GUJARAT TECHNOLOGICAL UNIVERSITY (GTU)

Competency-focused Outcome-based Green Curriculum-2021 (COGC-2021)
Semester-III

Course Title: Metrology and Instrumentation
(Course Code: 1336501)

Diploma programme in which this course is offered	Semester in which offered
CAD/CAM Mechanical Engineering	3rd Semester

1. RATIONALE

The students of the CAD/CAM mechanical engineering programme are basically concerned with manufacturing of various machine, components in shops as per given drawing. Today the industrial processing and manufacturing techniques have become complex and complicated, so their control is very much difficult by visual inspection only. Hence accurate and precise measurements by precision measuring instruments are the basic need of the industries. This course of Metrology and Instrumentation provides practical exposure, skills and self-confidence in the students so that they can operate those precision measuring instruments accurately in the benefit of manufacturing industries.

2. COMPETENCY

The course content should be taught and implemented with the aim to develop different types of skills so that students are able to acquire following competency.

- **Select and operate appropriate precision measuring instruments for the measurement of given manufacturing product/component.**

3. COURSE OUTCOMES (COs)

The theory should be taught and practical should be carried out in such a manner that students are able to acquire different learning out comes in cognitive, psychomotor and affective domain to demonstrate following course outcomes.

CO-1	Measure the given mechanical elements and assemblies using appropriate linear and angular measuring instruments.
CO-2	Measure geometrical tolerances and surface roughness of given components.
CO-3	Measure important dimensions of different types of gears and threads.
CO-4	Use appropriate limit gauges, transducers and sensors for given applications.
CO-5	Use appropriate temperature and pressure measuring devices for given application.

4. TEACHING AND EXAMINATION SCHEME

Teaching Scheme (In Hours)			Total Credits (L+T+P/2)	Examination Scheme				
				Theory Marks		Practical Marks		Total Marks
L	T	P	C	CA	ESE	CA	ESE	
3	0	2	4	30*	70	25	25	150

(*): Out of 30 marks under the theory CA, 10 marks are for assessment of the micro-project to facilitate integration of COs and the remaining 20 marks is the average of 2 tests to be taken during the semester for the assessing the attainment of the cognitive domain UOs required for the attainment of the COs.

***Legends:** **L**-Lecture; **T**– Tutorial/Teacher Guided Theory Practice; **P** -Practical; **C** – Credit, **CA** - Continuous Assessment; **ESE** -End Semester Examination.*

5. SUGGESTED PRACTICAL EXERCISES

Following practical outcomes (PrOs) are the sub-components of the Course Outcomes (Cos). These PrOs need to be attained to achieve the Cos.

Sr. No.	Practical Exercises (Outcomes in Psychomotor Domain)	Unit No.	Approx. Hrs. Required
1	**Preparatory Activity:** a. 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 mm^2 to $inch^2$ and vice- versa, mm^3 to $inch^3$ and vice-versa, etc.). b. Convert given degree to radian and vice-versa. c. Various drafting, surface finish and geometrical symbols. d. Define axis, axes, center, angles, plane and solid angle.	I	02
2	**Linear And Angular Measurement:** Each student will select and bring at least such five mechanical components which will have use of instruments specified below. Same are to be approved by teacher. After approval, student will: a. Sketch each component. b. Sketch and label main parts of instruments to be used. c. Calculate least count of the instrument/s to be used. d. Measure and record applicable dimensions of each component using: i. Vernier caliper. ii. Inside & Outside micrometer. iii. Telescopic gauge iv. Height gauge/depth gauge. v. Slip gauges (Calibration of vernier caliper and micrometer) vi. Bevel protector and sine bar.	I	08
3	**Measurement of geometrical tolerances:** Sketch the part and setup, list the instruments used, list the steps followed and record the observations for checking various geometrical tolerances like: a) Straightness b) Flatness	II	04

Sr. No.	Practical Exercises (Outcomes in Psychomotor Domain)	Unit No.	Approx. Hrs. Required
	c) Squareness, perpendicularity and parallity d) Roundness, Cylindricity, Concentricity, Runout and Ovality.		
4	**Surface Roughness:** a. Tabulate machining processes, and roughness values (Ra, mm), roughness grade number and roughness symbol. b. Demonstrate various surfaces having different roughness values. c. For given component, sketch the component, judge the roughness of surfaces and show surface roughness symbols on applicable surfaces. d. Measure surface roughness value of given machined surface.	III	02
5	**Gear Measurement:** a. Sketch gear tooth nomenclature. b. Sketch gear tooth vernier and label each part. c. Calculate chordal thickness and height of given gear. d. Determine tooth height. e. Measure and compare chordal thickness of given spurs gear using gear tooth vernier.	IV	02
6	**Thread Measurement:** For given external threaded part: a. Draw nomenclature for ISO screw threads (Internal and external both). b. Explain and derive best wire size. c. Sketch the part and show the dimensions to be measured. d. Sketch the set up and instruments used to measure/derive major diameter, minor diameter and effective diameter using two wire and three wire methods. e. Measure the pitch. f. Use threaded ring gauge. g. Record observations.	IV	03
7	**Limit Gauges:** a. Demonstrate use of various limit gauges. b. Select appropriate limit gauge for given dimension/part and check the dimension with gauge. c. Record your observations.	V	02
8	**Demonstration of Transducers and Sensors:** a. Demonstrate electrical (LVDT type, resistance type, capacitance type, inductance type and piezo-electric.) transducers and various sensors. b. Sketch each demonstrated transducers and sensors and tabulate specifications, range, resolution and applications of each.	V	02
9	**Temperature Measurement and Pressure Measurement:** **Temperature Measurement:** a. Sketch the set up and constructional sketch of thermocouple used to measure temperature. b. Measure the temperature of hot body/hot liquid with thermocouple.	VI	03

Sr. No.	Practical Exercises (Outcomes in Psychomotor Domain)	Unit No.	Approx. Hrs. Required
	c. Record the observation. **Pressure Measurement:** a. Sketch the set up and constructional sketch of pressure gauge used to measure pressure. b. Measure the pressure with pressure gauge. c. Record the observation.		
		Total	28

Note

a. It is compulsory to prepare log book of exercises. It is also required to get each exercise/practical's recorded in logbook, checked and duly dated signed by faculty.
b. Term work report content of each experience should also include following.
    1. Reports.
    2. Student activities.
c. For 25 marks of ESE, students are to be assessed for competencies achieved. They should be given following tasks. (i and any one from ii, iii and iv.)
    1. Measure the linear/angular dimensions and geometrical tolerances of given part/assembly.
    2. Measure important dimensions of different types of gears/threads.
    3. Use appropriate limit gauge for given components.
    4. Explain working of transducers and sensors.

The following are some **sample** 'Process' and 'Product' related skills (more may be added/deleted depending on the course) that occur in the above listed **Practical Exercises** of this course required which are embedded in the Cos and ultimately the competency.

S. No.	Sample Performance Indicators for the PrOs	Weightage in %
1	Knowledge of concept and Selection of instrument	25
2	Standard operating procedure	15
3	Measurement skill and data record	20
4	Result and Troubleshooting	25
5	Workplace safety and Ethical practice	15
Total		**100**

Sample rubrics Performance Indicators for the PrOs

Criteria	Rating Scale			
	Excellent (4)	**Good (3)**	**Fair (2)**	**Poor (1)**
Knowledge of concept and Selection of instrument	Student has excellent knowledge of concept and precisely select appropriate instrument for high accuracy.	Student has good knowledge of concept and able to select appropriate instrument.	Student has fair knowledge of concept and managed to select instrument for measurement.	Student has poor knowledge of concept and unable to select appropriate instrument.
Standard operating procedure	Student always Follow all the standard Procedure with utmost precaution and in logical order.	Student Follow all the standard Procedure with precaution and in logical order.	Student Follow all the standard Procedure with some precaution.	Student not completely Follow all the standard Procedure.
Measurement skill and data record	Student demonstrate excellent measurement skill by taking all measurement very accurately and note it down in lab manual.	Student demonstrate good measurement skill by taking all measurement and note it down in lab manual.	Student demonstrate fair measurement skill by taking some measurement and note it down in lab manual.	Student demonstrate poor measurement skill by not taking measurement accurately and has poor record of data keeping.
Result and Troubleshooting	Student get very accurate result & has ability to detect and correct the error.	Student get accurate result & has managed to detect and correct the error.	Student get result within tolerance range & has managed to detect and correct the error with little help.	Student get result which is not accurate nor in tolerance range. Student has not able to detect error.
Workplace safety and Ethical practice	Student display excellent punctuality & always follow and also encourage others to follow all safety norms ethically during measurement.	Student display good punctuality and always follow all safety norms ethically during measurement.	Student display fair punctuality and follow safety norms during measurement.	Student is not punctual nor follow safety norms during measurement.

6. MAJOR EQUIPMENT/INSTRUMENTS REQUIRED

These major equipment with broad specifications for the PrOs is a guide to procure them by the administrators to use in uniformity of practical in all institutions across the state.

Sr. No.	Equipment Name with Broad Specifications	Practical No.
1	1. Surface plate, 500 x 500 mm. 2. Vernier calliper, 0 to 200 mm, least count 0.02 mm. 3. Vernier calliper, 0 to 200 mm, least count 0.01 mm, digital. 4. Inside micrometers, least count 0.01 mm, 50-75 mm. 5. Micrometer, least count 0.01 mm, 0-25mm, 25-50 mm, 50-75 mm. 6. Outside micrometer, least count 0.001 mm, 0-250 mm. 7. Telescopic gauge- 10-100 mm. 8. Height gauge- 300 mm with least count 0.02 mm. 9. Depth gauge- 200 mm with least count 0.02 mm. 10. Bevel protector with least count 5'. 11. Slip gauge box (Preferably M112/1) 12. Sine bar- 100 mm, 200 mm.	2
2	1. Straight edge, 500 mm. 2. Feeler gauge, radius gauge, thread pitch gauge. 3. Dial indicators magnetic stand. 4. Dial indicators, least count 0.01 mm. 5. V blocks.	3
3	1. Samples of various surface textures and different surface roughness. 2. Microprocessor- stylus-probe based surface roughness testing machine. 3. Microscope to compare various textures and surface roughness.	4
4	1. Gear tooth vernier. 2. Profile Projector 3. Set of best wire to measure thread dimensions. 4. Thread Micrometers	5 & 6
5	Set of limit gauges- sorted sizes, plug gauges, thread ring gauges and Snap gauges.	7
6	1. LVDT type, resistance type, capacitance type, inductance type and piezo-electric type transducers. 2. Sensors, position, proximate, velocity, force/strain	8
7	1. Thermometers. 2. Various types of thermocouples.	9

7. AFFECTIVE DOMAIN OUTCOMES

The following ***sample*** Affective Domain Outcomes (ADOs) are embedded in many of the above-mentioned COs and PrOs. More could be added to fulfill the development of this course competency.

a) Work as a leader/a team member.
b) Follow safety practices.
c) Follow ethical practices
d) Maintain instruments and equipment.
e) Practice environment friendly methods and processes. (Environment related).

The ADOs are best developed through the laboratory/field-based exercises. Moreover, the level of achievement of the ADOs according to Krathwohl's 'Affective Domain Taxonomy' should gradually increase as planned below:

I. 'Valuing Level' in 1st year
II. 'Organization Level' in 2nd year.
III. 'Characterization Level' in 3rd year.

8. UNDERPINNING THEORY

The major underpinning theory is given below based on the higher level UOs of Revised Bloom's taxonomy that are formulated for development of the COs and competency. If required, more such higher level UOs could be included by the course teacher to focus on attainment of COs and competency.

Unit	Unit Outcomes (UOs) (4 to 6 UOs at different levels)	Topics and Sub-topics
Unit – I **Linear and angular measurement**	1a. Distinguish between accuracy, precision and error.	1.1 Inspection, quality and quality control-definitions and differences. 1.2 Define accuracy, precision and error. 1.3 Surface plates-types, important features, standards/important sizes, applications and precautions in use.
	1b. Determine least count of given measuring instrument. 1c. Select suitable linear measuring instrument and measure the linear dimension of given component.	1.4 Principle of vernier scale and least count. 1.5 Types, constructional sketch, major parts and their functions, least count, measuring methods and measurement illustration (for e.g., 12.48mm) of: i. Vernier caliper. ii. Micrometer. iii. Telescopic gauge. iv. Height gauge. v. Depth gauge.
	1d. Describe the procedure for wring the slip gauge and set given dimension.	1.6 Slip gauge-types, applications, and wringing method.

Unit	Unit Outcomes (UOs) (4 to 6 UOs at different levels)	Topics and Sub-topics
	1e. Select suitable angular measuring instrument. 1f. Describe the measurement procedure for the angular dimension of given component.	1.7 Sketch, major parts and their functions, least count, measuring methods and measurement illustration of: I. Bevel Protector. II. Sine bar. III. Angle gauges. IV. Spirit level. V. Clinometers. VI. Auto collimator. 1.8 Calibration – concept and need.
Unit – II **Measurement of geometrical tolerances**	2a. Explain working of dial indicators. 2b. Select the measuring method and describe the measurement procedure for geometrical tolerance of given part/assembly.	2.1 Dial indicators/gauge-types, constructional sketch and applications. 2.2 Definition, symbol and measuring methods of: I. Straightness. II. ii. Flatness. III. Squareness. IV. Parallism. V. Perpendicularity. VI. Roundness. VII. Concentricity. VIII. Cylindricity. IX. Run out and ovality.
Unit – III **Measurement of surface roughness**	3a. Define various terminology used for surface roughness. 3b. Explain working of direct instrument methods.	3.1 Terminology used in connection with surface finish. 3.2 Comparison methods to inspect surface finish-concept and applications. 3.3 Direct instrument measurement methods-types and concepts. 3.4 Construction, working and applications of Talysurf surface roughness tester and Tomlinson tester.
	3c. Determine surface roughness of given data.	3.5 Centre line average and Root Mean Square systems of surface texture evaluation-terminology used, concept, equations and numerical examples. 3.6 Indication of various surface roughness characteristics with surface roughness symbols-interpretation.
Unit – IV **Gear and thread measurement**	4a. Define various terms used for gear nomenclature. 4b. Use gear tooth vernier to measure gear tooth thickness.	4.1 Types of gears. 4.2 Forms of gear teeth-types and concept. 4.3 Gear tooth Terminology. 4.4 Sketch, major parts and their functions, least count, measuring methods and measurement illustration of gear tooth vernier. 4.5 Derivation and numerical example to measure gear tooth thickness using: I. Gear tooth vernier. II. Constant chord method. III. Base tangent method.

Unit	Unit Outcomes (UOs) (4 to 6 UOs at different levels)	Topics and Sub-topics
	4c. Explain working of profile projector. 4d. Define various terms used for thread nomenclature. 4e. Determine best wire size. 4f. Use two and three wire methods to determine effective diameter of thread. 4g. Describe method for measuring the pitch of given thread.	4.6 Gear tooth profile measurement. 4.7 Threads-classification, elements, specifications and forms. 4.8 Measurement of major and minor diameters. 4.9 Three and two wire method of measuring effective diameter of external thread-concept, terminology used, best wire size, derivation of equation and numerical example. 4.10 Thread micrometer-sketch, method to use and determination of dimension. 4.11 Pitch measurement methods.
Unit – V **Limit gauges, Transducers and sensors**	5a. Select and check the given dimension using limit gauge.	5.1 Limit gauges-classification, sketch and applications. 5.2 Comparators-concept, types and applications.
	5b. Define static characteristics of instruments.	5.3 Instrumentation-introduction, performance characteristics. 5.4 Static characteristics of instruments.
	5c. Explain various transducers and sensors.	5.5 Transducers-concept, classifications, physical quantities which can be measured, advantages and disadvantages. 5.6 Electrical transducers-types, working principles and applications of: I. Linear Variable Differential Transducers (LVDT). II. Resistance type. III. Capacitance type. IV. Inductance type. V. Piezo-electric type. 5.7 Sensors- classification and applications. 5.8 Use of transducers and sensors as a safety measures.
Unit – VI **Temperature and Pressure measurement**	6a. Select and describe the method for using appropriate temperature measuring device to measure temperature of given hot body.	6.1 Introduction. 6.2 Classification, working principle, construction, working, advantages, limitations and applications of temperature measuring devices: I. Mercury in glass thermometer. II. Bimetallic thermometer. III. Resistance thermometer. IV. Thermistor. V. Thermocouple. VI. Radiation pyrometers. VII. Optical pyrometers.

Unit	Unit Outcomes (UOs) (4 to 6 UOs at different levels)	Topics and Sub-topics
	6b. Select and describe the method for using appropriate pressure measuring device to measure pressure.	6.3 Pressure measurement scales. 6.4 Types and applications of manometers (only list and applications). 6.5 Working principle, construction, working, advantages, limitations and applications of pressure measuring devices: I. Bellows type pressure gauge. II. Diaphragm type pressure gauge. III. Bourdon tube pressure gauge. IV. Dead weight piston gauge. 6.6 Concept of transducer-based pressure measuring devices resistance type, capacitance type and inductance type. 6.7 Use of Temperature and Pressure measurement as a safety measures.

9. SUGGESTED SPECIFICATION TABLE FOR QUESTION PAPER DESIGN

Unit	Unit Title	Teaching Hours	Distribution of Theory Marks			
			R Level	U Level	A Level	Total Marks
I	Linear and angular measurement	10	06	08	06	20
II	Measurement of geometrical tolerances	06	02	03	03	08
III	Measurement of surface roughness	06	02	03	03	08
IV	Gear and Thread measurement	08	04	08	04	16
V	Limit gauges, transducers and sensors	08	02	06	04	12
VI	Temperature and Pressure measurement	04	02	04	00	06
	Total	**42**	**18**	**32**	**20**	**70**

Legends: *R=Remember, U=Understand, A=Apply and above (Revised Bloom's taxonomy)*

Note: This specification table provides general guidelines to assist student for their learning and to teachers to teach and question paper designers/setters to formulate test items/questions to assess the attainment of the COs. The actual distribution of marks at different taxonomy levels (of R, U and A) in the question paper may slightly vary from above table.

10. SUGGESTED STUDENT ACTIVITIES

Other than the classroom and laboratory learning, following are the suggested student-related ***co-curricular*** activities which can be undertaken to accelerate the attainment of the various outcomes in this course: Students should perform following activities in group and prepare reports for each activity. They should also collect/record physical evidences for their (student's) portfolio which may be useful for their placement interviews:

a) Visit the workshop and identify the machined components which require geometrical tolerances.
b) Visit any industry/tool room and observe the working of inspection and testing department and also prepare the report.
c) Calibrate any one instrument having error in laboratory.

11. SUGGESTED SPECIAL INSTRUCTIONAL STRATEGIES (if any)

These are sample strategies, which the teacher can use to accelerate the attainment of the various outcomes in this course:

a) Massive open online courses (***MOOCs***) may be used to teach various topics/sub topics.
b) Guide student(s) in undertaking micro-projects.
c) ***'L' in section No. 4*** means different types of teaching methods that are to be employed byteachers to develop the outcomes.
d) About ***20% of the topics/sub-topics*** which are relatively simpler or descriptive in nature is to be given to the students for ***self-learning***, but to be assessed using different assessment methods.
e) With respect to ***section No.10***, teachers need to ensure to create opportunities and provisions for ***co-curricular*** activities.
f) Guide students on how to address issues on environment and sustainability.
g) For this course teacher may use one or combine of any strategies from below for better teaching learning experience.
   - Demonstration of actual instrument.
   - Videos of measuring methods.
   - Perform virtual lab experiments.
   - Industrial visits.

12. SUGGESTED MICRO-PROJECTS

Only one micro-project is planned to be undertaken by a student that needs to be assigned to him/her in the beginning of the semester. In the first four semesters, the micro-projects are group-based (group of 3 to 5). However, **in the fifth and sixth semesters**, the number of students in the group should ***not exceed three.***

The micro-project could be industry application based, internet-based, workshop-based, laboratory-based or field-based. Each micro-project should encompass two or more COs which are in fact, an integration of PrOs, UOs and ADOs. Each student will have to maintain dated work diary consisting of individual contribution in the project work and give a seminar presentation of it before submission. The duration of the micro project should be about **14-16** ***(fourteen to sixteen) student engagement hours*** during the course. The students ought to submit micro-project by the end of the semester to develop the industry-oriented COs.

A suggestive list of micro-projects is given here. This has to match the competency and the COs. Similar micro-projects could be added by the concerned course teacher:

a) Perform a Virtual lab experiment of any one from Linear measuring instrument/Angular measuring instrument/Temperature measurement/Pressure measurement/gear and thread measurement and prepare an observation table for the same.

b) Select a readymade mechanical component/product/assembly from college workshop/industry/market of distinct dimensions, prepare a drawing of it, select and

measure it with various available precision measuring instruments and note it down in drawing. (Select items with at least 5-6 dimensions and try to cover many varieties of instruments like linear, angular, indirect, analog, digital etc.)

c) Prepare a poster/PPT/Animation of any precision measuring instrument containing working principle, least count, construction, reading method, types etc.

d) Do an industrial visit of nearby manufacturing industries/calibration lab and prepare a detail report on list of instruments with its types, range and least count used in the particular industries.

e) Select a mechanical part, measure same dimensions with different instrument also having different least count and observe the change in readings.

13. SUGGESTED LEARNING RESOURCES

Sr. No.	Title of Book	Author	Publication with place, year and ISBN
1	Mechanical measurements and instrumentation	R.K.Rajput	KATSON
2	Engineering Metrology and Measurements	N.V. RAGHAVENDRA & L. KRISHNAMURTHY	OXFORD University press
3	Mechanical Measurement	Sirohi R.S., Radha Krishnan H.C.	New Age International
4	Practical Engineering Metrology	K.W.B.Sdarp	Pitman
5	Engineering Metrology	R.K.Jain	Khanna Publications.
6	Metrology & Measurement	Anand Bewoor & Vinay Kulkarn	Tata McGrawHill
7	Industrial Instrumentation & Control	S K Singh	Tata McGrawHill
8	Mechanical Measurement	Beckwith & Buck	Narosa publishing House
9	Mechanical Measurement and Control	D.S.Kumar	Metropolitan Book Pub.
10	Mechatronics	W.Bolten	PEARSON
11	Gear Metrology	C.A.Scoks	

14. SOFTWARE/LEARNING WEBSITES

MOOCS

- https://swayam.gov.in/ (SWAYAM Portal)
- Reference videos from IIT Kanpur MOOC on Engineering Metrology (Gear Metrology).
  - i. https://youtu.be/7ZteZ5UTW6E (Part-1)
  - ii. https://youtu.be/GzMPsjMQKGY (Part-2)
- Reference videos from IIT Roorkee MOOC on Inspection and Quality control in Manufacturing (Gear Measurement).
  1. https://youtu.be/X8KPNVZhvmo

Vertual Labs

- 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).

You tube links

- https://www.youtube.com/watch?v=xgQYvEELbfc (Vernier Caliper).
- https://www.youtube.com/watch?v=FNdkYIVJ3Vc (Vernier Caliper).
- https://www.youtube.com/watch?v=O8vMFFYNIfo (Micrometer)
- https://www.youtube.com/watch?v=h98HPVuWjLA (depth micrometer)
- https://www.youtube.com/watch?v=SmXfGan_NXQ (telescopic gauge)
- https://www.youtube.com/watch?v=eVpoJzLJa0U(surface roughness)
- https://www.youtube.com/watch?v=3Od7vnoMwGg(surface roughness)
- https://www.youtube.com/watch?v=XnLiTPGE6pk (three wire thread measurement)
- https://www.youtube.com/watch?v=Gdvtw0pTAOs (thread pitch)
- https://www.youtube.com/watch?v=qMgXGedDffw (dial indicator)
- http://www.youtube.com/watch?v=lc4dsNvm2Ks (principle of mechanical measurement).
- http://www.youtube.com/watch?v=nv3GuJArjNU (Transducers).
- http://www.youtube.com/watch?v=iMIzApq1CQ0 (pressure measurement).
- http://www.youtube.com/watch?v=JKuoQ5FV2c8 (temperature measurement).
- http://www.youtube.com/watch?v=GNOI_7ftbQ0(temperature measurement).
- http://www.youtube.com/watch?v=QItuf6lNvmI (Capacitive sensors)
- http://www.youtube.com/watch?v=inLkCOwVgyM (force sensors).
- http://www.youtube.com/watch?v=0MP_9n08urA(force sensors).
- http://www.youtube.com/watch?v=zAddvPHfKnw (force sensors)
- http://www.youtube.com/watch?v=_fQSMVf3hdM (calibration).
- http://www.youtube.com/watch?v=ZymDMUuVuyY (geometrical Tolerance).
- http://www.youtube.com/watch?v=5eaSkU6Ecik (flatness measurement).
- http://www.youtube.com/watch?v=1JNCe9fwRUw (Measuring Perpendicularity)
- http://www.youtube.com/watch?v=eJ8a0k8kQIE (Roundness and cylindricity).
- https://youtu.be/jTfUFQ-sbas (Types of Gear in Hindi).
- https://youtu.be/bH3v2bGvLyM (Types of Gear in English).
- https://youtu.be/8AS15R_Q52o (Gear teeth form in Hindi).
- https://youtu.be/ococqpOzbt8 (Gear Tooth Terminology in Hindi).
- https://youtu.be/8hkmFClpwPU (Gear Tooth Terminology in English).
- https://youtu.be/fdz8x5Rgswo (Gear Tooth Terminology in English).
- https://youtu.be/LDhZJ5Ya5YI (Line of action and pressure angle in English).
- https://youtu.be/3L5ZlG8p9Co (measurement of gear tooth thickness in English).
- https://youtu.be/suWlbCsIomg (measurement of gear tooth thickness in Hindi).
- https://youtu.be/FR8Jxr-b3ds (Gear Tooth Vernier Caliper).
- https://youtu.be/Ws98uEZA1MY (Constant chord method in English).
- https://youtu.be/ZKx7jQYj0jk (Constant chord method in Hindi).
- https://youtu.be/_P2q9w49j_w (David brown base tangent comparator method in English)
- https://youtu.be/lyo2POzjslY (David brown gear tooth form testing).
- https://youtu.be/RuAnfLllaDY (Tool room microscope as projection method for small gear).
- https://youtu.be/DYUsqEzV5pY (Parkinson's gear tester in Hindi/English).
- https://youtu.be/qCSCR5RSiPI (Parkinson's gear tester in English).

15. PO-COMPETENCY-CO MAPPING

Semester III	Metrology and Instrumentation (Course Code: - 1336501)						
	POS						
Competency & Course Outcomes	PO1 Basic and Discipline specific knowledge	PO2 Problem analysis	PO3 Design/ development of solutions	PO4 Engineering Tools, Experimentation and Testing	PO5 Engineering practices for society, sustainability and environment	PO6 Project Management	PO7 Life-long learning
Competency	**Select and operate appropriate precision measuring instruments for the measurement of given manufacturing product/component.**						
CO1-Measure the given mechanical elements and assemblies using appropriate linear and angular measuring instruments.	3	-	-	3	-	2	2
CO2-Measure geometrical tolerances and surface roughness of given components.	3	-	-	3	-	1	2
CO3-Measure important dimensions of different types of gears and threads.	3	-	-	3	-	2	2
CO4-Use appropriate limit gauges, transducers and sensors for given applications.	2	-	-	3	2	2	2
CO5-Use appropriate temperature and pressure measuring devices for given application.	3	-	-	3	2	1	2

*Legend: '**3**'for high, '**2**'for medium, **'1'**for low and **'-'**for no correlation of each CO with PO.*

16. COURSE CURRICULUM DEVELOPMENT COMMITTEE

GTU Resource Persons

S. No.	Name and Designation	Institute	Contact No.	Email
1.	Dr. Hemang J. Parekh Lecturer in Mechanical Engg.	Government Polytechnic Jamnagar	9426481731	parekhhemang080@gmail.com
2.	Mr. Kanaksinh M. Zala Lecturer in Mechanical Engg	Government Polytechnic Jamnagar	9723280611	kanaksinhzala03@gmail.com
3.	Mr. Dipak B. Harsora Lecturer in Mechanical Engg	Government Polytechnic Jamnagar	9913492919	dipak.harsoraedu@gmail.com

BOS Resource Persons

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