NATIONAL INSTITUTE OF TECHNOLOGY WARANGAL

Minor in
MECHANICAL ENGINEERING

SCHEME OF INSTRUCTION AND SYLLABI

for B.Tech. Program

(Effective from 2021-22)

DEPARTMENT OF MECHANICAL ENGINEERING

Scheme of Instruction
Minor in Mechanical Engineering

S.No.	Subject name	Semester
1	MEM01 Fluid Mechanics and Heat Transfer	III
2	MEM02 Kinematics and Dynamics of Machinery	IV
3	MEM03 Manufacturing Processes	V
4	MEM04 Applied Thermal Engineering	VI
5	MEM05 Solid Mechanics and Machine Design	VII
6	ME401 Robotics	VII
7	ME415 Total Quality Management	VII
8	MEM06 Operations Management	VIII
9	MEM07 Measurements & Metrology	VIII

Course Code: MEM01	FLUID MECHANICS AND HEAT TRANSFER	3-0-0: 3

Prerequisites: NIL

Course Outcomes:

CO1	Evaluate the hydrostatic forces acting over a plane solid surface of any orientation
CO2	Apply the conservation equations to fluid flow problems and also estimate the losses in pipe flows
CO3	Evaluate the heat transfer rate for one-dimensional regular geometries
CO4	Apply the conservation equations to solve problems involving fluid flow for convective heat transfer rate
CO5	Estimate the heat transfer performance of heat exchangers using LMTD Method

Syllabus:

Fluid properties: Density, specific weight, specific gravity, Viscosity, Vapor Pressure, Surface tension

Fluid statistics: Pressure, hydrostatic pressure force on a curved surface, buoyancy, floatation and stability

Fluid kinematics: Eulerian & Lagrangian approach, classification of flows, stream lines streak lines and path lines, Acceleration and material derivative, Control volume.

Integral and Differential analysis of fluid flow: Derivation of Conservation equations, Euler's equation and Bernoulli's equation.

Viscous flows in pipes: Laminar and turbulent flows, Pipe flow losses: major losses, minor losses, Flow over Immersed bodies: Boundary layer, Lift and drag

Basic modes of heat transfer: Conduction, Convection and Radiation

Heat Conduction: General Heat Conduction Equation, One –dimensional steady state heat transfer, Lumped heat capacity system.

Convection Heat Transfer: Derivation of energy equation, Analogy between fluid flow and heat transfer. Forced Convection –Internal flow and External flow, Free Convection.

Heat Exchangers: Types of Heat Exchangers, LMTD method,

Radiation: Radiation exchange between Black bodies and grey bodies.

Learning Resources:

Text Books:

1. Introduction to fluid mechanics, Fox, R. W., McDonald, A. T., & Pritchard, P. J. Hoboken, N.J: Wiley.2008
2. Fundamentals of Heat and Mass Transfer, Incropera, Frank P, Hoboken, NJ: John Wiley, 2011, 7th edition.

Reference Books:

1. Fundamentals of fluid mechanics, Munson, B. R., Young, D. F., & Okiishi, T. H Hoboken, NJ: J. Wiley & Sons, 2006
2. Heat Transfer, Holman, J. P., Tata McGraw Hill, New Delhi.
3. Heat Transfer - A Basic Approach, M. Necati Ozisik, McGraw Hill, New York.

Online Resources:

1. Fluid Mechanics, NPTEL course by S.K. Som, IIT Kharagpur (Link:https://nptel.ac.in/courses/112/105/112105171/#)
2. Heat and mass transfer NPTEL Web Course (https://nptel.ac.in/courses/112/108/112108149/#)

Course Code: MEM02	KINEMATICS AND DYNAMICS OF MACHINERY	3-0-0: 3

Pre-Requisites: NIL

Course Outcomes:

CO1	Understand the principles of Four bar mechanism and planar mechanisms
CO2	Understand the Velocity and Acceleration Analysis
CO3	Characterize and design flywheels
CO4	Design centrifugal governors
CO5	Understand the principles of mechanical vibrations

Syllabus:

Basics of Mechanisms: Definitions of Mechanism and Machine and distinguishing these two. Plane and space mechanisms with examples. Four bar mechanism and slider crank mechanism with practical examples; deriving the latter from the former. Kinematic pairs with examples. Kinematic chains with examples. Kinematic inversions of single and double slider crank mechanisms. Degrees of freedom of mechanisms. Grashof and non-Grashof mechanisms. Quick return mechanisms and time ratio. Geneva and eccentric mechanisms, Cam and follower mechanism and applications.

Velocity and Acceleration Analysis: Concept of instantaneous center, Kennedy's theorem. Velocity analysis. Concept of relative velocity method. Examples on simple mechanism. Acceleration analysis: Klein's construction, slider crank linkage, Coriolis acceleration component, Crank and slotted lever.

Spur Gears: Kinematics of gears, law of gearing, involute teeth, terminology such as addendum, dedendum, addendum circle, dedendum circle, pitch circle, base circle, pitch point, pressure line, pressure angle, clearance, rack and pinion, different types of pitches, path of contact.

Gear Trains: Kinematics of gear trains, simple gear trains and velocity ratio. Planetary gear trains and analysis; simple problems only. Differential gear of automobiles.

Flywheels: Working principle, Force analysis of single slider crank chain. Turning moment diagrams. Maximum fluctuation of energy and its determination. Coefficient of fluctuation of speed. Rim type versus solid type flywheel.

Gyroscope: Principle of gyroscope, Roll, Pitch and Yaw motions, Gyroscopic effect in a two-wheeler, car, ship and airplane.

Balancing of Rotors: Balancing and its types, Rotor balancing, Single plane and two plane balancing. Unbalanced forces and couples. Static and dynamic balancing, Balancing of rotors by analytical method and graphical method. Balancing of reciprocating machines- primary and secondary and higher order unbalanced forces.

Mechanical Vibrations: Free and forced vibrations of spring mass system with and without

damper. Natural frequency, Degree of freedom, Resonance. Energy method and Rayleigh's method. Vibration of undamped system under harmonic excitation, Effect of frequency of excitation on the amplitude of vibrations. Magnification Factor, Phase difference between excitation and motion. Rotating unbalance, whirling of shaft, critical speed and its practical

importance in the design of shafts. Vibration isolation and some practical cases.

Learning Resources:

Text Books:

1. Theory of Mechanisms and Machines, Amitabha Ghosh and Ashok Kumar Mallik, East West Press Pvt. Ltd., New Delhi, 2017, 3rd edition.
2. Theory of Machines, S.S.Rattan, McGraw-Hill Publications, New Delhi, 2011, 3rd edition.
3. Theory of Machines and Mechanisms, Shigley J. E. and John Joseph Uicker, McGraw-Hill international edition 2003, 2nd edition.
4. Design of Machinery: An Introduction to the Synthesis and Analysis of Mechanisms and Machines, Robert Norton, McGraw-Hill, 2003, 5th edition.

Course Code: MEM03	MANUFACTURING PROCESSES	3-0-0: 3

Prerequisites: NIL

Course Outcomes:

CO1	Design patterns and cores for metal casting process
CO2	Design near net shaped components from metal and ceramic powders
CO3	Develop joints using solid state and fusion joining, brazing and soldering techniques
CO4	Develop process-maps for metal forming processes using plasticity principles
CO5	Understand the classification of AM processes

Syllabus:

Introduction to Manufacturing, History of Manufacturing, Net and near-net shape manufacturing and their evolution

Primary Processes:

Casting: Introduction, Types of different Casting Methods, Solidification of Alloys and its mechanism, Gating System Design and Estimation of Solidification time, Riser Design and Riser Placement, Process Variations, Defects and Remedies. Problems on casting

Powder Metallurgy: (Metals and Ceramics) Techniques of near net shape manufacturing, techniques of powder manufacturing, powder compaction methods, introduction to sintering, Sintering phenomenon, post sintering operations. Problems on sintering

Welding: Physics of Welding - Types of welding - Fusion and Solid-state welding processes- - Solidification Phenomenon in Welding – Microstructural Evolution – Different Zones of Weld Region and their Microstructural Evolution - Brazing and Soldering, Defects and Remedies - Problems on welding

Deformation Processes:

Metal Forming: Introduction, Types of Forming Methods - Bulk and Sheet, Mechanism of plastic deformation, State of Stress and boundary conditions in Upsetting/forging, Rolling, Wire and tube drawing, Extrusion and Deep Drawing, Defects, Load estimation for one plane strain and one axi-symmetric bulk deformation processes. Problems on forming

Subtractive Processes

Machine Tools: Introduction: Generatrix and Directrix, Elements of M/C Tools, M/C Tool drives, Classification of Machine Tools.

Lathe: Types, Parts, Feed Mechanisms, Specifications of lathe, Lathe Operations, Accessories and Attachments, Machining time estimation.

Shaper and Planer: Types, Specifications, Crank and slotted link mechanism, Stroke length and position adjustments, Automatic feed mechanisms, Shaper Vs Planer, Machining time estimation

Drilling: Operations, Types, Mechanisms, Nomenclature of a drill, Machining time estimation.

Milling: Types, Up Milling Vs Down Milling, Types of milling cutters, Operations, Machining time estimation, Methods of indexing, dividing head

Grinding: Specification and selection of grinding wheels, Truing, Dressing, Classification of Grinding wheels.

Additive Processes:

Introduction to AM and its need, categorization of AM process, steps in AM process, Additive processes for non-metal, metal based additive manufacturing process, development of functionally graded material, applications of AM using case studies

Learning Resources:

Text Books:

1. Manufacturing Science, Amitabha Ghosh and Mallick A. K, Affiliated East-West Press Pvt. Ltd. 2010
2. Manufacturing Technology Vol1 – Foundry, Forming and Welding, P N Rao, 2018, 5th Edition
3. Manufacturing Technology Vol2 – Metal Cutting and Machine Tools, P N Rao, 2018, 4th Edition

Reference Books:

1. Manufacturing Engineering and Technology (SI Edition), Serope Kalpakjian, Steven R. Schmid, Pearson, 2014, 7th Edition
2. DeGarmo's Materials and Processes in Manufacturing, J. T. Black, Ronald A. Kohser, 2019, 13th Edition

Online Resources:

1. https://www.mooc-list.com/tags/manufacturing

Course Code: MEM04	APPLIED THERMAL ENGINEERING	3-0-0: 3

Prerequisites: NIL

Course Outcomes:

CO1	Apply thermodynamic concepts to understand the working of thermal systems.
CO2	Understand the construction and principle of operation of boiler, compressor, nozzle, turbine and condenser.
CO3	Understand the concepts of air conditioning, psychrometry and cooling load calculations.
CO4	Analyse the steam power plant and air standard cycles.
CO5	Design and analysis of steam nozzles and steam turbines.

Syllabus:

Review of thermodynamics: Laws of thermodynamics; process and cycles, Closed and Open Systems, Mass and energy balance, Rankine cycle and modified Rankine cycle

Boilers: Different types of boilers, description and working procedure, boiler mountings and accessories. Performance characteristics.

Compressor: Types of compressors: Reciprocating, rotary and centrifugal Compressors. Principle of Operation, Temperature-Entropy diagram, velocity triangles, Flow analysis

Steam turbines: Types of turbines: Impulse and reaction turbines, compounding of turbines, optimum velocity ratio, reheat factor, losses in steam turbines, steam turbine governing equation.

Nozzles: Convergent and convergent-divergent nozzles, mass flow rate, choking of nozzles, performance characteristics of nozzles.

Analysis and sizing of power plant components: Steam generators, condenser, Cooling tower and heat exchangers.

Air standard cycles: Otto Cycles, Diesel Cycles, Dual cycle, Actual cycles.

Refrigeration: Vapour compression refrigeration systems, Refrigerants and their properties. Vapour absorption refrigeration system: Water-Lithium bromide; Aqua-ammonia

Air-conditioning: Introduction to Psychrometric principles. Application of mass and energy balances to air-conditioning systems. Wet and dry bulb temperatures. Psychrometric chart. Air conditioning processes and Cooling Load basic calculations.

Text Books:

1. Thermal Engineering, R K Rajput, 6th Edition, Laxmi Publications Limited, New Delhi.
2. A Course in thermal Engineering, Domkundwar and Kothandaraman, Dhanpat Rai & Co, 2013
3. Textbook of Thermal Engineering, R S Khurmi, JK Gupta, S Chand & Co Ltd, 2006.

Reference Books:

1. Yonus A Cengel and Michale A Boles, Thermodynamics: An Engineering Approach, McGraw Hill, 2002
2. P L Ballaney, Thermal Engineering, 5th Edition, Khanna Publishers, 2010

Online reference:

1. Basic Thermodynamics, NPTEL COURSE by Prof. S.K.Som, IIT Kharagpur
https://cosmolearning.org/courses/basic-thermodynamics-528/

Course Code: MEM05	SOLID MECHANICS AND MACHINE DESIGN	3-0-0: 3

Pre-Requisites: NIL

Course Outcomes:

CO1	Understand the types of stresses and strains in machine members while subjected to axial, flexural and torsional loads
CO2	Evaluate principal stresses, strains and apply the concept of failure theories for designing the mechanical components
CO3	Design the required size of shaft, coupling and gear for a mechanical system
CO4	Select a suitable bearing for the given load conditions in a mechanical system

Syllabus:

Concept of Stress and Strain: Various types of loads and its responses in solids – Tension, compression and shear stresses and strains-Thermal Stresses and strains – volumetric strains- pure shear – Young's modulus of elasticity, Poisson's ratio, Modulus of rigidity and Bulk modulus - Relation between elastic constants - Stress-strain diagrams for brittle and ductile materials - working stress.

Bending of Beams: Types of supports - Types of beams - Types of loads – Assumptions (Euler and Bernoulli) - Shear Force and Bending Moment diagrams. Governing equation of bending. Deflection of Beams - Bending stresses in beams. Flexural, shear stress distribution in different cross sections of beams.

Torsion of Circular cross sections: Theory of pure torsion - transmission of Power in Solid and Hollow circular shafts -Governing equation of torsion - Combined bending and torsion. Analysis of Uniaxial, Biaxial and Triaxial state of stresses with and without shear – Principal stresses and strains– Stress-Strain relations–Graphical representation of stress-strain behaviour of solids (Mohr's Circle).

Theories of failure: Distortion - Maximum Principal Stress Theory - Maximum Principal Strain Theory - Maximum Shear Stress Theory - Strain Energy Theory - Distortion energy theory. Cyclic loading - Fatigue Failure.

Design of Shafts and Couplings: Types of loading on shafts, causes of stress concentration in shafts, Design of shafts based on strength, Design of shafts based on rigidity, use of fatigue and stress concentration factors in Shaft Design. Purpose of shaft couplings, Different types of couplings, Design of rigid couplings - muff coupling and working principles of flanged couplings and other types of couplings "Oldham's coupling and Universal coupling".

Design of Gears: Classification of Gears, Law of gearing, Terminology of spur gear, Standard Systems of gear tooth, Interference and undercutting, backlash, Stresses produced in a gear tooth, Concept of uniform strength beam, Shape of uniform strength cantilever beam with point load at its free end, Lewis's equation, Design of spur gear tooth based on strength.

Design of Friction Bearings: Conditions of proper lubrication, Mechanism of dry friction, Petroff's law, Assumptions involved in Petroff's law, Hydrodynamic lubrication. hydrodynamic conditions in a bearing, McKeey's equation. Stability of lubrication, bearing modulus. Design of journal bearing. Introduction and working principle of antifriction bearings.

Other Mechanical components: Design of flat belt. Design of band brake, block brake and single plate clutch.

Learning Resources:

Text Books:

1. Mechanics of Materials, Timoshenko and Gere, CBS Publishers, 2011.
2. Strength of Materials, R. K. Bansal, Laxmi Publications, 2013.
3. Mechanical Engineering Design. Richard G. Budynas, J Keith Nisbett, Shigley's. McGraw Hill, 2011, Ninth edition.
4. Design of Machine Elements, V B Bhandari, Tata McGraw Hill Education Private Limited, 2012, Third Edition.

Reference Books:

1. Engineering Mechanics of Solids, E. P. Popov, PHI, 2009.
2. Machine design an integrated approach., Robert L Norton, Pearson Education, 2009, Second edition.
3. Machine Design, Black and Adams, McGraw Hill and Co, New Delhi, 2002.

Course Code: ME401	ROBOTICS	3-0-0: 3

Prerequisites: NIL

Course Outcomes:

CO1	Understand the basic components of robots and their grippers.
CO2	Model forward and inverse kinematics of robot manipulators.
CO3	Analyze forces in links and joints of a robot.
CO4	Develop a program for the robot to perform tasks in industrial applications.
CO5	Design intelligent robots using sensors.

Course Articulation Matrix:

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2
CO1	2	1				1						2	1	1
CO2	3	2	2	2	2	2						2	2	2
CO3	3	2	2	2	2	2						2	2	2
CO4	3	3	3	3	3	3						2	3	3
CO5	3	2	3	3	3	3						2	3	3

Syllabus:

Introduction: Multibody systems, Automation, Classification of robots, Anatomy, Sensors (velocity, proximity, touch, torque etc), Grippers, selection of Robot based on the Application. Demonstration of different types of Robots & tools using Robot Simulator Software like ROBODK.

Kinematics: Manipulators Kinematics, Rotation Matrix, Homogenous Transformation Matrix, Direct and Inverse Kinematics for industrial robots for Position and orientation. Demonstrate FK and IK using simulation tools.

Differential Kinematics, statics and Dynamics: Jacobian, Lagrangian Formulation, Newton- Euler Formulation for RR & RP Manipulators. Demonstrate differential kinematics using simulation tools.

Trajectory planning: Motion Control- Interaction control, Rigid Body mechanics. Demonstrate trajectory planning using simulation tools.

Control: architecture- position, path velocity and force control systems, computed torque control, Adaptive control, and Servo system for robot control.

Advanced Topics in Robotics: Motion Planning (Methods of Path planners), Robot Vision (Feature Detection & Matching, Motion Tracking, Machine Learning methods).

Robot programming: Programming of Robots and Vision System- overview of various programming Languages.

Applications: Application of Robots in production systems- Application of robot in welding, machine tools, material handling, and assembly operations parts sorting and parts inspection.

Learning Resources:

Text Books:

1. Introduction to Robotics Mechanics and Control, Craig, J.J., Addison Wesley, 1999.
2. Introduction to robotics, Saha, Subir Kumar, Tata McGraw-Hill Education, 2014.
3. Robot modeling and control, Spong, Mark W., Seth Hutchinson, and Mathukumalli Vidyasagar. New York: Wiley, 2006.

Reference Books:

1. Modern Robotics: Mechanics, Planning, and Control, Kevin M. Lynch, Frank C. Park, Cambridge University Press, 2017.

Online Resources:

1. nptelCourses: https://nptel.ac.in/courses/107/106/107106090/ , https://nptel.ac.in/courses/112/101/112101098/, https://nptel.ac.in/courses/112/107/112107289/, https://nptel.ac.in/courses/112/104/112104298/
2. Stanford Lecture Series: https://see.stanford.edu/Course/CS223A
3. MIT OCW: https://ocw.mit.edu/courses/mechanical-engineering/2-12-introduction-to-robotics-fall-2005/

Course Code: ME415	TOTAL QUALITY MANAGEMENT	3-0-0: 3

Prerequisites: NIL

Course Outcomes:

CO1	Understand quality management philosophies, techniques, and frameworks
CO2	Adopt TQM methodologies for continuous quality improvement
CO3	Identify the areas of improvement through measurement of cost of poor quality, effectiveness and efficiency of processes
CO4	Apply TQM process and concepts to enhance the performance of systems
CO5	Understand the implications of quality management standards and systems

Course Articulation Matrix:

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PS02
CO1	2							3	2	2	2	2	2	2
CO2	2					2		3	2	2	2	2	2	2
CO3	2				2	3		3	2	2	2	2	3	2
CO4	2	2		3	3	2		3	3	3	3	2	2	3
CO5	2	2			2	2		3	2	2	2	2	3	2

1 - Slightly; 2 - Moderately; 3 – Substantially

Syllabus:

Introduction: Dimensions of Quality, Quality Planning, Quality Costs and Analysis, Axioms of TQM.

Contribution of Quality Gurus: Shewhart SPC**,** Deming Philosophy, Juran Trilogy, Crosby zero Defect Philosophy, Barriers to TQM Implementation, Benefits of TQM, Characteristics of successful quality leader, Contributions of Gurus of TQM, Case studies.

TQM Principles: Customer satisfaction - Customer Perception of Quality, Customer Complaints, Service Quality. Customer Retention, Employee Involvement - Motivation, Empowerment teams, Continuous Process Improvement - Juran Trilogy, PDSA Cycle, Kaizen, Supplier Partnership, Performance Measures, Case studies.

TQM Tools: Benchmarking, Quality Function Deployment (QFD) - House of Quality, Taguchi Robust Design Concept, Total Productive Maintenance (TPM), FMEA, The seven tools of quality, Process capability, Concept of six sigma, New seven management tools, Case studies.

Quality Systems: Need for ISO 9000 and Other Quality Systems, ISO 9000:2000 Quality System - Elements, Implementation of Quality System, Documentation, Quality Auditing, QS 9000, ISO 14000 - Concept, Requirements and Benefits, Case Studies

Text Books:

1. Total Quality Management, Dale H.Besterfiled, Pearson Education, Delhi, 2006.
2. Total Quality Management, Subburaj Ramasamy, Tata McGraw Hill Publishing Company Ltd., New Delhi, 2005.
3. Quality Management - Concepts and Tasks, Narayana V and Sreenivasan N.S., New Age International, Delhi, 1996.

Reference Books:

1. Out of the Crisis, Edward Deming, MIT Press, July, 2000
2. ISO 9000: Concepts, Methods and Implementation, Tapan P Bagchi, A.H.Wheeler, 1999

Online Resources:

1. https://deming.org/explore/seven-deadly-diseases/ - Video by Edward Deming
2. https://www.iso.org/standard/45481.html - For ISO 9000 standards

Course Code: MEM06	OPERATIONS MANAGEMENT	3-0-0: 3

Prerequisites: NIL

Course Outcomes:

CO1	Explain production systems and their characteristics.
CO2	Evaluate MRP and JIT systems against traditional inventory control systems.
CO3	Analyze aggregate planning strategies.
CO4	Apply forecasting and scheduling techniques to production systems.

Syllabus:

Introduction: Milestones in the evolution of production systems, Overview of Production Planning and Control Hierarchy; Review of EOQ and Inventory control systems.

Material Requirements Planning: Concept of Dependent Demand; Structure of MRP system, MRP Calculations, Planning Issues, Implementation Issues.

Just in Time Production Systems: Evolution, Characteristics of JIT Systems: Small lot production, Stable MPS, Kanban System, Continuous Improvement, TPM, Strategic Implications of JIT System.

Aggregate Planning: Purpose & Methods, Reactive and Aggressive Alternatives, Planning Strategies, LP Formulation, Master Production Scheduling.

Scheduling: Scheduling in Manufacturing, Sequencing Operations for One Machine, Sequencing Operations for a two-station Flow Shop, Job Shop Dispatching.

Forecasting Methods: Demand Forecasting: Principles and Methods, Judgment methods, Causal methods, Time-series methods.

Text Books:

1. Operations Management: Strategy and Analysis, Krajewski L.J. and Ritzmen L.P , Pearson Education, 2010, 9th Edition.
2. Operations Management for Competitive Advantage, Chase R.B. Jacobs F.R. and Aquilano N.J., Tata McGraw Hill Book Company, New Delhi, 2011, 11th Edition.

Reference Books:

1. Operations Management: Theory and Practice, Mahadevan. B., Pearson Education, 2015, 3rd Edition.

Online Resources:

1. Swayam/NPTEL lectures

Course Code: MEM07	MEASUREMENTS & METROLOGY	3-0-0

Prerequisites: NIL

Course Outcomes:

CO1	Comprehend the basic measurement terminology and the concept of generalized measurement system.
CO2	Estimate errors and uncertainty in measurements using statistical analysis.
CO3	Understand the principals involved in measuring various thermos-physical variables
CO4	Understand the various linear and angular measurement principles and apply them

Syllabus:

Introduction to metrology: Definition, types, terminologies, standards, generalized measurement system

Statistical Analysis of experimental data: Types of errors, Error Propagation, Uncertainty analysis, Error distribution (Guassian or Normal distribution), Chi-square test for goodness of fit

Pressure measurement: Mechanical-pressure measurement devices, dead weight tester, Bourdon tube pressure gauge, McLeod pressure gauge

Flow Measurement: Flow obstruction Methods, Hot Wire Anemometers, Magnetic Flow meters

Temperature Measurement: Liquid-in-glass Thermometers, Thermocouples, Resistance Temperature Detectors, Thermistors, Pyrometry

Force measurement: Direct Methods, Load Cells, Cantilever Beams, Proving Rings, Differential Transformers

Torque Measurements: Torsion-bar Dynamometer, Servo-controlled Dynamometer Absorption Dynamometer

Strain Measurement: Mechanical Strain Gauges, Electrical Strain Gauges

Linear metrology: Steel rule, Vernier Instruments, Micrometre Instruments, Slip Gauges

Angular Measurement: Protractors, Sine bar, Interferometers

Comparators: Mechanical and Electrical Comparators

Limits fits and Tolerances: Principle of interchangeability and selective assembly, Limits, fit and tolerances, limit gauging, design of limit gauges

Text Books

1. Engineering Metrology and Metrology, N.V Raghavendra & L Krishnamurthy, Oxford University press, 2013
2. Engineering Metrology, R. K. Jain, Khanna Publishers, 19/e, 2005.
3. Experimental Methods for Engineers, J P Holman, McGraw hill,7 edition,2001

Reference books

1. Mechanical Measurements by Thomas G Beckwith, Pearson publications, 6th edition, 2020.

2. Measurement systems by Ernest O Doebelin, Tata McGraw Hill publications
4. Mechanical Measurements, S.P Venkatesan, publications, 2 edition, 2015

Online Resources:

1. Engineering Metrology, NPTEL Course by J.Ram Kumar and Prof Amandeep singh IIT KANPUR https://youtu.be/HplEeBtJupY