .
- **Metric Thread (ISO):** Similar to Whitworth but with a 60° angle and flattened crest and root. Most common for general engineering.
- **Square Thread:** Thread profile is square. Used for power transmission (e.g., vices, presses).
- **Acme Thread:** A modified square thread with a 29° angle, stronger and easier to cut. Used for lathe lead screws.
- **Knuckle Thread:** Rounded profile, used for rough work like lamp holders and hose couplings.

2. Based on the Direction of the Helix:

- **Right-Hand Thread:** The bolt advances into the nut when turned clockwise. (Most common).
- **Left-Hand Thread:** The bolt advances when turned counter-clockwise. (Used on rotating shafts to prevent loosening, e.g., left bicycle pedal).

3. Based on the Number of Starts:

- **Single-Start Thread:** Only one continuous helical ridge. The lead is equal to the pitch.
- **Multi-Start Thread:** Two or more parallel ridges running alongside each other. Provides faster axial movement (greater lead) for the same pitch. Used in valve stems and pen caps.

Part B: Common Errors in Threads

Errors can occur during the manufacturing of threads, affecting their fit and strength.

1. Major Diameter Errors:

- If the major diameter of an external thread is too large, or an internal thread's major diameter is too small, the threads will interfere and not assemble.
- If the major diameter is too small, it results in a weak and sloppy fit.

2. Minor Diameter Errors:

- An excessively large minor diameter on an internal thread will result in a weak thread form.
- An excessively small minor diameter on an internal thread can prevent the bolt from entering.

3. Effective (Pitch) Diameter Error:

- This is the most critical error. If the effective diameter of the bolt is too large or the nut's effective diameter is too small, the threads will interfere on the flanks and will not assemble, even if the major/minor diameters are correct.

4. Pitch Error:

- **Progressive Error:** The pitch increases or decreases uniformly along the length. The bolt will eventually jam in the nut after a few turns.
- **Periodic/Drunken Error:** The pitch varies in a regular pattern, often due to a worn or inaccurate lead screw on the threading machine.

5. Flank (Thread Angle) Error:

- If the angle of the thread flank is incorrect, contact will occur only near the crest or root of the thread instead of the flanks, leading to a loose fit or rapid wear.
