SANT GADGE BABA AMRAVATI UNIVERSITY, AMRAVATI
Draft Syllabus of Semester V & VI of B.E. (Mechanical Engineering)
SEMESTER: V

Program:	**B. E. Mechanical Engineering**	**Semester:**	**V**
Course:	**Heat Transfer (PCC-I)**	**Code:**	**5ME220PC**

Lecture	**Tutorial**	**Hours**	**Credit**	**CT-I**	**CT-II**	**TA**	**Th. Exam**	**Total**
3	0	3	3	30	30	40	60	100

Methods of Teacher Assessment (TA): Class Tests, Assignments, Class Attendance, Quiz

Course Objectives:

1. To provide details of heat transfer involving conduction, convention and radiation mechanisms.
2. To carry out heat transfer analysis and to demonstrate different techniques used in solving a heat transfer problem.
3. To impart basics of designing heat transfer equipment.

CO No.	**Course Outcome (After completion of the course, the student will be able to:)**	**Bloom's Level**
CO1	**Solve** one-dimensional, steady-state heat conduction problems for simple and composite geometries (slabs, cylinders, spheres) with and without internal heat generation.	L1-Remember, L2-Understand, L3-Apply
CO2	**Evaluate** the performance of thermal insulation (critical radius) and extended surfaces (fins), and **apply** the lumped capacitance method to determine temperature history in solids.	L2-Understand, L3-Apply L5-Evaluate
CO3	**Analyze** thermal radiation heat transfer using radiation laws, shape factors, and radiation network analysis, including the effect of radiation shields.	L2-Understand, L3-Apply, L4-Analyze
CO4	**Apply** boundary layer theory, dimensionless parameters, and empirical correlations to **solve** forced convection heat transfer problems over flat plates and through pipes.	L2-Understand, L3-Apply
CO5	**Understand** free convection, boundary layer development, condensation, and boiling phenomena, and **solve** free convection heat transfer problems using empirical correlations.	L2-Understand, L3-Apply
CO6	**Design** and **analyze** the performance of heat exchangers using NTU and LMTD methods. **Explain** the working principles and applications of heat pipes.	L2-Understand, L4-Analyze L6-Design

SYLLABUS:

UNIT I: **Introduction-** Modes of heat transfer; basic laws of heat transfer and their basic equations, Thermal conductivity & diffusivity, specific heat capacity, Steady & unsteady state, Overall heat transfer coefficient.
Conduction- General heat conduction differential equation, resistance concept and electrical analogy, one-dimensional steady state heat conduction through simple and composite for basic geometries, 1-D steady flow conduction equations with internal heat generation for infinite slab, cylinder & Sphere. **(7 Hrs)**

UNIT II: **Critical radius-** Insulations, critical radius of insulation for Cylinder & Sphere.
Fin- Analysis of a uniform C.S. fin, fin efficiency, fin effectiveness, heat transfer through fins.
Unsteady heat conduction- Biot & Fourier number. lumped parameter system, Introduction to Heisler's charts (no numerical on Heisler's charts). **(7 Hrs)**

UNIT III: **Radiation-** General concepts and definitions related to kinds of bodies & Surfaces, Laws of radiation (Plank's, Stefan- Boltzman's, Wien's, Kirchoff's law), Shape factors, radiation network analysis, Radiation errors in temperature, measurement, radiation shield. **(7 Hrs)**

UNIT IV: **Forced convection-** Hydrodynamic & thermal boundary layer theory, flow over flat plate and through pipes/tubes (only concept, no derivation & analytical treatment), dimensionless parameters, heat transfer correlations for flow over flat plates and through pipes and numerical on its application, effect of turbulence. **(6 Hrs)**

UNIT V: **Free convection-** Velocity and thermal boundary layer, free convection over vertical plate & cylinder and horizontal plate & cylinder (only concept, no derivation & analytical treatment), heat transfer correlations and numerical on it.
Condensation & Boiling- introduction to condensation heat transfer, film & drop condensation. Boiling heat transfer, pool boiling curves. **(6 Hrs)**

UNIT VI: **Heat exchanger -** Applications, classification, fouling, LMTD & NTU methods, temperature profiles, selection

of heat exchangers. Introduction to working of heat pipe with and without wick. **(7 Hrs)**

Text Books:

1. Heat and Mass Transfer; R.K Rajput; S. Chand, New Delhi
2. Heat and Mass Transfer; V.M. Domkundwar; Dhanpat Rai & Co. Delhi
3. Heat Transfer; P.K. Nag; TMH.
4. Heat Transfer & Mass Transfer-A Practical Approach, Yunus A. Cengel, McGraw Hill Co.

Reference Books:

1. Heat Transfer; J.P. Holman; McGraw Hill
2. Heat and Mass Transfer Data book, V.M. Domkundwar, Dhanpat Rai & Co.
3. Heat and Mass Transfer Data book; C.P. Kothandaraman; New age International
4. Heat Transfer; A. F.Mills, V. Ganesan, Pearson Publication.

NPTEL Web Videos / Online Learning Resources:

1. Fundamentals of heat transfer-https://nptel.ac.in/courses/112105771
2. Introduction to Heat and Mass Transfer- https://nptel.ac.in/courses/112101097
3. The fundamental and applied aspects of heat transfer – https://www.nptelprep.in/courses/103105140/videos
4. Radiative heat transfer- https://www.nptelprep.in/courses/112107256/videos
5. Conduction and Convection Heat Transfer- https://www.nptelprep.in/courses/112105271/videos
6. Heat transfer- https://nptel.ac.in/courses/112106315
7. Heat transfer- https://nptel.ac.in/courses/103103031
8. Heat transfer- https://nptel.ac.in/courses/103103032
9. Fundamentals of Convective Heat Transfer- https://nptel.ac.in/courses/112103297
10. Heat transfer- https://nptel.ac.in/courses/103101137

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Program	**B.E. Mechanical Engineering**	**Semester**	**V**
Course	Theory of Machines (PCC-II)	**Code**	5ME221PC

Lecture	**Tutorial**	**Hours**	**Credit**	**TA**	**CT-I**	**CT-II**	**Th.Exam**	**Total**
3	0	3	3	10	15	15	60	100

Method of Teacher Assessment (TA): Class Tests, Assignments, Quiz, Class Attendance, etc.

5ME221PC Theory of Machines (PCC -II)

Course Learning Objectives:

The course aims to:

1. To understand the fundamental concepts of mechanisms, machines, kinematic pairs, and mobility criteria.
2. To analyse motion transmission and force transmission in planar and spatial mechanisms.
3. To study the designing and importance of cams in machines.
4. To evaluate dynamic forces in reciprocating engines and gyroscopic effects in rotating systems.
5. To understand and analyse mechanical vibrations and their control in engineering systems.
6. To develop competency in balancing rotating and reciprocating masses to minimize vibration and dynamic effects.

Course Outcomes: Students will be able to-

CO	**Course Outcomes**	**BT Level**
CO1	Understand & apply the concept and its applications of link, mechanisms and machines.	L2, L3
CO2	Understand the knowledge of dynamic force analysis analytically.	L2, L4
CO3	Design and construct cam profiles; apply law of gearing and analyse gear trains for required speed ratios.	L3, L4, L6
CO4	Apply the knowledge of space mechanism and vehicle dynamics.	L3, L4
CO5	Understand and analyse concept of free, force and damped vibration.	L2, L4
CO6	Analyse the concept of balancing of machinery.	L4

SYLLABUS

Unit I: 1. Introduction to study of mechanisms, machines, different types of links, kinematic pairs. Grashof's law- class-I and class –II mechanisms. Grubler's criterion, Kutzbach's criterion for planer mechanism. Inversions of four bar, single slider, double slider mechanisms

2. Transmission angle, Mechanical Advantage (8 Hrs)

Unit II: 1. Space mechanism:- Gyroscope, gyroscopic effect as applied to ship, aeroplane.

2. D'Alemberts Principle. Engine force analysis-piston effort, thrust along connecting rod, side of cylinder, on the bearings, crank effort and turning moment on the crank shaft. (8 Hrs)

Unit III: 1. Cams:- Introduction, types of cam & follower, different motions of followers, graphical layout of cam profiles.

2. Gear: Introduction, terminology, gear tooth profiles, law of gearing

3. Gear Trains:- Types of gear trains and its speed ratio, applications. (8 Hrs)

Unit IV: 1. Types of vibrations, elements of mechanical vibrating systems, degree of freedom in mechanical vibratory system.

2. Longitudinal vibrations- Natural frequency of free longitudinal vibrations by equilibrium, energy and Rayleigh method. Damped vibrations with mass, spring and dash pot. Concept of logarithmic decrement, magnification factor, transmissibility, vibration isolation.

Unit V: 1. Transverse vibrations- Natural frequency of free transverse vibrations. Natural frequency of free transverse vibrations due to point load and uniform distributed load acting over a simply supported shaft. Frequency of free transverse vibrations of a shaft subject to a number of point loads by energy and Dunkerley's method.

2. Whirling or critical speed shaft. (8 Hrs).

Unit VI: Balancing: - Balancing of rotating masses in same and different transverse planes, Partial balancing of reciprocating masses & Study of its effect. (8 Hrs)

BOOKS RECOMMENDED:

Text Books:

1) Theory of Machines, P.L.Ballaney, Published by Dhanpat Rai and sons-N Delhi.
2) Theory of Machines, S.S.Ratan, Published by Tata Mc Graw Hill.
3) Theory of Machines, V.P.Singh, Published by Dhanpat Rai-N Delhi.
4) Theory of Machines, R.S.Khurmi and Gupta J.K., Published by Eurasia Publishing house-N Delhi.

Reference Books:

1) Theory of Machines and Mechanisms, J.E.Shigley, Uicker and Gordon, Published by Oxford University press-New York.
2) Theory of Machines and Mechanisms, Ghosh and Amitabh, published affiliated East West Press N-Delhi.

MOOCs & e-Resources :

- NPTEL: Kinematics of Mechanisms and Machines – https://nptel.ac.in/courses/112105268
- NPTEL: Dynamics of Machines – https://nptel.ac.in/courses/112106137
- NPTEL: Mechanical Vibrations – https://nptel.ac.in/courses/112101096
- SWAYAM: Theory of Machines – https://swayam.gov.in
- Coursera: Mechanical Vibrations / Dynamics of Machines – https://www.coursera.org

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Program:	**B. E. Mechanical Engineering**	Semester:	**V**
Course:	**Measurement Systems** (PCC-III)	Code:	**5ME222PC**

Lecture	Tutorial	Hours	Credit	TA	CT-I	CT-II	Th. Exam	Total	**Exam duration**
3	0	3	3	40	30	30	60	100	**3 Hrs**

Methods of Teacher Assessment (TA): Class Tests, Assignments. Quiz Class, Attendance, etc.

Course Objectives:

1. To study the generalized measurement system and the general performance characteristics of measuring instruments, applications, general configuration and functional elements of measuring instruments.
2. To study appropriate liquid level and displacement measurement techniques in the measurement system
3. To study the types, constructional details and working of temperature and pressure measuring devices.
4. To study the different types of force and flow measurement using different methods
5. To study the mechanical and electrical types of speed measuring devices, contact and Contactless speed measuring devices and their applications.
6. To study the methods of strain gauges devices for several industrial applications .

After completion of the course, the student will be able to:

CO	**Course Outcome**	**BT Level**
CO-1	Explain different measurement systems and calculate different types of errors	L2
CO-2	Examine appropriate liquid level and displacement measurement techniques in the measurement system	L3

CO-3	Calculate different temperature and pressure measurement ranges in measurement system	L3
CO-4	Illustrate different methods of force and flow measurement using different methods	L3
CO-5	Compare speed of motors and rotating shafts by using tachometers, stroboscope	L4
CO-6	Use strain gauges devices for several industrial applications	L4

SYLLABUS

SECTION-A

Unit I :

1. Generalized Measurement system: Significance of measurement, generalized systems. Application of measuring instruments. Types of measuring instruments.

2. General configuration: Functional elements of measuring instruments. Static and Dynamic performance characteristics – sources of error, Classification, and elimination of error. **(6 Hrs)**

Unit II:

1.Measurement of Displacement: Theory and construction of various transducers to measure displacement – Piezo electric, Inductive, capacitance, resistance, ionization and Photo electric transducers, Calibration procedures.

2.Measurement of Level: Direct method – Indirect methods – capacitive, ultrasonic, magnetic, cryogenic fuel level indicators – Bubbler level indicators. **(6 Hrs.)**

Unit III :

1. Temperature Measurement: Classification – Ranges – Various Principles of measurement –Expansion, Electrical Resistance – Thermistor – Thermocouple – Pyrometers – Temperature Indicators.

2. **Pressure Measurement:** Units – classification – different principles used. Manometers, Bourdon pressure gauges, Bellows – Diaphragm gauges. Low pressure measurement – Thermal conductivity gauges – ionization pressure gauges, Mcleod pressure gauge **(8 Hrs.)**

SECTION-B

Unit IV:

1. Force 1. Force Measurement: Various mechanical. Hydraulic, pneumatic, and electrical methods.

2. Flow Measurements: Rotameter, magnetic, Ultrasonic, Turbine flow meter, Hot – wire anemometer, Laser Doppler Anemometer (LDA). **(6 Hrs.)**

Unit V:

1. Measurement of Speed: Mechanical Tachometers – Electrical tachometers – Stroboscope, Noncontact type of tachometer

2. Measurement of Acceleration and Vibration: Different simple instruments – Principles of Seismic instruments – piezoelectric accelerometers, Vibrometer and accelerometer using this principle. **(6 Hrs.)**

Unit VI:

Stress Strain Measurements: Various types of stress and strain measurements – electrical strain gauge – gauge factor – method of usage of resistance strain gauge for bending compressive and tensile strains (**6 Hrs.)**

Text Books:

Sr. No.	Title	Author	Publication
T-1	1. Measurement Systems	Erenest O. Doebelins	MC Graw Hill.
T-2	2. Mechanical Measurement & Control	D.S. Kumar	S. Chand publications.

Reference Books:

Sr. No.	Title	Author	Publication
R-1	1. Mechanical Measurements	T.G.Beckwith & N.L.Bulk	Addison Werllv.
R-2	2.Instrumental Measurement & Analysis	Nakra Choudhari	Tata Mc Graw Hill.
R-3	nicalMeasurement&Instrumentation	R.K.Rajput	Katsons Books Publications

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Program	B.E. Mechanical Engineering	Semester	V
Course	PEC-I: Non-Conventional Energy Sources	Code	5ME223PE

Lecture	Tutorial	Hours	Credit	TA	CT-I	CT-II	Th.Exam	Total
3	0	0	2	10	15	15	60	100

Method of Teacher Assessment (TA): Class Tests, Assignments, Quiz, Class Attendance, etc.

Course Objectives:
To understand the basic concept of Non-conventional Energy e.g. Solar Energy, P-V Cell, Geothermal Energy, Tidal Energy, Ocean Thermal Energy Conversion, Wind Energy, Biomass Energy Conversion

After completion of the course, the students will be able to:

CO	Course Outcomes	BT Level
CO 1	Understand the fundamentals of renewable and non-renewable energy sources, solar radiation concepts and measurement techniques.	L2
CO 2	Understand the basic concept solar collectors, methods of solar energy storage, and various applications of solar energy.	L2
CO 3	Understand the basic concept of Solar Photo Voltaic Cells, Fuel Cells and Geothermal energy.	L2
CO 4	Understand the basic concept of energy from ocean.	L2
CO 5	Understand the basic concept of energy from Wind.	L2
CO 6	Understand biomass energy resources including photosynthesis mechanism, biogas production, gasifiers, and biofuels such as biodiesel and ethanol.	L2

SYLLABUS

UNIT I:

Introduction: Renewable & Non-renewable sources. Need of renewable energy sources, Overview of Global and Indian Energy Scenario.

Solar Radiation: Solar constant, Definitions of basic earth-sun angles. Types of Solar radiation, Measurement of solar radiation using Pyrheliometer, Pyranometer and Sunshine Recorder. (7Hrs)

UNIT II:

Solar Collectors: classifications of collectors- concentrating, non-concentrating collectors and Evacuated tube solar collectors, it's construction, and working.

Solar Energy Storage & Utilization: Methods of storage such as Mechanical, Thermal, Electrical, Thermochemical and Electromagnetic storage. Applications of solar energy in heating, cooling, pumping, power production, distillation, drying, etc. (7Hrs)

UNIT III: Direct Energy Conversion:

1. Solar Photo voltaic cells: Principle, Construction and Working, Conversion efficiency.

2. Fuel Cells: working principle, types of fuel cells, applications.

3. Geothermal Energy Resources: Hot Dry Rock system, Vapour dominated, liquid dominated, flash steam, binary fluid and total flow concept of power generation. (7 Hrs)

UNIT IV: Energy from Ocean:

Tidal Power: Types of tidal plants such as single and two basin plants, power developed & operation of tidal power plant.

Ocean thermal energy conversion system: Construction and working of open cycle and closed cycle OTEC systems. (7Hrs)

UNIT V: Wind Power: Introduction, Principles of wind energy conversion, Operation, maintenance and economics. Wind patterns and Wind speed data, Types of wind mills, application for pumping and power generation. Conversion efficiency, Site selection. (No derivations and numericals). (7 Hrs)

UNIT VI: Biomass Energy Resources: Mechanism of green plant photosynthesis. Efficiency of conversion, solar energy plantation, Biogas-**Ty**pes of biogas plants, factors affecting production rates. Types of gasifiers, Introduction to bio-diesel and ethanol as alternative fuels, properties of bio-fuel. (7Hrs)

BOOKS RECOMMENDED:

Text Books:

1. Solar Energy; S.P. Sukhatme; TMH.
2. Non-Conventional Energy Sources; G.D. Rai; Khanna Publications.
3. Non-Conventional Energy Sources; B. H. Khan.

Reference Books:

1. Treatise on Solar Energy; H.P. Garg; John Wiley & Sons.
2. Renewable Energy Conversion, Transmission and Storage; Bent Sorensen; Elsevier Publication.
3. Renewable Energy; Godfrey Boyle; Oxford University Press, Mumbai.
4. Renewable Energy Sources and Emerging Technology; D.P. Kothari, K.C. Singal, Rakesh Ranjan; PHI.

MOOC Links:

Renewable Energy Engineering: Solar, Wing, Biomass Energy Systems:
https://archive.nptel.ac.in/courses/103/103/103103206/

Non-Conventional Energy Sources: https://archive.nptel.ac.in/courses/121/106/121106014/
Hydro and Renewable Energy: https://nptel.ac.in/courses/109107397

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Program:	**B. E. Mechanical Engineering**	**Semester:**	**V**
Course:	Productivity Techniques **(PEC-I)**	**Code:**	**5ME223PE**

Lecture	**Tutorial**	**Hours**	**Credit**	**TA**	**CT-I**	**CT-II**	**Th. Exam**	**Total**
3	0	3	3	40	30	30	60	100

Methods of Teacher Assessment (TA): Class Tests, Assignments, Class Attendance, Quiz

Course Objectives:

1. Understand the fundamental concepts, importance, and measurement of productivity in industrial and organizational contexts.
2. Apply method study, process charts, and work measurement techniques to improve efficiency.
3. Analyze productivity gaps and identify factors affecting performance.
4. Evaluate techniques for human resource optimization, incentive schemes, and ergonomic work design.
5. Understand and apply contemporary productivity improvement tools, including Business Process Reengineering (BPR).
6. Develop solutions to enhance productivity by integrating technical, organizational, and human factors.

Course Outcomes:

After completion of the course, the student will be able to:

CO No.	**Course Outcome**	**Bloom's Level**
CO1	Explain the concept, importance, and measurement of productivity, including productivity indices and factors affecting productivity.	Understand (Level 2)
CO2	Demonstrate the application of method study techniques, including process charts, flow diagrams, therbligs, and motion analysis.	Apply (Level 3)
CO3	Apply work measurement techniques, including time study, PMTS, and basic motion time systems, for improving efficiency.	Apply (Level 3)
CO4	Analyze ergonomic principles, work system design, and human factors to optimize worker performance.	Analyze (Level 4)
CO5	Evaluate performance rating, wage payment, and incentive schemes to enhance productivity.	Evaluate (Level 5)
CO6	Explain and apply Business Process Reengineering (BPR) concepts, methodology, and tools for organizational productivity improvement.	Understand / Apply / Create (Level 2–6)

SYLLABUS:

UNIT I: Productivity (6 Lectures)

- Definition, Concept, and Importance of Productivity
- Difference between Production & Productivity
- Productivity Index & Ratio
- Technical Methods for Productivity Improvement
- Causes of Low Productivity and Improvement Techniques
- Advantages of Increased Productivity

UNIT II: Method Study (6 Lectures)

- Definition, Concept, Objectives, and Procedure of Method Study
- Process Chart Symbols
- Recording Techniques: Flow Process Charts, Operation Charts, Flow Charts, Two-handed Process Charts
- Multiple Activity Chart
- Design of Workplace Layout

UNIT III: Work Measurement (6 Lectures)

- Definition, Concept, and Objectives of Work Measurement
- Stopwatch Procedure for Collecting Time Study Data
- Time Estimating Techniques:
  - Analytical Estimating ,
  - PMTS (Predetermined Motion Time Systems),

- Elemental Motion Time System
- Method Time Measurement (MTM)

UNIT IV: Ergonomics (6 Lectures)

- Introduction and Principles of Ergonomics
- Work System Design: Objectives, Principles and Steps
- Man-Machine System: Components, Characteristics & Design Considerations
- Human Behavior and Equipment Design:
- Tools, Techniques, and Applications of Ergonomics
- Effect of Environment on Worker Performance

UNIT V: Performance Rating, Wage Payment & Incentive Plans (6 Lectures)

- Salary vs. wage concepts.
- Concept and importance of performance rating
- Various incentive schemes
- Wage Payment Systems
- Time-based wage systems.
- Piece-rate wage systems.
- Relationship between incentive schemes and worker productivity.
- Factors affecting effectiveness of incentive
- Challenges in Wage Payment and Incentive Implementation

UNIT VI: Business Process Reengineering (BPR) (6 Lectures)

1. Introduction to BPR, Applicability and Advantages of BPR
2. Steps for Implementation of BPR
3. Applications of BPR
4. Tools Used in BPR
5. Types of Changes in BPR
6. Success Strategies in BPR

Text Books:

1. P. C. Jain, *Productivity Management* by PHI Learning / Prentice-Hall India
2. L. S. Srinath, *Productivity and Work Study* by East-West Press Pvt. Ltd.
3. R. Panneerselvam, *Productivity & Work Study* by PHI Publications.
4. Ralph M. Barnes by Wiley (John Wiley & Sons)
5. K. Kroemer, *Ergonomics: How to Design for Ease and Efficiency* by Pearson / Prentice-Hall
6. L. S. Srinath, *Productivity Management* by East-West Press
7. R. C. Sharma, *Industrial Engineering and Management* by Dhanpat Rai & Co.
8. P. Choudhury, *Business Process Reengineering* —by Tata McGraw-Hill Education or PHI Learning Pvt. Ltd.

Reference Books:

1. R. C. Sharma, *Industrial Engineering and Management*, Dhanpat Rai & Co.
2. S. Srinath, *Productivity and Work Study*, East-West Press Pvt. Ltd.
3. Michael Hammer & James Champy, *Reengineering the Corporation: A Manifesto for Business Revolution*, HarperBusiness / HarperCollins
4. P. Choudhury, *Business Process Reengineering*, Tata McGraw-Hill / PHI Learning

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Program:	**B. E. Mechanical Engineering**	Semester:	**V**
Course:	**Computer Aided Design and Simulation** (PEC-I)	Code:	**5ME223PE**

Lecture	**Tutorial**	**Hours**	**Credit**	**TA**	**CT-I**	**CT-II**	**Th. Exam**	**Total**	**Exam duration**
3	0	3	3	40	30	30	60	100	3 Hr

Methods of Teacher Assessment (TA): Class Tests, Assignments. Quiz Class, Attendance, etc.

Course Objectives:

1. To study product cycle & fundamentals of CAD/CAM.
2. To understand the concept of representations of curves and surfaces.
3. To study the solid modeling techniques.
4. To study the geometric transformation techniques.
5. To study basic probability & statistics and physical modeling.
6. To study Simulation of Mechanical Systems & Simulation of manufacturing systems.

After completion of the course, the student will be able to understand the:

1. Comprehend the product development lifecycle and the significance of CAD/CAM/CIM.
2. Apply the knowledge of computer aided design for modeling of mechanical components and products.
3. Apply modeling and simulation approach for the systems in Mechanical Engineering.

CO	Course Outcome	BT Level
CO-1	Illustrate the concept of CAD/ CAM and CIM .	L2
CO-2	Explain the representation techniques of curves and surfaces	L2
CO-3	Apply knowledge using CAD modeling for component design	L3
CO-4	Apply the knowledge of geometric transformation.	L3
CO-5	Illustrate the Mechanical Modeling & simulation.	L2
CO-6	Analyze Mechanical Engineering problems using FEA approach.	L4

SYLLABUS:

Unit I: Fundamentals of CAD/CAM:

Product cycle and scope of CAD/CAM/CIM in product cycle, CAD/CAM, Hardware and software, selection of software, CAD workstation configurations. (6 Hrs)

Unit II: Representations of curves and surfaces:

Introduction to analytical curves, synthetic curves: Hermite cubic Spline, Bezier Curve, B- Spline curve. Surface Representation: Synthetic Surfaces, Applications of surface modeling. (6 Hrs)

Unit III: Solid Modeling:

2D Vs 3D modeling, Comparison of Wireframe, surface and solid modeling techniques, Geometry Vs Topology, Requirements of Solid Modeling Methods: Constructive Solid Geometry (CSG) and Boundary Representation (B-rep). (6 Hrs)

Unit IV: Geometric transformation:

2D geometric transformations, Homogeneous co-ordinate representation, Composite Transformations, 3D transformations, Inverse transformations, geometric mapping. (6 Hrs)

Unit V: Introduction to Modeling and Simulation:

Physical Modeling- Concept of System and environment, Principles of modeling, types of models. Basic Simulation modeling, Role of simulation in model evaluation and studies, advantages of simulation, Flexible manufacturing systems, Simulation software for manufacturing. (8 Hrs)

Unit VI: Finite Element Analysis:

Steps of FEM, Stress and Equilibrium, Boundary conditions, Strain Displacement Relations, Stress-strain Relations, Von mises stress, Temperature effect, Potential Energy & Equilibrium, Gelerkin's Method, stiffness (Displacement) Method, Applications and Benefits of FEA, Shape function, global stiffness matrix and load vectors, Properties of stiffness Matrix, Solution to simple problems using FEA. (8 Hrs)

BOOKS RECOMMENDED:

Text Books:

1) P. N. Rao; CAD/CAM Principles and Applications; McGraw Hills Publications.
2) Mikel P. Groover and Emory W. Zimmers: Computer Aided Design and Manufacturing, Prentice hall.
3) Ibrahim Zeid: Mastering in CAD- CAM, Tata McGraw Hill Publication.
4) Introduction to Finite Element Engineering – T.R.Chandrupatla, Belegunda; PHI.

Reference Books:

1) Mikell P. Groover: Automation, Production systems & Computer Integraded manufacturing, PHI.
2) Robert E. Shannon; System Simulation: The Art and Science ; Prentice Hall
3) J. Schwarzenbach and K.F. Gill Edward Arnold; System Modelling and Control.

4) P. Radhakrishnan and Subramaniam: CAD/CAM/CIM, wiley Eastern Ltd.
5) The Finite Element Method in Engineering- S.S.Rao, Elsveir Pub., 4th Edition.

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5ME224PL Heat Transfer (PCC-I) -LAB.

Course learning objectives:
The lab work should clear the vision about all the modes of heat transfer. The practical knowledge should enhance the approach of student towards real life applications of the subject.

Course Outcomes:
Upon successful completion of lab Course, student will be able to:
CO1–**Determine& analyze** thermal conductivity of a material with simple or composite arrangement
CO2– **Determine & analyze** fin efficiency
CO3–**Analyze & Verify** Radiation terms and laws
CO4–**Determine** heat transfer coefficient for forced convection.
CO5–**Determine** of heat transfer coefficient for natural convection.
CO6–**Understand & analyze** heat transfer performance of heat exchanger

List of Practical's (Any six of the following): -
1. Determination of thermal conductivity of a metal bar.
2. Determination of thermal conductivity of insulating powder.
3. Study of heat transfer through composite wall.
4. Study of heat transfer through composite cylinders.
5. Determination of fin efficiency.
6. Verification of Stefan-Boltzman's law.
7. Determination of emissivity of grey body.
8. Determination of heat transfer coefficient for forced convection.
9. Determination of heat transfer coefficient for natural convection.
10. Study of pool & nucleate boiling.
11. Trial on double pipe heat exchanger.
12. Determination of efficiency of cross flow heat exchanger.
13. To write a computer program for conduction heat transfer problem.

Practical Examination: - The practical examination shall consist of oral on the term work and syllabus.
❖ Heat Transfer Virtual Lab link- https://ht-nitk.vlabs.ac.in/

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Course code	Course Title	L	T	P	HRS
5ME225PL	**Theory of Machines (PCC-II) LAB**	**0**	**0**	**2**	**2**

5ME225PL Theory of Machines (PCC-II) LAB.

Course Learning Objectives: The laboratory course aims to:
1. Provide hands-on exposure to working models of mechanisms and machines.
2. Develop the ability to analyse kinematic chains, inversions, and mobility of mechanisms.
3. Enable students to perform experimental determination of dynamic effects such as gyroscopic couple and balancing.
4. Develop competency in graphical construction of cam profiles and analysis of gear trains.
5. Familiarize students with vibration analysis and experimental determination of natural frequency and critical speed.
6. Enhance analytical, experimental, and interpretation skills through comparison of theoretical and practical results.

Course Outcomes:
On successful completion of the course students will be able to:
1. Identify links, kinematic pairs, joints, and determine degree of freedom of four-bar and slider crank mechanisms using working models.
2. Analyse inversions of mechanisms and interpret their practical engineering applications.
3. Construct cam profiles graphically for different follower motions.
4. Determine speed ratio & train value various gear trains.
5. Evaluate gyroscopic couple and study its effects
6. Conduct experiments on free and damped vibrations to determine natural frequency, time period and damping characteristics.
7. Determine natural frequency of longitudinal vibration of a helical spring and compare theoretical and experimental results.
8. Determine critical (whirling) speed of shaft
9. Perform static and Dynamic balancing of rotating masses.

At least eight practicals from the following list:
1. To Study, Analyse and drawing of inversions of four bar mechanism.

2. To Study and analyse of inversions of single slider crank mechanism.
3. To Study and analyse of inversions of Double slider crank mechanism
4. Determination of gyroscopic couple using motorized gyroscope.
5. Study of vehicle dynamics.
6. To draw Cam profile for a given follower type and follower motions. (2 Problems)
7. To Study and find speed ratio & train value various types of gear trains
8. Experiment on free and damped vibration of systems with one degree of freedom.
9. To study the longitudinal vibration of helical spring and to determine the frequency and time period of oscillation theoretically and experimentally.
10. To determine the whirling speed of shaft.
11. Experiment on static & dynamic balancing of rotating masses (2 problems)

Practical Examination: - The practical examination shall consist of oral on the term work and syllabus.

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Program:	**B. E. Mechanical Engineering**	Semester:	**V**
Course:	**Measurement Systems (PCC-III)**	Code:	**5ME226PL**

Practical	Hours	Credit	Practical Evaluation		Total
			INT	EXT	
2	**2**	**1**	**25**	**25**	**50**

LIST OF PRACTICALS:

At least eight practicals from the following list:

1. Measurement of strain using strain gauges.
2. Calibration of pressure gauge with pressure gauge tester.
3. Measurement of linear displacement by LDR and inductive pick-up transducers.
4. Performance of capacitance transducer as an angular displacement measuring device.
5. Performance of inductive Transducers.
6. Measurement of flow using optical flow meter and Rotameter.
7. Speed measurement by a stroboscope.
8. Speed measurement by magnetic pick up or photo electric pick up tachometer.
9. Pressure measurement by strains gauge type transducer.
10. Vibration measurement by using Seismic Transducer.
11. Measurement of Liquid level by using capacitive pickup transducer.
12. Temperature measurement using contact and non contact type instruments or various types of sensors.

*The practical examination shall consist of viva-voce on the above syllabus & practical work.

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Program:	B.E. Mechanical Engineering	**Semester:**	V
Course:	Engineering Thermodynamics	**Code:**	5ME227MD

Lecture	**Tutorial**	**Hours**	**Credit**	**TA**	**CT-I**	**CT-II**	**Th.Exam**	**Total**
02	00	02	02	10	5	5	30	50

Methods of Teacher Assessment (TA): Class Tests, Assignments. Quiz, Class Attendance, etc.

Course Objectives:

1. To understand the fundamental concepts and properties of thermodynamics used in engineering applications.
2. To apply the First Law of Thermodynamics to energy analysis of closed systems and simple engineering devices.
3. To understand the Second Law of Thermodynamics and analyze the performance of basic thermodynamic cycles.

After completion of the course, the student will be able to:

CO	**Course Outcome**	**BT Level**
CO-1	To understand basic thermodynamic concepts, properties, gas laws and Zeroth Law of Thermodynamics.	L2
CO-2	To apply First Law of Thermodynamics for energy balance in closed systems and simple engineering devices.	L2
CO-3	To understand Second Law of Thermodynamics and analyze heat engines, refrigerators and Carnot cycle.	L2

SYLLABUS

Unit-I: Basic Thermodynamic Concepts and Properties: Introduction to thermodynamics and its importance in engineering applications, Macroscopic and microscopic approaches, Thermodynamic system, surroundings, boundary, Types of systems: closed, open, isolated, Properties: intensive and extensive, State, path, process, and cycle, Thermodynamic equilibrium, Temperature and Zeroth Law of Thermodynamics, Quasi-static process, Gas laws and ideal gas equation of state, Concept of gas constant and universal gas constant.

Unit-II: Energy, Heat, Work and First Law of Thermodynamics: Energy and its various forms, Internal energy and its significance, Heat and modes of heat transfer (basic concepts only), Work and its forms: Mechanical work, Electrical work, First Law of Thermodynamics, Energy balance for closed systems, Energy conversion efficiency, Basic concept of flow energy, Applications of First Law to simple engineering devices (qualitative): Turbines, Compressors, Pumps, Heat exchangers, Environmental impact of energy conversion.

Unit-III: Second Law of Thermodynamics and Basic Power Cycles: Second Law of Thermodynamics, Limitations of First Law, Thermal energy reservoir, Heat engines, refrigerators and heat pumps, Kelvin–Planck and Clausius statements, Coefficient of Performance (COP), Reversible and irreversible processes, Carnot cycle and Carnot efficiency.

Text Books:

1. Yunus Çengel and Michael, Boles, Thermodynamics: An Engineering Approach, Tata McGraw Hill.
2. P. K. Nag, Basic and Applied Thermodynamics, Tata McGraw Hill Education.
3. R.Yadav, Fundamentals of Engineering Thermodynamics, Central Publishing House (CPH), Allahabad.
4. V. Ganeshan, Thermodynamics Basics and Applied, Tata McGraw Hill Education.
5. Mahesh M. Rathore, Thermal Engineering, Tata McGraw Hill Education.

Reference Books:

1. Reyner Joel, Basic Engineering Thermodynamics, Pearson Education
2. C.P.Arora, Thermodynamics, Tata McGraw Hill Education.
3. G. J. Vanwylen, Fundamentals of Classical Thermodynamics, Wiley (John Wiley & Sons).
4. P. Chattopadhyay, Engineering Thermodynamics, Oxford University Press.
5. Gordon Rogers, Yon Mayhew, Pearson, Engineering Thermodynamics, Pearson Education.

MOOC Links:

1.https://ncert.nic.in/textbook/pdf/keph204.pdf
2.https://www.sfu.ca/~mbahrami/ENSC%20388/Notes/First%20Law%20of%20Thermodynamics_Closed%20Systems.pdf
3.https://www.sfu.ca/~mbahrami/ENSC%20388/Notes/Intro%20and%20Basic%20Concepts.pdf
4.https://coursecontent.indusuni.ac.in/wp-content/uploads/sites/8/2021/11/3.1.-PROPERTIES-OF-STEAM.pdf
5.http://www.rshanthini.com/tmp/ThermoBook/ThermoChap10.pdf
6.https://www.sfu.ca/~mbahrami/ENSC%20388/Notes/Second%20Law%20of%20Thermodynamics.pdf
7.https://www.sathyabama.ac.in/sites/default/files/course-material/2020-10/UNIT-1.PDF

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Program:	**B. E. Mechanical Engineering**	Semester:	**V**
Course:	**Manufacturing Technology**	Code:	**5ME228M**

Lecture	Tutorial	Hours	Credit	TA	CT-I	CT-II	Th. Exam	Total
2	0	2	2	10	5	5	30	50

Methods of Teacher Assessment (TA): Class Tests, Assignments. Quiz Class, Attendance, etc.

Course Objectives:

1. Provide fundamental knowledge of various manufacturing processes used in industry.
2. Explain the principles, working, and applications of welding processes and related defects.
3. Develop understanding of conventional and advance machining processes such as turning, drilling, milling, and CNC.
4. Enable students to select appropriate manufacturing and finishing processes for given engineering applications.

After completion of the course, the student will be able to:

CO	Course Outcome	BT Level
CO-1	Understand the fundamentals of manufacturing processes including casting, forming and metal joining techniques.	L2
CO-2	Understand the conventional and advance machining processes such as turning, drilling, milling, CNC and the construction and operations of machine tools.	L2
CO-3	Understand the additive manufacturing process, grinding and finishing processes, and their applications in achieving surface finish and dimensional accuracy.	L2

SYLLABUS

Unit I:

Introduction of manufacturing process: Casting (sand mould casting, permanent mould casting), Forming (forging, rolling, extruding etc).

Joining processes: Mechanical joining processes, Welding, types of welding processes – arc welding - principle and working, gas welding - principle and working, types and purpose of electrodes, Welding defects & remedial actions. (08hrs)

Unit II:

Machining processes - Lathe construction, accessories and operations performed on lathe such as turning, facing, chamfering, taper turning etc. Fundamentals of drilling processes, types of drilling machines. Fundamental of milling process, Introduction to NC, CNC and DNC machines. (08hrs)

Unit III:

Additive manufacturing processes: Definition and fundamentals of Additive Manufacturing, Additive manufacturing process chain: CAD → STL → slicing → printing → post-processing. Advantages and limitations of additive manufacturing.

Grinding and Finishing Processes: Grinding wheels and its structure, grinding machines. Honing, lapping, super-finishing, buffing and burnishing processes. (8hrs)

Text Books:

1. Chapman W. A.: - "Workshop Technology, Vol. II, III and I", Edward Arnold Pub. Ltd. London.
2. Hajra Chaudhary S. K. – "Elements of workshop technology Vol. I & II," Media Prom & pub, Mumbai
3. P. N. Rao :- "Manufacturing technology Vol. II" McGraw Hill 1998
4. Cad/CAM: Computer-Aided Design and Manufacturing, by Emory W Jr Zimmers, Mikell P. Groover, Emory W. Zimmers, et al.

Reference Books:

1. "Workshop Technology" O.P Khanna, Dhanpatrai & sons.
2. "Workshop Technology Vol. II" B. S. Raghuvanshi.

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Program:	**B. E. Mechanical Engineering**	Semester:	**V**
Course:	**Computer Aided Design and Drafting Lab.** (MDM Lab – I)	Code:	**5ME229ML**

Practical	**Hours**	**Credit**	**Practical Evaluation**		**Total**
			INT	**EXT**	
2	2	1	25	25	50

Methods of Teacher Assessment (TA): Continuous Evaluation, Viva-voca

Course Objectives:

1. To understand fundamentals of CAD.
2. To understand the sketching module
3. To study the solid modeling techniques.
4. To understand the concept of automated drafting
5. To use automated drafting environment for creation of drawings from models.

After completion of the course, the student will be able to understand the -

Comprehend Computer Aided Design and Drafting Environment.

Apply the knowledge of computer aided design creation of part models and assembly models.

Use automated drafting environment for creation of drawings from models.

CO	**Course Outcome**	**BT Level**
CO-1	Illustrate the concepts of Solid Modeling.	L2
CO-2	Apply knowledge of CAD modeling for component design.	L3
CO-3	Apply knowledge of CAD modeling for assembly of components.	L3
CO-4	Illustrate the concepts of Automated Drafting.	L2
CO-5	Use automated drafting environment for creation of drawings from models.	L3

List of Practicals (Any Six of the following):

1. Creation of 2D drawing (Sketching Module) of any mechanical machine component using any modeling/drawing software.
2. Creation of isometric view (3D model) from given orthographic view of any mechanical machine part using any modeling software.
3. Creation of 3D models of any mechanical machine part using any modeling software.
4. Creation of 3D models of Knuckle joint/ Cotter joint using any modeling software
5. Creation of assembly of mechanical parts with five or more components using any modeling software.
6. Creation of orthographic drawing of any mechanical machine part using automated drafting environment
7. Creation of orthographic drawing of any mechanical assembly using automated drafting environment
8. Creation of section view and detailed view drawing of any mechanical assembly using automated drafting environment

Practical Examination:

Note: Practical examination shall consist of performance and viva voce based on the above practical work.

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Program:	**B. E. Mechanical Engineering**	**Semester:**	**V**
Course:	**Open Elective- III: 1) Optimization Techniques**	**Code:**	**5ME230OE**

Lecture	**Tutorial**	**Hours**	**Credit**	**TA**	**Th. Exam**	**Total**
2	0	2	2	20	30	50

Methods of Teacher Assessment (TA) : Class Tests, Assignments, Class Attendance, Quiz

Course Objectives The course aims to:

1. Introduce students to the fundamental concepts and historical development of optimization and its engineering applications.
2. Develop the ability to formulate engineering design problems as mathematical programming models.
3. Provide knowledge of classical and advanced optimization techniques including calculus-based methods, dynamic programming, and integer programming.
4. Familiarize students with network models (PERT/CPM) and replacement models used in engineering decision-making.

CO No.	**Course Outcomes: After completion of the course, the student will be able to:**	**Bloom's Level**
CO1	Explain fundamental concepts of optimization and classify different types of optimization problems.	L2-Understand
CO2	Formulate engineering problems as mathematical programming models and solve simple optimization problems using calculus and graphical methods.	L3-Apply
CO3	Apply dynamic programming and integer programming techniques to solve discrete optimization problems.	L3-Apply
CO4	Analyze project networks using PERT/CPM and evaluate replacement decisions using appropriate models.	L4-Analyze

SYLLABUS:

UNIT I:	**Introduction to Optimization and Problem Formulation:** Historical development of optimization; engineering applications of optimization; art of mathematical modeling. Objective function; constraints and constraint surface; formulation of engineering design problems as mathematical programming problems. Classification of optimization problems: linear and nonlinear, constrained and unconstrained, single and multi-variable, discrete and continuous problems. Overview of optimization techniques: classical and advanced methods. Optimization using calculus: necessary and sufficient conditions for single and multivariable optimization; constrained optimization using Lagrange multipliers. Graphical method for two-variable optimization problems with illustrative examples.	**(8 Hrs**)
UNIT II:	**Advanced Optimization Techniques:** Geometric programming; polynomial and signomial programming – basic concepts and simple problems. Dynamic programming: discrete and continuous dynamic programming; formulation of multistage decision problems; multiple state variables; curse of dimensionality; applications. Integer programming: formulation of integer programming problems; branch and bound technique; primal-based methods.	**(8 Hrs)**

UNIT III:	**Network and Replacement Models** Network models: network construction; PERT analysis; CPM analysis; time–cost trade-off; cost analysis and crashing of networks; updating; resource smoothing and resource leveling. Replacement models: introduction; value of money concepts; individual and group replacement policies.	**(8 Hrs)**

Text Books:

1. Rao, S. S. – *Engineering Optimization: Theory and Practice*, New Age International Publishers, New Delhi.
2. Gupta, P. K. and Hira, D. S. – *Operations Research*, S. Chand & Company Ltd., New Delhi.
3. Sharma, J. K. – *Operations Research: Theory and Applications*, Macmillan India Ltd.

Reference Books:

1. Kanti Swarup, Gupta, P. K., and Man Mohan – *Operations Research*, Sultan Chand & Sons, New Delhi.
2. Taha, H. A. – *Operations Research: An Introduction*, Pearson Education.
3. Hillier, F. S. and Lieberman, G. J. – *Introduction to Operations Research*, McGraw Hill.
4. Bazaraa, M. S., Sherali, H. D., and Shetty, C. M. – *Nonlinear Programming: Theory and Algorithms*, Wiley India.
5. Hadley, G. – *Linear Programming*, Narosa Publishing House.

NPTEL Web Videos / Online Learning Resources:

1. NPTEL Course on Optimization Methods – Offered by IITs (e.g., IIT Madras / IIT Kharagpur).
   https://nptel.ac.in/courses/108105019
2. NPTEL Course on Operations Research – IIT Roorkee / IIT Bombay.
   https://nptel.ac.in/courses/111107128
3. NPTEL Course on Project Management (PERT/CPM) – IIT Delhi.
   https://nptel.ac.in/courses/112102106

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Course Code	Course Title	L	T	P	C
Open Elective III	**Industrial Robotics and Automation (5ME230OE)**	02	00	00	2

Course Prerequisites:

1. Knowledge of production processes and manufacturing techniques
2. Knowledge of processing Tools and Machines.

Course Learning Objectives:

1. To study the concepts of Automation in industries and role of Robots for Industrial automation.
2. To study the Anatomy working of Industrial robots.

Course Outcomes:

At the end of course, students will be able to –

1. Understand the concepts, importance of automation and basics of CNC technology.
2. To Understand the Anatomy, Construction of Industrial robots.
3. Understand and apply the knowledge of robotics for its application in industries.

	Subject: **Industrial Robotics and Automation**	**L**
UNIT I	**Introduction to Industrial Automation:** Automation & its types, Automation for mass manufacturing and assembly, Reasons for automating, **CNC Technology:** Numerical control, and Computer Numerical Control, Basic concept, NC Control- point to point, Straight line, Continuous path control, Drives in NC/CNC- Servo and Stepper motors, , Manual Part programming, Programming formats, Programming codes, DNC concept.	8
UNIT II	**Introduction to Industrial Robotics:-** Evolution of industrial robots, Robots anatomy, Arm geometry, drive system, types of end efforts-Grippers and Tools, sensors, common geometrical configurations for industrial robots, Programming techniques of Robots	7
UNIT III	**Application of Robots in manufacturing:** 1.Part handling- Pick and Place, Machine Tending, Palletizing, Unit Load Handling. 2.Part processing- Machining, Welding, Painting, Heat Treatment 3. Part building- Part Assembly, Clamping and Bolting etc 4. Part Inspection- Inspection, Measurement and Gauging Technical Specifications of an Industrial Robot.	6
	Total	21

BOOKS RECOMMENDED:

Text Books:

1) Production system, Automation and CIM By Mikhal Groover, Pearson Publication
2) Industrial Robotics By Mikhal Groover, McGraw Hill Publication

Reference Books:

1) Computer aided Design and Manufacturing by Sadhu Singh
2) CNC Machines: M. Aditham & B.S. Pabla, New Age International
3) Robotics for Engineering, Korean Yoram, McGraw Hill Publication

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Course Code	Course Title	L	T	P	C
Open Elective III	Introduction to 3D Printing **(5ME230OE)**	02	00	00	2

Course Prerequisites:

1. Basic knowledge of Manufacturing Processes.
2. Preliminary knowledge of Engineering Graphics and Solid Modelling.

Course Learning Objectives:

1. Comprehend the Fundamentals and Evolution of Rapid Prototyping &3D Printing.
2. Explore the 3D Printing Processes.

Course Outcomes: Students will be able to –

1. Understand a prototype and its types also the importance of compression in product development timelines.
2. Comprehend the fundamental principles of 3D Printing including pre-processing, processing, and post-processing.
3. Understand the process physics and principle of material deposition in different 3D printing systems also Compare the applications, limitations, and advantages of various 3D printing processes.

	Subject: **Introduction to 3D Printing**	**L**
UNIT I	**Introduction:** Definition of Prototype, Types of prototype, Need for the compression in product development time span, History 3D Printing systems, classification of 3D Printing systems, applications of 3D printing, Growth of 3D Printing industry, Software for 3D Printing.	6
UNIT II	**Introduction to 3D Printing:** Fundamentals of 3D Printing, Process Chain, Classification of 3D Printing systems, Dawn of slice age, benefits, applications, important issues in 3D Printing. Pre and Post Processing requirements in 3D Printing. **Errors in 3D Printing Processes:** Pre-processing, processing, post-processing errors, Part building errors.	7
UNIT III	3D Printing **Processes:** Process Physics, Tooling, Material and technological aspects, Applications, limitations and comparison of various rapid manufacturing processes, **Photopolymerization** (Stereolithography ,SL), **Powder Bed Fusion** (Selective laser Sintering (SLS), Electron Beam melting (EBM)),**Extrusion Based RP Systems,3D Printing**, **Sheet Lamination** (Laminated Object Manufacturing (LOM), Ultrasonic Consolidation (UC)),**Beam Deposition**(Laser Engineered Net Shaping process(LENS))	8
	Total	21

Text Books:

1. Rapid Prototyping by Amitabh Ghosh, Affiliated East-West Press Pvt. Ltd.
2. 3D Printing; Publisher- Hanser (ISBN- 978-1-56990-702-3
3. 3D Printing and Design; Publisher-Khanna (ISBN-13- 9789386173768)

Reference Books:

1. 'Design for 3D Printing'; Publisher –Make Community LLC (ISBN-13: 978-1457187360)
A to Z3D Printing; Publisher – CreateSpace Independent Publishing Platform LLC (ISBN-13: 978-1523401628)

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