GUJARAT TECHNOLOGICAL UNIVERSITY

Program Name: Engineering
Level: Diploma
Branch: Mechanical Engineering/Mechanical Engineering (CAD/CAM)/ Mechatronics Engineering
Course / Subject Code: DI03000151
Course / Subject Name: Measurements and Metrology

w. e. f. Academic Year:	2024-25
Semester:	3rd
Category of the Course:	PCC

Prerequisite:	The Metrology and Measurement subject in diploma mechanical engineering requires a basic understanding of mathematics, physics, and engineering concepts. Students should be familiar with measurements, and error analysis, along with algebra and trigonometry for dimensional calculations. Knowledge of engineering drawing is essential, including geometric dimensioning and tolerancing (GD&T) and surface roughness symbols. A fundamental grasp of mechanical engineering concepts such as material properties, tolerances, and fits is necessary. Practical experience with measuring instruments like Vernier calipers and micrometers, gained through workshop practice, is beneficial. Understanding optical principles, force, and pressure measurement from physics helps in using precision instruments.
Rationale:	The mechanical engineering students primarily focus on the fabrication of diverse machine components in workshops according to specified drawings. Contemporary industrial processing and manufacturing procedures have grown intricate and convoluted, rendering their supervision just by visual examination very challenging. Thus, reliable and exact measurements via precision measuring tools are essential for enterprises. This Measurements & Metrology course offers practical experience, skills, and self-assurance to students, enabling them to operate precise measuring devices correctly for the benefit of industrial-sectors.

Course Outcome:

After Completion of the Course, Student will be able to:

Course Outcomes (COs) for Measurement and Metrology

CO No.	Course Outcome Statement
CO1	Explain the principles of linear, angular, and geometrical measurements and apply them in industrial quality control.
CO2	Demonstrate proficiency in using measuring instruments such as Vernier callipers, micrometres, dial gauges, slip gauges, and sine bars for precision measurement.
CO3	Analyse the surface roughness, gear, and thread parameters using appropriate metrology tools and techniques.
CO4	Evaluate the accuracy and precision of measurement systems, including transducers, sensors, and temperature measurement devices, in various applications.
CO5	Apply Industry 4.0 technologies in metrology for precise, automated, and data-driven quality control in manufacturing.

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Teaching and Examination Scheme:

Teaching Scheme (in Hours)			Total Credits L+T+ (PR/2)	Assessment Pattern and Marks				Total Marks
				Theory		Tutorial / Practical		
L	T	PR	C	ESE (E)	PA (M)	PA (I)	ESE (V)	
3	0	2	4	70	30	20	30	150

Course Content:

No.	Content	No. of Hours	% of Weightage
1.	**Introduction to Metrology** • Definition, Need & Scope of Metrology • Precision & Accuracy, Sensitivity, Readability, and Calibration • Standards of Measurement (Line, End, Wavelength Standards)	4	10
2.	**Linear and Angular Measurement** • Vernier Calliper, Micrometre, Dial Gauge, Slip Gauges • Height Gauge, Depth Gauge, Combination Set • Sine Bar, Bevel Protractor, Angle Gauges, Autocollimator • Applications and Errors in Measurements	7	16
3.	**Concept of Geometrical Tolerances** • Concept of Tolerance, Types of Fits, and Allowances • Measurement of Straightness, Flatness, Roundness, and Squareness • Introduction to Coordinate Measuring Machine (CMM)	6	14
4.	**Measurement of Surface Roughness** • Concept of Surface Finish, Surface Texture Terminology • Parameters of Surface Roughness (Ra, Rz, Rq) • Surface Roughness Measuring Instruments (Stylus Profilometer)	5	12
5.	**Gear and Thread Measurement** • Measurement of Spur Gear Parameters (Pitch, Module, Runout) • Gear Tooth Vernier and Base Tangent Method • Measurement of Thread Parameters (Pitch, Lead, Effective Diameter) • Two-Wire & Three-Wire Method	5	12
6.	**Limit Gauges** • Limit System: GO and NO-GO Gauges • Types of Gauges: Plug, Ring, Snap, and Thread Gauges • Interchangeability and Selective Assembly • Gauge design	4	10
7.	**Transducers and Sensors** • Definition and Classification of Transducers	4	10

	• Displacement, Pressure, Force, and Strain Measurement • Applications in Mechanical Systems		
8.	**Temperature Measurement** • Measurement of Temperature using Thermocouples, and Pyrometer • Infrared and Digital Temperature Sensors	3	7
9.	**Quality Control & Industry 4.0 in Metrology** • Introduction to Digital Measurement Techniques • Role of IoT in Quality Control • Automation in Metrology & Smart Inspection Systems	4	9
	Total	42	**100**

Suggested Specification Table with Marks (Theory):

Unit No.	Unit Name	Teaching Hours	Marks	R	U	A	N	E	C	Weight %
1	Introduction to Metrology	4	8	4	4	-	-	-	-	12
2	Linear and Angular Measurement	7	10	4	3	3	-	-	-	14
3	Measurement of Geometrical Tolerances	6	8	3	3	2	-	-	-	12
4	Measurement of Surface Roughness	5	8	3	3	2	-	-	-	12
5	Gear and Thread Measurement	5	8	2	4	2	-	-	-	12
6	Limit Gauges	4	8	2	4	2	-	-	-	12
7	Transducers and Sensors	4	7	-	2	3	2	-	-	9
8	Temperature Measurement	3	7	-	2	2	3	-	-	9
9	Quality Control & Industry 4.0 in Metrology	4	6	-	-	-	2	2	2	8
Total		**42**	**70**	**18**	**25**	**16**	**7**	**2**	**2**	**100**

Where R: Remember; U: Understanding; A: Application, N: Analyze and E: Evaluate C: Create (as per Revised Bloom's Taxonomy)

Note: *This specification table shall be treated as a general guideline for students and teachers. The actual distribution of marks in the question paper may vary slightly from above table.*

References/Suggested Learning Resources:

(a) Books:

Sr. No.	Author(s)	Book Title	Publication	Publication Place & Year	ISBN
1	Kesarmal Saini	Measurement & Metrology (ME-4001)	Neelkanth Publishers	India, 2023	978-9393570453
2	A.K. Bewoor, V.A. Kulkarni	Metrology and Measurement	McGraw-Hill Education	India, 2009	978-0070140003
3	S.P. Venkateshan	Mechanical Measurements	John Wiley & Sons	India, 2008	978-8120333508
4	R.K. Jain	Engineering Metrology	Khanna Publishers	India, 2008	978-8174091539
5	R.K. Rajput	Engineering Metrology and Instrumentation	S.K. Kataria & Sons	India, 2009	978-8131805854
6	I.C. Gupta	A Textbook of Engineering Metrology	Dhanpat Rai Publications	India, 2011	978-8188458523

(b) Open-source software and website:

1. Open-Source Software for Metrology & Measurement

Sr. No.	Software Name	Description	Download Link
1	**FreeCAD**	3D CAD modelling software with measurement tools for engineering applications.	https://www.freecad.org/
2	**OpenSCAD**	A parametric 3D modelling software useful for precision measurements.	https://www.openscad.org/
3	**Gwyddion**	Open-source software for surface metrology, mainly for scanning probe microscopy data analysis.	http://gwyddion.net/
4	**ImageJ**	Open-source image processing software for dimensional measurement from images.	https://imagej.nih.gov/ij/
5	**FEMM (Finite Element Method Magnetics)**	Useful for mechanical and metrology applications in finite element analysis.	http://www.femm.info/wiki/HomePage
6	**GNU Octave**	Open-source alternative to MATLAB, useful for metrology calculations and analysis.	https://www.gnu.org/software/octave/
7	**Python (SciPy,**	Used for data analysis, statistical	https://www.python.org/

	NumPy, Matplotlib)	calculations, and metrology-related computations.	

2. Educational Websites & Online Resources

Sr. No.	Website Name	Description	Link
1	**NPTEL (National Programme on Technology Enhanced Learning)**	Free online courses on metrology and measurement and Industry 4.0 by IIT professors.	https://nptel.ac.in/ https://shorturl.at/NySB6
2	**MIT Open Courseware (OCW)**	Engineering measurement and metrology resources from MIT.	https://ocw.mit.edu/
3	**Khan Academy**	Free educational videos related to measurement concepts and engineering applications.	https://www.khanacademy.org/
4	**Coursera**	Free and paid courses on metrology, measurement, and engineering topics.	https://www.coursera.org/
5	**EdX**	Online courses on measurement techniques from global universities.	https://www.edx.org/
6	**Metrology.net**	Online resources and latest advancements in industrial metrology.	https://www.metrology.net/
7	**CMM Quarterly**	Online magazine focused on coordinate measuring machines (CMM) and precision measurement.	http://www.cmmquarterly.com/

Suggested Course Practical List:
List of Practical for Metrology & Measurement

Sr. No.	Title of Experiment	Time Required (Hours)
1.	Preparatory Activity: S.I. basic, supplementary and derived units and their conversions. Convert given length, area and volume from one unit to another. (From mm to cm and m, from mm to inch, from m to yard and foot, from 2 mm to 2 inch and vice- versa, 3 mm to 3 inch and vice-versa, etc.). Convert given degree to radian and vice-versa. Various drafting, surface finish and geometrical symbols.	2
2.	Measurement using Vernier Calliper & Micrometre	4
3.	Measurement using Dial Gauge & Slip Gauges	4

4.	Angle Measurement using Bevel Protractor and Sine Bar	2
5.	Measurement of Straightness and Flatness using Dial Indicator	2
6.	Roundness Measurement using V block and dial indicator.	2
7.	Measurement of Surface Roughness using Stylus Profilometer.	2
8.	Measurement of Gear Tooth Parameters using Gear Tooth Vernier.	2
9.	Measurement of Thread Parameters using Two-Wire/Three-Wire Method.	2
10.	Study and Use of GO and NO-GO Gauges.	2
11.	Study of Strain Gauge for Force Measurement.	2
12.	Study of temperature measuring device.	2
TOTAL		**28**

Virtual Labs for Measurement & Metrology

- https://www.olabs.edu.in/?sub=1&brch=5&sim=16&cnt=4 (OLABS-Vernier Caliper).
- http://www.amrita.olabs.edu.in/?sub=1&brch=5&sim=16&cnt=4 (Vernier Caliper).
- https://amrita.olabs.edu.in/?sub=1&brch=5&sim=156&cnt=4 (Micrometer).
- https://kcgcollege.ac.in/Virtual-Lab/Mechanical/Exp-2/index.html (measurement of Major, Minor and Effective diameter of external screw thread using Floating Carriage micrometer).
- https://www.vlab.co.in/
- http://vlabs.iitkgp.ac.in/metro/loe.html

List of Laboratory/Learning Resources Required:

Sr. No.	Name of Equipment / Resource	Purpose / Application
1.	Vernier Calliper (Digital & Analog)	Measuring linear dimensions with high accuracy
2.	Micrometre (Inside & Outside)	Measuring small linear dimensions with high precision
3.	Dial Gauge with Magnetic Stand	Measuring small displacements, flatness, and alignment
4.	Slip Gauge Set	Calibration and precision measurement
5.	Bevel Protractor	Measuring angles with high precision
6.	Sine Bar	Measuring angles using slip gauges
7.	Surface Plate (Granite or Cast Iron)	Providing a reference surface for measurement
8.	Surface Roughness Tester (Stylus Profilometer)	Measuring surface texture and roughness
9.	Gear Tooth Vernier Calliper	Measuring gear tooth thickness and module
10.	Thread Micrometre & Screw Pitch Gauge	Measuring pitch diameter and lead angle of threads
11.	GO & NO-GO Gauges (Plug, Ring, Snap)	Checking tolerances of manufactured components

12.	Arduino-Based IoT Sensors	For real-time temperature, vibration & pressure monitoring

Suggested Project List:

Sr. No.	Project Title	Project Description	Expected Outcome
1.	Digital Vernier Calliper with Bluetooth Data Logging	Design a Vernier calliper that transmits measurement data via Bluetooth to a computer/mobile app.	Wireless data collection for quality control.
2.	Automated Gear Tooth Inspection System	Develop a system using image processing to measure gear parameters automatically.	Faster and more accurate gear measurement.
3.	Surface Roughness Analyzer using Arduino	Create a low-cost stylus-based roughness measuring device using Arduino and sensors.	Affordable roughness measurement solution.
4.	Smart Temperature Monitoring System	Use thermocouples, RTDs, and IoT for real-time temperature monitoring in industrial setups.	Improved temperature control and monitoring.
5.	LVDT-Based Displacement Measurement System	Design a working model of LVDT for measuring minute displacement variations.	Understanding of displacement measurement principles.
6.	3D Scanning for Measurement and Reverse Engineering	Utilize 3D scanning technology to capture dimensions of objects for analysis.	Hands-on experience with precision measurement tools.
7.	GO/NO-GO Gauge Design for a Specific Component	Develop a set of limit gauges for a machined part as per industry standards.	Practical understanding of tolerance checking.
8.	Smart Thread Pitch Measurement Tool	Build a digital thread pitch measurement system using image processing.	Accurate and automated thread inspection.
9.	Real-Time Strain Monitoring using Strain Gauges	Implement strain gauges on a structure and monitor strain variations in real time.	Understanding of material deformation under load.
10.	Automated Angle Measurement System	Create a digital angle measurement device using sensors and Arduino.	Accurate angle measurement with digital output.
11.	Quality Inspection Conveyor with Sensors	Develop a small working model of a conveyor belt with sensors to check object dimensions.	Hands-on learning in industrial quality control.
12.	Smart Digital Dial	Modify a dial indicator to store and	Improved data tracking

	Indicator with Data Storage	analyse measurements digitally.	and analysis.
13.	Contactless Temperature Measurement using IR Sensors	Design a non-contact temperature measurement system using infrared sensors.	Application of IR sensors in temperature measurement.

Suggested Activities for Students:

Sr. No.	Activity Title	Activity Description	Expected Outcome
1	Industrial Visit to a Metrology Lab	Visit an industry or quality control lab to observe real-world measurement applications.	Exposure to industrial metrology tools and techniques.
2	Hands-on Calibration of Measuring Instruments	Students calibrate Vernier calipers, micrometers, and dial gauges using standard gauges.	Understanding the importance of calibration in precision measurement.
3	Case Study on Quality Control in Manufacturing	Analyze a real-world case of a manufacturing defect due to improper measurement.	Learning about the role of metrology in quality assurance.
4	Debate: Manual vs. Digital Measuring Instruments	Conduct a debate on the pros and cons of manual vs. digital measuring devices.	Critical thinking and understanding technological advancements.
5	Demonstration of 3D Scanning and Reverse Engineering	Explore how 3D scanners are used for dimensional measurement and design.	Awareness of modern measurement techniques in engineering.
6	Group Activity: Tolerance and Fit Analysis	Students measure various components and classify fits (interference, clearance, transition).	Practical knowledge of engineering fits and tolerances.
7	DIY Surface Roughness Comparison	Compare different surface finishes by touch and use a roughness tester to verify perceptions.	Improved understanding of surface roughness measurement.
8	Measurement Error Analysis Experiment	Perform repeated measurements and analyze errors (systematic/random) using statistical tools.	Learning about accuracy, precision, and error minimization.
9	Role Play: Quality Inspector in a Manufacturing Unit	Students take turns acting as quality inspectors, identifying defects in sample parts.	Hands-on experience with quality control and defect detection.
10	Poster Presentation on Non-Destructive Testing (NDT)	Create and present posters on different NDT methods like ultrasonic, eddy current, and LPT.	Deep understanding of NDT techniques and applications.

11	Workshop on Latest Metrology Trends (CMM, Laser Scanning)	Attend a seminar on advanced metrology technologies like Coordinate Measuring Machines (CMM).	Awareness of modern metrology and automation in measurement.
12	Quiz Competition on Measurement & Metrology	Conduct a quiz covering fundamental metrology concepts and industrial applications.	Reinforcement of theoretical concepts in a fun and engaging way.
13	Virtual Lab Simulation on Precision Measurement	Use online simulation tools to practice measurement techniques virtually.	Hands-on virtual experience in metrology without physical tools.

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