CURRICULUM & SYLLABI

B.Tech. MECHANICAL ENGINEERING

Effective from AY: 2024-25

NATIONAL INSTITUTE OF TECHNOLOGY WARANGAL

WARANGAL, TELANGANA

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Vision and Mission of the Institute
National Institute of Technology Warangal

VISION
Towards a Global Knowledge Hub, striving continuously in pursuit of excellence in Education, Research, Entrepreneurship and Technological services to the society

MISSION
- Imparting total quality education to develop innovative, entrepreneurial and ethical future professionals fit for globally competitive environment.
- Allowing stake holders to share our reservoir of experience in education and knowledge for mutual enrichment in the field of technical education.
- Fostering product-oriented research for establishing a self-sustaining and wealth creating centre to serve the societal needs.

Vision and Mission of the Department
MECHANICAL Engineering

VISION
To be a global knowledge hub in mechanical engineering education, research, entrepreneurship and industry outreach services.

MISSION
- Impart quality education and training to nurture globally competitive mechanical engineers.
- Provide vital state of the art research facilities to create, interpret, apply and disseminate knowledge.
- Develop linkages with world class educational institutions and R&D organizations for excellence in teaching, research and consultancy services.

Program: B.Tech. Mechanical Engineering

Program Educational Objectives

PEO-1	Plan, design, construct, maintain and improve mechanical engineering systems that are technically sound, economically feasible and socially acceptable to enhance quality of life.
PEO-2	Apply analytical, computational and simulation tools & techniques to address the challenges faced in mechanical and allied engineering streams.
PEO-3	Communicate effectively using innovative tools and demonstrate leadership & entrepreneurial skills.
PEO-4	Exhibit professionalism, ethical attitude, team spirit and pursue lifelong learning to achieve career and organizational goals.

Program Articulation Matrix

PEO / Mission Statements	PEO-1	PEO-2	PEO-3	PEO-4
Impart quality education and training to nurture globally competitive mechanical engineers	3	3	2	2
Provide vital state of the art research facilities to create, interpret, apply and disseminate knowledge	3	2	2	2
Develop linkages with world class educational institutions and R&D organizations for excellence in teaching, research and consultancy services	2	2	3	2

1 - Slightly; 2 - Moderately; 3 - Substantially

Program: B.Tech. Mechanical Engineering

Program Outcomes

PO-1	**Engineering knowledge**: Apply the knowledge of mathematics, science, engineering fundamentals, and mechanical engineering to the solution of complex engineering problems.
PO-2	**Problem analysis**: Identify, formulate, research literature, and analyze complex engineering problems reaching substantiated conclusions using first principles of mathematics, natural sciences, and engineering sciences.
PO-3	**Design/Development of solutions**: Design solutions for complex mechanical engineering problems and design system components or processes that meet the specified needs with appropriate consideration for the public health and safety, and the cultural, societal, and environmental considerations.
PO-4	**Conduct investigations of complex problems**: Use research-based knowledge and research methods including design of experiments, analysis and interpretation of data, and synthesis of the information to provide valid conclusions.
PO-5	**Modern tool usage**: Create, select, and apply appropriate techniques, resources, and modern engineering and IT tools including prediction and modeling to complex mechanical engineering activities with an understanding of the limitations.
PO-6	**The engineer and society**: Apply reasoning informed by the contextual knowledge to assess societal, health, safety, legal and cultural issues and the consequent responsibilities relevant to professional engineering practice.
PO-7	**Environment and sustainability**: Understand the impact of the professional engineering solutions in societal and environmental contexts, and demonstrate the knowledge of, and need for sustainable development.
PO-8	**Ethics**: Apply ethical principles and commit to professional ethics and responsibilities and norms of the engineering practice.
PO-9	**Individual and team work**: Function effectively as an individual, and as a member or leader in diverse teams, and in multidisciplinary settings.
PO-10	**Communication**: Communicate effectively on complex engineering activities with the engineering community and with society at large, such as, being able to comprehend and write effective reports and design documentation, make effective presentations, and give and receive clear instructions.
PO-11	**Project management and Finance:** Demonstrate knowledge and understanding of the engineering and management principles and apply these to one's own work, as a member and leader in a team, to manage projects and in multidisciplinary environments.
PO-12	**Life-long learning**: Recognize the need for, and have the preparation and ability to engage in independent and life-long learning in the broadest context of technological change.

Program Specific Outcomes

PSO-1	Apply mechanical engineering and interdisciplinary knowledge for analyzing, designing and manufacturing products to address the needs of the society.
PSO-2	Apply state of the art tools and techniques to conceptualize, design and introduce new products, processes, systems and services.

CURRICULUM
B.Tech. Mechanical Engineering

1st Semester

S.No.	Code	Course Title	L-T-P	Credits
1	MA 1161	Linear Algebra, Calculus and Ordinary Differential Equations	3-0-0	3
2	CY 1161	Engineering Chemistry	3-0-2	4
3	EE 1161	Basic Electrical and Electronics Engineering	3-0-0	3
4	ME 1101	Design Thinking	0-1-4	3
5	ME 1103	Engineering Graphics	1-0-4	3
6	ME 1165	Engineering Workshop Practice	0-1-2	2
7	IC 1101	EAA-I (Games & Sports / Yoga & Wellness)	0-0-0	0
Total Credits				18

2nd Semester

S.No.	Code	Course Title	L-T-P	Credits
1	MA 1164	Integral and Vector Calculus & Laplace and Fourier Transforms	3-0-0	3
2	PH 1161	Engineering Physics	3-0-2	4
3	CS 1101	Programming and Data Structures	3-0-0	3
4	HS 1161	English for Technical Communication	2-0-2	3
5	BT 1161	Biology for Engineers	2-0-0	2
6	CS 1103	Programming and Data Structures Lab	0-1-2	2
7	ME 1102	Engineering Mechanics	3-0-0	3
8	IC 1102	EAA-II (Games & Sports / Yoga & Wellness)	0-0-0	0
		Total Credits		20

3rd Semester

S.No.	Code	Course Title	L-T-P	Credits
1	ME 1201	Mechanics of Solids	3-0-0	3
2	ME 1203	Kinematics of Machinery	3-0-2	4
3	MM 1213	Materials Engineering	3-0-0	3
4	ME 1205	Thermodynamics	3-1-0	4
5	ME 1207	Fluid Mechanics and Hydraulic Machines	3-0-0	3
6	ME 1209	Strength of Materials Lab	0-1-2	2
7	ME 1211	Fluid Mechanics and Hydraulic Machines Lab	0-1-2	2
			Total Credits	21

4th Semester

S.No.	Code	Course Title	L-T-P	Credits
1	MS 1262	Business Essentials for Engineers	3-0-0	3
2	ME 1202	Dynamics of Machinery	3-0-2	4
3	MA 1263	Partial Differential Equations, Statistics and Numerical Methods	3-0-0	3
4	ME 1204	Manufacturing Science	3-0-0	3
5	ME 1206	Fundamentals of Prime Movers	3-1-0	4
6	ME 1208	Manufacturing Science Lab	0-1-2	2
7	ME 1210	Computer Aided Machine Drawing	0-1-2	2
			Total Credits	21

5th Semester

S.No.	Code	Course Title	L-T-P	Credits
1	ME 1301	Machine Design	3-1-0	4
2	ME 1303	Machine Tools and Metrology	3-0-0	3
3	ME 1305	Heat Transfer	3-0-0	3
4	ME 1307	Management Science and Productivity	3-0-0	3
5		Professional Elective – I	3-0-0	3
6	ME 1381	Fractal Course - I	1*-0-0	0.5
7	ME 1309	Machine Tools and Metrology Lab	0-1-2	2
8	ME 1311	Heat Transfer and Energy Systems Lab	0-1-2	2
			Total Credits	20.5

6th Semester

S.No.	Code	Course Title	L-T-P	Credits
1	ME 1302	Refrigeration & Air conditioning	3-0-0	3
2	ME 1304	Machining Science	4-0-0	4
3		Professional Elective – II	3-0-0	3
4		Professional Elective - III	3-0-0	3
5	ME 1306	Product Development	0-1-4	3
6	ME 1383	Fractal Course - II	1-0-0	0.5
7	ME 1308	Thermal Engineering Lab	0-1-2	2
8	ME 1310	CAE Laboratory	0-1-2	2
			Total Credits	20.5

7th Semester

S.No.	Code	Course Title	L-T-P	Credits
1	ME 1401	CAD/CAM – Theory and Practice	3-0-2	4
2		Professional Elective - IV	3-0-0	3
3		Professional Elective - V	3-0-0	3
4		Open Elective	2-0-0	2
5	ME 1403	CFD Laboratory	0-1-2	2
6	ME 1489	Seminar & Technical Writing	0-0-0	2
7	ME 1495	Minor Project	0-0-0	2
8	ME 1491	Short Term Industrial / Epics / Research Experience**	0-0-0	2
		Total Credits		20

8th Semester

S.No.	Code	Course Title	L-T-P	Credits
1		Professional Elective - VI	3-0-0	3
2		Professional Elective -VII	3-0-0	3
3		Professional Elective - VIII	3-0-0	3
4	ME 1498	Major Project	0-0-0	6
		Total Credits		15

Professional Elective Courses:

Professional Elective-I		
S.No.	**Code**	**Course Title**
1	ME 1321	Computational Fluid Dynamics
2	ME 1323	Automobile Engineering
3	ME 1325	Advanced Welding Technology
4	ME 1327	Mechatronics
5	ME1329	Mechanical Vibrations
6	ME 1331	Geometric Modelling for CAD

Professional Electives-II and III		
S.No.	**Code**	**Course Title**
1	ME 1322	Mechanical Measurements
2	ME 1324	Alternate Fuels
3	ME 1326	Advanced Metal Casting and NDT
4	ME 1328	Advanced Metal Forming
5	ME 1330	Finite Element Method
6	ME 1332	Optimization for Engineering Design
7	ME 1334	Gas dynamics
8	ME 1336	Non-Conventional Energy Sources
9	ME 1338	Operations Planning and Control
10	ME 1340	Operation Research
11	ME 1342	Mechanics of Composite Materials
12	ME 1344	Design of Mechanical Elements

Professional Electives-IV and V		
S.No.	**Code**	**Course Title**
1	ME 1421	Convective Heat Transfer
2	ME1423	Automotive Safety
3	ME 1425	Design and Analysis of Experiments
4	ME 1427	Computer Control of Manufacturing Systems

5	ME 1429	Robotics
6	ME 1431	Condition Monitoring
7	ME 1433	Two-Phase Heat Transfer
8	ME 1435	Power Plant Engineering
9	ME 1437	Aerodynamics
10	ME 1439	Artificial Intelligence for Cyber-Physical Systems
11	ME 1441	Tool Design
12	ME 1443	Total Quality Management
13	ME 1445	Micro and Nano Manufacturing
14	ME 1447	Tribology
15	ME 1449	Fracture Mechanics

Professional Electives - VI, VII and VIII		
S.No.	**Code**	**Course Title**
1	ME 1422	Introduction to Turbulence
2	ME 1424	Hybrid Electric Vehicles
3	ME 1426	Flexible Manufacturing System
4	ME1428	Supply Chain Management
5	ME 1430	Additive Manufacturing Processes and Applications
6	ME 1432	Project Management
7	ME 1434	Reliability Engineering
8	ME 1436	Material Characterization
9	ME 1438	Heating Ventilation and Air-Conditioning
10	ME 1440	Fuel Cell Technology
11	ME 1442	Design for Manufacturing and Assembly
12	ME 1444	Advanced Material Processing
13	ME 1446	Lean Manufacturing and Six Sigma
14	ME 1448	Surface Coating Technology
15	ME 1450	Lubrication and Rotor Dynamics
16	ME 1452	Jet Propulsion and Rocketry
17	ME 1454	Applied Heat Transfer
18	ME 1456	Engineering Acoustics
19	ME 1458	Analysis of Mechanisms

20	ME 1460	Industry 4.0 and IIoT
21	ME 1462	Virtual Reality and Augmented Reality
22	ME 1464	Biofluids and Bio-heat transfer
23	ME 1466	Heat Exchanger Design
24	ME 1468	Thermal Energy Storage

Open Elective Courses:

Open Elective		
S.No.	**Code**	**Course Title**
1	ME 1473	Alternative Sources of Energy
2	ME 1475	3D Printing
3	ME 1477	Composite Materials
4	ME 1479	Industrial Management

Basic Science Courses

S.No.	Code	Course Title	L-T-P	Credits
1	MA 1161	Linear Algebra, Calculus and Ordinary Differential Equations	3-0-0	3
2	CY 1161	Engineering Chemistry	3-0-2	4
3	MA 1162	Laplace Transforms, Integral and Vector Calculus	3-0-0	3
4	PH 1161	Engineering Physics	3-0-2	4
5	MA 1261	Fourier Series, Partial Differential Equations and Complex Variables	3-0-0	3

Engineering Science Courses

S.No.	Code	Course Title	L-T-P	Credits
1	EE 1161	Basic Electrical and Electronics Engineering	3-0-0	3
2	CS 1101	Programming and Data Structure	3-0-0	3
3	BT 1161	Biology for Engineers	2-0-0	2
4	CS 1103	Programming and Data Structure Lab	0-1-2	2
5	MM 1261	Materials Engineering	3-0-0	3

Humanities and Social Science Courses

S.No.	Code	Course Title	L-T-P	Credits
1	HS 1161	English For Technical Communication	2-0-2	3
2	MS 1262	Business Essentials for Engineers	3-0-0	3

The Overall Credit Structure

Course Category	Credits
Basic Science	17
Engineering Science	13
Humanities and Social Sciences	6
Program Core	81
Professional Elective	24
Open Elective	2
Seminar and Technical Writing	2
Minor Project	2
Short Term Industrial/EPICS/Research Experience	2
Fractal Course	1
Major Project	6
Total Graded Credit Requirement	156

Minor in Mechanical Engineering:

Code	Course Title	L-T-P	Credits
ME M01	Fluid Mechanics and Applied Thermodynamics	3-0-0	3
ME M02	Kinematics and Dynamics of Machinery	3-0-0	3
ME M03	Manufacturing Processes	3-0-0	3
ME M04	Engineering Design	3-0-0	3
ME 1307	Management Science and Productivity	3-0-0	3
		Total	**15**

Honors in Thermal Engineering:

Code	Course Title	L-T-P	Credits
ME 16001	Advanced Fluid Mechanics	3-0-0	3
ME 16005	Advanced Heat and Mass Transfer	3-0-0	3
ME 16002	Prime Movers and Propulsion	3-0-0	3
ME 16024/ ME 16022	Advanced Computational Fluid Dynamics / Heating, Ventilation and Air-Conditioning (HVAC)	3-0-0	3
ME 16023	Power Plant Engineering	3-0-0	3
		Total	**15**

Honors in Design Engineering:

Code	Course Title	L-T-P	Credits
ME 46001	Mechanical Design	3-0-0	3
ME 46005	Advanced Materials for Design	3-0-0	3
ME 46021/ ME 46003	Computer Aided Geometric Design/Mechanical Vibrations	3-0-0	3
ME 46002	Product Design & Development	3-0-0	3
ME 46022/ ME 46030	AI & ML for Engineering Analysis/Robotics	3-0-0	3
		Total	**15**

Honors in Smart Manufacturing:

Code	Course Title	L-T-P	Credits
ME 26003	Advanced CAM and Intelligent Mfg.	3-0-0	3
ME 26001	Advanced Manufacturing Technology	3-0-0	3
ME 26005	Machining Physics	3-0-0	3
ME 36004/ ME 26002	Industry 4.0 and IIoT / Additive Manufacturing	3-0-0	3
ME 26028/ ME 36032/ ME 36036	Design and Analysis of Experiments/AI & ML for Mechanical Systems/Soft Computing Techniques	3-0-0	3
		Total	**15**

Honors in Computational Mechanics:

Code	Course Title	L-T-P	Credits
ME 16001	Advanced Fluid Mechanics	3-0-0	3
ME 16003	Computational Methods in Thermal Engineering	3-0-0	3
ME 26003/ ME 46021	Advanced CAM and Intelligent Manufacturing Systems/ Computer Aided Geometric Design	3-0-0	3
ME 46004	Finite Element Analysis for Design	3-0-0	3
ME 16054/ ME 46028/ ME 36032	Design and Optimization of Thermal Systems/ Optimization Methods for Engineering Design/ AI & ML for Mechanical Systems	3-0-0	3
Total			**15**

SYLLABI

B.Tech. Mechanical Engineering

1st Semester

MA 1161 **3-0-0 (3)**

Linear Algebra, Calculus and Ordinary Differential Equations

Pre-Requisites: **None**

Course Outcomes:

CO-1	Understand to solve the consistent system of linear equations
CO-2	Apply orthogonal transformations to a quadratic form
CO-3	Determine the series expansion of a given function
CO-4	Explore the properties of functions of several variables
CO-5	Solve arbitrary order linear differential equations

Course Articulation Matrix:

	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6	PO-7	PO-8	PO-9	PO-10	PO-11	PO-12	PSO-1	PSO-2
CO-1	3	3	1	2	1	–	–	–	–	–	–	–	1	1
CO-2	3	3	1	2	1	–	–	–	–	–	–	–	-	-
CO-3	3	3	1	2	1	–	–	–	–	–	–	–	1	-
CO-4	3	3	1	2	1	–	–	–	–	–	–	–	-	-
CO-5	3	3	1	2	1	–	–	–	–	–	–	–	2	1

1 - Slightly; **2 - Moderately;** **3 - Substantially**

Syllabus:

Linear Algebra: Vector space, Subspace, Examples, Linear span, Linear independence and dependence, Basis, Dimension, Extension of a basis of a subspace, Intersection and sum of two subspace, Examples. Linear transformation, Kernel and Range of a linear map, Rank-Nullity Theorem (without proof). Rank of a matrix, Row, and column spaces, Solvability of the system of linear equations, Inner product spaces, Orthogonal basis, Gram-Schmidt orthogonalization process. Eigenvalues, Eigenvectors, and properties Caley-Hamilton Theorem (without proof) and applications, diagonalization of a matrix, diagonalization by similarity, and orthogonal transformations.

Differential Calculus: Taylor's theorem with remainders; Taylor's and Maclaurin's expansions; Functions of several variables – continuity, differentiability, partial derivatives, Euler's theorem, change of variables, Jacobians, Functional dependence; Maxima and minima of functions of several variables (2 and 3 variables) - Lagrange's method of multipliers.

Ordinary Differential Equations: First order differential equations - Basic definitions, Geometric interpretation of solutions of first-order ODE $y' = f(x, y)$, Exact differential equations, Integrating factors, Linear equation, Reducible to linear form: Bernoulli's equations; Orthogonal trajectories; Higher order linear differential equations with constant coefficients - Cauchy-Euler and Legendre's differential equations, Method of variation of parameters - System of linear differential equations; Applications to physical problems.

Learning Resources:

Text Books:

1. Howard Anton and Chris Rorres, Elementary Linear Algebra with Supplementary Applications, John Wiley & Sons, 2014, Eleventh Edition.
2. George B. Thomas and Ross L. Finney, Calculus and Analytic Geometry, Pearson, 2020, Ninth Edition.
3. Erwin Kreyszig, Advanced Engineering Mathematics, John Wiley and Sons, 2015, Eighth Edition.

Reference Books:

1. Dennis G. Zill, Advanced Engineering Mathematics, Jones & Bartlett Learning, 2018, Sixth Edition.
2. R. K. Jain and S. R. K. Iyengar, Advanced Engineering Mathematics, Narosa Publishing House, 2016, Fifth Edition

CY 1161 **3-0-2 (4)**

Engineering Chemistry

Pre-Requisites: **None**

Course Outcomes:

CO-1	Understand the basic concepts of chemistry relevant to materials.
CO-2	Apply electrochemical concepts for energy harvesting, conversion and storage.
CO-3	Analyze the properties of materials for various applications.
CO-4	Comprehend the concepts of instrumentation principles, Spectroscopy and procedures involved in characterization of materials

Course Articulation Matrix:

	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6	PO-7	PO-8	PO-9	PO-10	PO-11	PO-12	PSO-1	PSO-2
CO-1	3	-	-	-	-	-	-	-	-	-	-	-	-	2
CO-2	3	-	-	-	-	-	-	-	-	-	-	-	2	2
CO-3	3	2	-	-	-	-	-	-	-	-	-	-	2	2
CO-4	3	-	-	-	-	-	-	-	-	-	-	-	2	2
CO-5	3	-	-	-	-	-	-	-	-	-	-	-	-	2

1 - Slightly; **2 - Moderately;** **3 - Substantially**

Syllabus:

Chemical Kinetics and Thermodynamics: Order of a Reaction, Theories of Reaction Rates, Homogeneous and Heterogeneous Catalysis. Laws of Thermodynamics, Thermodynamic functions (A,G,U and H), Maxwell Relationships.

Electrochemistry and Energy Systems: Introduction to Electrochemistry, Nernst's law and its applications. Batteries, fuel cell and photo electrochemical systems. Corrosion and its prevention.

Transition Metal Chemistry and Organometallic Chemistry: Bonding in transition metal complexes; Crystal field and MO Theories, Jahn-Teller effect. Properties of Coordination complexes; Metal Carbonyls, EAN and 18-electron rule, Ligands and hapticity; Type of reactions: Oxidative addition, Reductive elimination, Migratory insertion, Hydrogenation, Hydroformylation, Monsanto process and Wacker process.

Engineering Materials: Inorganic and Organic Semiconductors, Magnetic materials, Liquid crystals, Superconductors, Photo conducting Materials and conducting polymers.

Chromatographic and Spectroscopic Methods: Liquid Chromatographic and Gas Chromatographic methods. UV-VIS spectroscopy, Infrared spectroscopy, NMR spectroscopy.

List of Experiments:

1. Standardization $KMnO_4$ solution
2. Estimation of metal content in an ore
3. Estimation of Calcium in milk powder by complexometry

4. Extraction and identification of DNA from green peas/onions
5. Estimation of iodine in iodized common salt
6. Blue printing of an object by photochemical reaction
7. Kinetics of acid hydrolysis of methyl acetate
8. Determination of acid strength in citrus fruit
9. Verification of Beer-Lambert Law and estimation of concentration of food color
10. Evaluation of E^o values of $Zn|Zn^{2+}$ and $Cu|Cu^{2+}$ Electrodes and measure the emf by constructing the Daniel cell
11. Estimation of phosphoric acid in soft drinks by pH metry
12. Separation of natural pigments from mixture using paper chromatography
13. Determination of efficiency of a corrosion inhibitor
14. Verification of Freundlich adsorption isotherm
15. Preparation of a polymer and its analysis
16. Estimation of active pharmaceutical ingredient in a drug

Learning Resources:

Text Books:

1. Shashi Chawla, A Text Book of Engineering Chemistry, Danpathrao & Co. Publications, 2007, 6th India reprint edition
2. Ashutosh Kar, Text Book of Engineering Chemistry, ED-Tech Publications, 2018
3. William Kemp, Organic Spectroscopy, Macmillan Education Limited, 2017
4. Charles Corwin, Introductory Chemistry laboratory manual: Concepts and Critical Thinking, Pearson Education, 2012.
5. David Collins, Investigating Chemistry: Laboratory Manual, Freeman & Co., 2006.

Reference Books:

1. Michael F. Ashby, David R.H. Jones, Engineering Materials, Elsevier Science, 2012
2. V. Raghava, Material Science and Engineering, PHI Learning, 2015
3. J.M. Martin, Materials for Engineering, Elsevier Science, 20006
4. Peter Atkins, Julio de Paula, James Keeler, Physical Chemistry, Oxford University Press, 2018.

EE 1161 **3-0-0 (3)**

Basic Electrical & Electronics Engineering

Pre-Requisites: None

Course Outcomes:

CO-1	Able to Analyze DC & AC circuits and determine power & power factor.
CO-2	Able to Understand the operation and characteristics of various electrical machines.
CO-3	Understand the operation of basic electronic circuits and characteristics of semiconductor devices.
CO-4	Able to select appropriate meters/transducers for measurement of various electrical /non-electrical quantities.

Course Articulation Matrix:

	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6	PO-7	PO-8	PO-9	PO-10	PO-11	PO-12	PSO-1	PSO-2
CO-1	3	3	2	2	2	2	1	1	1	1	2	1	--	--
CO-2	3	3	2	2	2	2	1	1	1	1	2	1	--	--
CO-3	3	3	2	2	2	2	1	1	1	1	2	1	--	--
CO-4	3	3	2	2	2	2	1	1	1	1	2	1	--	--

1 - Slightly; **2 - Moderately;** **3 - Substantially**

Syllabus:

DC Circuits: Kirchhoff's Voltage and Current Laws, Superposition Theorem, Star-Delta Transformations.

AC Circuits: Complex representation of Impedance, Phasor diagrams, Power & Power Factor, Solution of 1-Phase Series & Parallel Circuits.

Single Phase Transformers: Principle of Operation of a Single-Phase Transformer, EMF Equation, Phasor Diagram, Equivalent Circuit of a 1-Phase Transformer, Determination of Equivalent circuit parameters, calculation of Regulation & Efficiency of a Transformer.

DC Machines: Principle of Operation, Classification, EMF and Torque Equations, Characteristics of Generators and Motors. Speed Control Methods.

AC Machines: 3-Phase Induction Motor- Principle of Operation, Torque – Speed Characteristics of 3-Phase Induction Motor & Applications, Principle of Operation of Alternator- EMF equation.

Electronic Devices & Circuits: P-type and N-Type semiconductors, P-N junction diode and its I-V characteristics, Single-phase Half-wave and Full wave rectifiers. Bipolar Junction Transistor-operation and CE, CC & CB configurations, Static Characteristics of SCR-MOSFET- IGBT.

Sensors & Transducers: Thermocouple, Thermistor, Resistance Temperature Detector, Hall effect and Piezoelectric Transducers (Qualitative Treatment only)

Electrical Measuring Instruments: Moving Coil & Moving iron ammeters & voltmeters. Wattmeter's

(Qualitative).

Electronics Measurements: Principle of Operation of Digital Multi Meter & Cathode Ray Oscilloscope

Learning Resources:

Text Books:

1. Ed Hughes, Electrical & Electronic Technology, Pearson Education, 2016, 12th Edition.
2. Vincent Del Toro, Electrical Engineering Fundamentals, Pearson Education, 2015, 2nd Edition.
3. V. K Mehtha, Principals of Electrical & Electronics Engineering, S. Chand Publications, New Delhi, 2010, 3rd Edition.
4. V N Mittle and Arvind Mittal, Basic Electrical Engineering, Tata McGraw Hill, 2005, 2nd Edition.

Reference Books:

1. Jacob Millman, Christos Halkias, Chetan Parikh, Integrated Electronics - Analog and Digital Circuit and Systems, Tata McGraw-Hill Education, 2017, 2nd edition.
2. U Bakshi & A. Bakshi, Basic Electrical Engineering, Technical Publications, 2019, 2019-Edition.
3. A Fitzgerald, Charles Kingsley, Stephen Umans, Electrical Machines, McGraw Hill Education, 2017, 6th edition.
4. Stephen.J.Chapman, Electric Machinery, McGraw Hill International Edition, 2017, 4th edition.
5. P.S. Bimhbra, Electrical Machinery - Theory, Performance & Applications, Khanna Publishers 2014, 7th edition.

Other Suggested Readings:

1. https://nptel.ac.in/courses/108/108/108108076/

ME 1101 **0-1-4 (3)**

Design Thinking

Pre-Requisites: None

Course Outcomes:

CO-1	Identify user needs
CO-2	Define problems to stimulate ideation
CO-3	Ideate on problems to propose solutions by working collaboratively
CO-4	Test aspects of proposed solutions
CO-5	Improve solutions by gaining user feedback

Course Articulation Matrix:

	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6	PO-7	PO-8	PO-9	PO-10	PO-11	PO-12	PSO-1	PSO-2
CO-1	2	2	2	3	3	3	2	2	3	3	2	3	3	2
CO-2	2	2	2	3	3	3	2	2	3	3	2	3	3	2
CO-3	2	2	2	3	3	3	2	2	3	3	2	3	3	2
CO-4	2	2	2	3	3	3	2	2	3	3	2	3	3	2
CO-5	2	2	2	3	3	3	2	2	3	3	2	3	3	2

1 - Slightly; **2 - Moderately;** **3 - Substantially**

Syllabus:

Introduction to Engineering: "Engineering" as a vehicle for social and economic development; impact of science/engineering our day to day lives; process of engineering a product; various career options.

Introduction and identifying the need: Understanding the unique needs of the user - empathize - define - ideate - prototype - test. Case Studies - Develop appreciation for the design process and its application in specific settings (Guest lectures, Videos, Field visits, Interplay lectures of design-based movies).

Problem Formulation: Framing a problem statement neutrally using adequate checks. Case studies.

Concept Generation: Generate multiple concepts using various creativity tools and thinking styles.

Prototyping: Select from ideas and make quick prototypes (mock-ups) using available material.

Evaluation: Iterative process of ideation, prototyping and testing-Take the mock-ups to users for feedback and iterate process till users feel delighted.

Activities:

Some of the activities which are undertaken as a part of this course include:

- Field Visits
- Case Studies on innovation, failures etc.
- Guest lecture
- Group Discussions

- Presentation by student
- Experiential learning workshops

Learning Resources:

Reference Books:

1. Andrew Pressman, Routledge, Design Thinking, A guide to creative problem solving for everyone, Taylor and Francis group, 2019, First Edition.
2. Tim Brown, Change by Design, How Design Thinking Transforms Organizations and Inspires Innovation, Harper Business, 2019.
3. George E. Dieter, Linda C. Schmidt, Engineering Design, McGraw-Hill Education,2019, Fifth Edition.
4. Ulrich, K., Eppinger, S. and Yang, M. Product design and development, 2020, Seventh Edition.

Online Resources:

1. Functional and Conceptual Design: https://www.youtube.com/playlist?list=PLyqSpQzTE6M88PUx4AtV1WWNeKYVIvPAl
2. https://www.arvindguptatoys.com/
3. https://honeybee.org/
4. https://dschool.stanford.edu/resources/getting-started-with-design-thinking
5. https://designthinking.ideo.com/

ME 1103 **1-0-4 (3)**

Engineering Graphics

Pre-Requisites: **None**

Course Outcomes:

CO-1	Apply BIS standards and conventions while drawing Lines, printing Letters and showing Dimensions.
CO-2	Classify the systems of projection with respect to the observer, object and the reference planes.
CO-3	Construct orthographic views of an object when its position with respect to the reference planes is defined.
CO-4	Analyse the internal details of an object through sectional views
CO-5	Analyse the internal details of an object through sectional views in CAD environment.

Course Articulation Matrix:

	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6	PO-7	PO-8	PO-9	PO-10	PO-11	PO-12	PSO-1	PSO-2
CO-1	1	1	1	-	-	-	1	1	3	3	-	-	-	-
CO-2	1	1	1	-	-	-	1	1	3	3	-	-	-	-
CO-3	1	1	1	-	-	-	1	1	3	3	-	-	-	-
CO-4	1	1	1	-	-	-	1	1	3	3	-	-	-	-
CO-5	1	1	1	-	-	-	1	1	3	3	-	-	-	-

1 - Slightly; **2 - Moderately;** **3 - Substantially**

Syllabus:

Introduction: Drawing instruments and their uses, Types of lines, Lettering, General rules for dimensioning, Geometrical constructions using instruments. **(Conventional)**

Orthographic Projection: Methods of projection, Principles of Orthographic projection, First angle versus third angle of projection, Six views of an object, Conventions. **(Conventional)**

Projection of Points: Projections of points when they are situated in different quadrants. **(Conventional)**

Projections of Lines: Projections of a line parallel to one of the reference planes and inclined to the other, line inclined to both the reference planes, Traces. **(Conventional)**

Fundamentals of AutoCAD: Introduction to Auto-CAD, DRAW tools, MODIFY tools, TEXT, DIMENSION, PROPERTIES **(AutoCAD)**

Projections of Planes: Projections of a plane perpendicular to one of the reference planes and inclined to the other, Oblique planes. **(AutoCAD)**

Projections of Solids: Projections of solids whose axis is parallel to one of the reference planes and inclined to the other, axis inclined to both the planes. **(AutoCAD)**

Section of Solids: Sectional planes, Sectional views - Prism, pyramid, cylinder and cone, true shape of the section. **(AutoCAD)**

Isometric Views: Isometric axes, Isometric lines, Isometric Planes, Isometric scale, Isometric Views, Isometric projections. (AutoCAD)

Development of Surfaces: Development of lateral surfaces of right solids – cube, prisms, cylinders, pyramids, cones. (AutoCAD)

Intersection of surfaces: Methods of determining the line of intersection between surfaces of two interpenetration solids in simple positions – Intersection of two prisms, two cylinders, cylinder and prism, cone and cylinder, cone and prism, two cones. (AutoCAD)

Learning Resources:

Text Books:

1. N.D.Bhatt. and V.M.Panchal, Engineering Graphics, Charotar Publishers, 2016, 53rd Edition

Reference Books:

1. B. Agarwal, Engineering Drawing, 2015, McGraw Hill Education, 2015, 2nd Edition
2. S. Tickoo, Auto CAD 2017 for Engineers & Designers, Dreamtech, 2016, 23rd Edition

ME 1165 **0-1-2 (2)**

Engineering Workshop Practice

Pre-Requisites: None

Course Outcomes:

CO-1	Identify workshop tools and their operational capabilities Credits
CO-2	Practice on manufacturing of components using workshop trades including fitting, foundry and welding
CO-3	Apply suitable tools for machining processes including turning, facing, thread cutting and tapping
CO-4	Apply basic electrical engineering knowledge for House Wiring Practice

Course Articulation Matrix:

	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6	PO-7	PO-8	PO-9	PO-10	PO-11	PO-12	PSO-1	PSO-2
CO-1	3	3	1			1			2	2			2	
CO-2	3	3	1		2	1			2	2			2	
CO-3	3	3	1		2	1			2	2			2	
CO-4	3	3	1		2	1			2	2			2	

1 - Slightly; **2 - Moderately;** **3 - Substantially**

Syllabus:

Demonstration: Safety practices and precautions to be observed in workshop.

Fitting Trade: Demonstration and practice of fitting tools, Preparation of T-Shape, Dovetail Joint. Carpentry: Demonstration and practice of carpentry tools, Preparation of Cross Half lap joint and Mortise Tenon Joint.

Machine shop: Demonstration and practice on Lathe Machine, Preparation of work pieces involving Facing, Plane Turning, step turning, knurling and parting operations.

House Wiring: Demonstration and practice on Electrical tools, wiring and earthing, Exercises on Staircase Wiring & Godown wiring.

Power Tools: Demonstration and practice on Power tools (Bosch Power Tools) and Safety Practices.

Foundry Trade: Demonstration and practice on Moulding tools and processes, Preparation of Green Sand Moulds for given Patterns.

Welding Shop: Demonstration and practice on Arc Welding and Gas welding. Preparation of Lap joint and Butt joint.

Learning Resources

Text Books:

1. Felix W., Basic Workshop Technology: Manufacturing Process, Independently Published, 2019.
2. Bruce J. Black, Workshop Processes, Practices and Materials, Routledge publishers, 5th Edition. 2015.
3. B.S. Raghuwanshi, A Course in Workshop Technology Vol I. & II, Dhanpat Rai & Co., 2015 & 2017.

Reference Books:

1. S. K. Hajra Choudhury, and Nirjahar Roy, Elements of Workshop Technology, Vol. I, Media Promoters and Publishers, Mumbai. 2007, 14th edition.
2. S. K. Hajra Choudhury and Nirjahar Roy, Elements of Workshop Technology, Vol. II, Media Promoters and Publishers, Mumbai. 2007, 12th edition
3. H. S. Bawa, Workshop Practice Tata-McGraw Hill, 2004.
4. Steve F. Krar, Arthur R. Gill and Peter Smid, Technology of machine tools, McGraw Hill Education (India) Pt. Ltd., 2013.
5. Ramesh Babu.V., Engineering Practices Laboratory Manual, VRB Publishers Private Limited, Chennai, Revised edition, 2013 – 2014.
6. T.Jeyapoovan, Engineering Practices Lab Manual; Vikas Publishers, 2008, 4th Edition
7. John K.C.,Mechanical Workshop Practice; PHI, 2010.
8. Soni P.M. & Upadhyay P.A.; Atul Prakashan, Wiring Estimating, Costing and Contracting; 2021-22.

Online Resources:

1. Different Trade E-Books (Fitting, Plumbing, Welding, Carpentry, Foundryman, Turner and House Wiring etc.) developed by National Instructional Media Institute, Chennai. Directorate General of Training, Ministry of Skill Development & Entrepreneurship, Govt. of India. (https://bharatskills.gov.in).

2nd Semester

MA 1164 **3-0-0(3)**

Integral and Vector Calculus & Laplace and Fourier Transforms

Pre-Requisites: MA 1161

Course Outcomes:

CO-1	Analyze improper integrals for extracting certain properties of beta and gamma integrals.
CO-2	Evaluate multiple integrals in different coordinate systems.
CO-3	Apply the concepts of gradient, divergence and curl of scalar and vector point functions to formulate engineering problems.
CO-4	Find Laplace transforms of functions
CO-5	Find Fourier Series and Fourier Transforms of functions

Course Articulation Matrix:

	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6	PO-7	PO-8	PO-9	PO-10	PO-11	PO-12	PSO-1	PSO-2	PSO-3	PSO-4
CO-1	3	3	1	2	1	–	–	–	–	–	–	–	–	1	2	–
CO-2	3	3	1	2	1	–	–	–	–	–	–	–	–	1	2	–
CO-3	3	3	1	2	1	–	–	–	–	–	–	–	–	1	2	–
CO-4	3	3	1	2	1	–	–	–	–	–	–	–	–	1	2	–
CO-5	3	3	1	2	1	–	–	–	–	–	–	–	–	1	2	–

1 - Slightly; **2 - Moderately;** **3 - Substantially**

Syllabus:

Integral Calculus: Improper integrals; Beta and Gamma functions, and their properties; Differentiation under integral sign, Evaluation of double and triple integrals; Areas and Volumes, Change of order of integration; Change of variables in double and triple integrals.

Vector Calculus: Scalar and vector fields; Vector differentiation; Level surfaces; Directional derivative; Gradient of a scalar field; Divergence and curl of a vector field; Laplacian operator; Parameterization of curves and surfaces; Line, surface and volume integrals; Green's theorem in a plane; Stoke's theorem; Gauss divergence theorem.

Laplace Transforms: Laplace transforms; Inverse Laplace transforms; Properties of Laplace transforms; Laplace transforms of unit step, impulse and periodic functions; Convolution theorem;.

Fourier Series: Expansion of a function in Fourier series for a given range - Half range sine and cosine expansions.

Fourier Transforms: Fourier transformation and inverse transforms - sine, cosine transformations and inverse transforms.

Learning Resources:

Text Books:

1. George B. Thomas and Ross L. Finney, Calculus and Analytic Geometry, Pearson, 2020, Ninth Edition.
2. Dennis G. Zill, Advanced Engineering Mathematics, Jones & Bartlett Learning, 2018, Sixth Edition

Reference Books:

1. Maurice D. Weir, Joel Hass and Christopher Heil, Thomas' Calculus: Early Transcendentals, Pearson, 2014, Thirteenth Edition.
2. Erwin Kreyszig, Advanced Engineering Mathematics, John Wiley and Sons, 2015, Eighth Edition.
3. R. K. Jain and S. R. K. Iyengar, Advanced Engineering Mathematics, Narosa Publishing House, 2016, Fifth Edition.

PH 1161 **3-0-2(4)**

Engineering Physics

Pre-Requisites: None

Course Outcomes:

CO-1	Examine the concepts of Interference, diffraction, polarisation to solve engineering problems
CO-2	Assess the technological applications of lasers and optical fibers
CO-3	Apply the quantum mechanical principles for solving engineering problems
CO-4	Understand the basics of nanomaterials and their engineering applications
CO-5	demonstrate the production, detection and applications of ultrasonics

Course Articulation Matrix:

	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6	PO-7	PO-8	PO-9	PO-10	PO-11	PO-12	PSO-1	PSO-2
CO-1	3	3	1	2	-	-	-	-	-	-	-	-	3	2
CO-2	3	3	2	2	-	-	-	-	-	-	-	-	3	2
CO-3	3	3	2	2	-	-	-	-	-	-	-	-	3	2
CO-4	3	3	2	2	-	-	-	-	-	-	-	-	3	2
CO-5	3	3	2	2	-	-	-	-	-	-	-	-	3	2

1 - Slightly; **2 - Moderately;** **3 - Substantially**

Syllabus:

Interference: Principle of Superposition, Coherence and Coherent Sources, Production of Coherent Light, Young's Double Slit Experiment, Concept of interference, Newton's Rings, working of Michelson Interferometer, Fabry-Perot Interferometer, and its application as wavelength filter.

Diffraction: Definition and types of Diffractions, Huygen's Principle and types of wave fronts, types of Diffraction, Single Slit Diffraction, Double Slit Diffraction, Diffraction Grating, Derivation of Resolving Power and Dispersive Power, Rayleigh's Criterion and applications.

Polarization: Introduction to Polarization, Production of Polarized Light by Reflection and Refraction, Phenomenon of Double Refraction, Construction and Working of Nicol's Prism, Half-Wave and Quarter Waveplates, Representation of Different Polarized Lights, Optical Activity, Practical Applications of Polarized Light, Construction and Working of Laurent's Half Shade Polarimeter and Engineering Applications.

Lasers & Optical Fibers: Basic theory of Laser, Fundamentals of lasers, Einstein Coefficients, Characteristics of Laser Pumping Mechanisms; Basic Components of Laser System, 2-Level, 3-Level and 4-Level Systems, Construction and working of He-Ne, Nd-YAG, and semiconductor diode Lasers and Engineering Applications of Lasers. Basic Principle of Optical Fiber, Derivation-Numerical Aperture and Acceptance Angle, Types of Optical Fibers (Step and Graded Index, Single Mode and Multimode), Applications in Communications and Sensors.

Quantum Mechanics: Concepts and experiments that led to the discovery of Quantum Nature, de Broglie hypothesis of matter waves, Heisenberg uncertainty principle, Schrodinger time independent and

time dependent wave equations, the free particle problem, Particle in an infinite and finite potential well, Quantum mechanical tunnelling and applications.

Nanomaterials: Introduction and importance of Nanomaterials, classification (0D, 1D, 2D and 3D) of nanomaterials, properties of nanomaterials, carbon-based nanomaterials, synthesis of nanomaterials, top-down and bottom-up approaches, characterization of nanomaterials, Engineering Applications of Nanomaterials:

Ultrasonics: Production, detection, and applications of ultrasonics

List of Experiments:

1. Determination of Wavelength of Sodium light using Newton's Rings.
2. Determination of Wavelength of He-Ne laser - Metal Scale.
3. Measurement of Width of a narrow slit using He- Ne Laser.
4. Determination of Specific rotation of Cane sugar by Laurent Half-shade Polarimeter.
5. Determination of Numerical aperture, loss, Acceptance angle of optical fiber.
6. Determination of plank constant by photo electric effect.
7. Determination of I – V characteristics of photo diode.
8. Diffraction grating by normal incidence method.
9. Determination of capacitance by using R-C circuit.
10. Determination of resonating frequency and bandwidth by LCR circuit
11. Strain Gauge
12. Dielectric constant measurements
13. Determination of carrier concentration, charge by using Hall effect experiment
14. Study of I-V characteristics of Solar Cell
15. Determination of velocity of ultrasonic waves and adiabatic compressibility of liquids using ultrasonic interferometer.

Learning Resources:

Text Books:

1. Resnic and Walker, Fundamentals of Physics by Halliday, John Wiley, 2011, Ninth Edition.
1. Arthur Beiser, Shobhit Mahajan, S. Rai, Choudhury, Concepts of Modern PhysicS, McGraw Hill Publications, 2009, Sixth Edition
2. Shatendra Sharma, Jyotsna Sharma, Engineering Physics Pearson Education, 2018
3. Sulabha K. Kulkarni, Nanotechnology: principles and practices, Springer publications, 2018
4. 5. G.L. Squire, Practical Physics Cambridge University press, 2001, Fourth Edition

Reference Books:

2. Ajoy K. Ghatak, Optics, Tata McGraw Hill, 2017, Sixth Edition,
3. Jeff Hecht, Understanding Lasers An Entry-Level Guide, Wiley Publications,2018, Fourth Edition
4. M.N. Avadhanulu, P.G. Khirsagar, A Textbook of Engineering Physics, 2011, Ninth edition
5. Hugh D. Young,Roger A. Freedman, University Physics with modern physics, Pearson Ed., 2014
6. B. Rogers, J Adams and S. Pennathur, Nanotechnology the whole story, CRC Press, 2013
7. S.K. Gupta, Engineering Physics Practical Krishna Prakashan Media P. Ltd.-Meerut, 2010

Online Resources:

1. https://nptel.ac.in/courses/122/107/122107035/

CS 1101 **3-0-0(3)**

Programming and Data Structures

Pre-Requisites: None

Course Outcomes:

CO-1	Design algorithms for solving simple mathematical problems including computing, searching and sorting
CO-2	Compare and contrast algorithms in terms of space and time complexity to solve simple mathematical problems
CO-3	Explore the internals of computing systems to suitably develop efficient algorithms
CO-4	Examine the suitability of data types and structures to solve specific problems
CO-5	Apply control structures to develop modular programs to solve mathematical problems

Course Articulation Matrix:

	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6	PO-7	PO-8	PO-9	PO-10	PO-11	PO-12	PSO-1	PSO-2
CO-1	3	1	1	1	2	1	-	-	-	-	-	3	3	3
CO-2	2	1	2	1	2	3	-	-	-	-	-	3	3	2
CO-3	1	2	2	2	2	1	-	-	-	-	-	3	3	2
CO-4	2	2	2	2	2	2	-	-	-	-	-	2	3	2
CO-5	2	2	3	1	2	2	-	-	-	-	-	2	3	2

1 - Slightly; **2 - Moderately;** **3 - Substantially**

Syllabus:

Fundamentals of Computers: Components of a computers, Problems, Flowcharts, Memory, Variables, Values, Instructions, Programs.

Problem solving techniques: Algorithmic approach, characteristics of algorithm, Problem solving strategies: Top-down approach, Bottom-up approach, Number systems and data representation,

Elements of C++ programming language: Data types, constants, and variables, expressions and assignment statements, input and output statements, conditional and branch statements: If-else, Switch-case constructs, iteration statements: while, do-while, for, Arrays – Single and Multi-Dimensional Arrays, strings. Bit-wise operations.

Functions and Recursion: Modular approach for solving real time problems, user defined functions, library functions, parameter passing - call by value, call by reference, return values, passing arrays as parameters to functions Recursion.

Structures and Classes: Declaration, member variables, member functions, access modifiers, function overloading, Problems on Complex numbers, Date, Time, Large Numbers.

Pointers and Files: Introduction to pointers and dynamic allocation, String processing, File operations-create, read and write.

Searching and sorting: Linear and binary search, selection sort, bubble sort, insertion sort, merge sort, quick sort.

Data structures: Abstract Data Types (ADTs) - Stack ADT- Array-Based Implementation of Stack - Applications, Queue ADT - Array-Based Implementation – Applications.

Learning Resources:

Text Books:

1. Walter Savitch, Problem Solving with C++, Pearson, 2018, Tenth Edition
2. Cay Horstmann, Timothy Budd, Big C++, Wiley, 2009, Second Edition
3. R.G. Dromey, How to solve it by Computer, Pearson, 2008
4. Mark Allen Weiss, Data Structures and Algorithm Analysis in C++, Pearson Education, 2006 Third Edition

HS 1161 **2-0-2(3)**

English for Technical Communication

Pre-Requisites: English proficiency above B1 level as per the CEFR (Common European Framework of Reference) for languages.

Course Outcomes:

CO-1	Understand and apply principles of technical communication to interact effectively in diverse environments.
CO-2	Analyze complex technical documents to extract and synthesize key information.
CO-3	Employ reported speech, active and passive voice in engineering and scientific contexts to compile technical reports.
CO-4	Demonstrate use of English speech sounds, stress, and intonation in day-to-day situations, conversations, and interactions.
CO-5	Interpret technical data presented in the form of graphs, pie charts, and diagrams.
CO-6	Critique and provide constructive feedback on peer communication performances and written works.

Course Articulation Matrix:

	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6	PO-7	PO-8	PO-9	PO-10	PO-11	PO-12	PSO-1	PSO-2
CO-1						2			3	3		3		
CO-2									3	3		3		
CO-3									3	3		3		
CO-4				2					3	3		3		
CO-5									3	3		3		
CO-6									3	3		3		

1 - Slightly; 2 - Moderately; 3 - Substantially

Syllabus:

Grammar Principles & Effective Sentence Construction: Correction of Sentences and Concord, - Vocabulary Building, - Synonyms and Antonyms, - Idioms and Phrasal Verbs: Patterns of Use and Suggestions for Effective Employment in Varied Contexts, - Technical Vocabulary (Jargons and Registers),- Strategies for Bringing Variety and Clarity in Sentences, - Removing Ambiguity, - Editing Long Sentences for Brevity and Clarity, - Reported Speech, - Contexts for Use of Reported Speech, - Impact on Audiences and Readers, - Active and Passive Voice, - Reasons for Preference for Passive Voice in Scientific English

Writing- Paragraph & Letter: Definition of Paragraph and Types, - Features of a Good Paragraph, - Unity of Theme, - Coherence, - Linking Devices, - Direction, - Patterns of Development. - Importance in the Context of Other Channels of Communication, - Qualities of Effective Letters, - Types of Letters, - Official Letters, - Letters for Various Purposes, - Letters of Application for Jobs, - Cover Letter and Resume Types, - Letters for Internship/Fellowship, - Writing Statements of Purpose (SOPs), - Examples and Exercises

Reading Techniques: Definition and Importance, - Skills and Sub-Skills of Reading, - Skimming and Scanning: Uses and Purposes, Examples and Exercises, - Reading Comprehension, - Reading Silently and with Understanding, - Process of Comprehension, - Types of Comprehension Questions

Technical Writing: Principles of a Technical Report, - Know Your Audience, Purpose, and Length of Report, - Understand the Cornerstones of a Presentation, - Define Various Purposes of Presentations and Plan the Correct Structure, - Writing Clear Sentences and Paragraphs, - Removing Jargon, Redundancy, and Wordiness, - Kinds of Graphics and Their Messages, - Suitability for Placement in Graphic Representation, - Introduction to Basic Concepts in Research, - Abstract, Keywords, Methodology,

Hypothesis, Plagiarism, Critical Reading, - Abstract Writing, - How to Read Scientific Articles, - Basics of Writing a Research Project Proposal, - Preparation and Presentation of Project Reports

Reviews: Oral and Written Review of a Chosen Novel/Play/Movie, - Review of Scientific Articles and Science Fiction, - Focus on Appropriate Vocabulary and Structure, - Use of Special Vocabulary and Idioms

Language laboratory

English Sound System -vowels, consonants, Diphthongs, phonetic symbols- using dictionary to decode phonetic transcription-- Received Pronunciation, its value and relevance- transcription.

Stress and Intonation –word and sentence stress - their role and importance in spoken English- Intonation in spoken English -definition, -use of intonation in daily life-exercises

Introducing oneself in formal and social contexts- Role plays. - their uses in developing fluency and communication in general.

Oral presentation - definition- occasions- structure- qualities of a good presentation with emphasis on body language and use of visual aids.

Listening Comprehension- Challenges in listening, good listening traits, some standard listening tests- practice and exercises.

Debate/ Group Discussions-concepts, types, Do's and don'ts- intensive practice, Guided writing practice with examples, Drafting – the mindset to avoid writer's block, Checking your own reports and presentations, Giving and receiving constructive feedback.

Learning Resources:

Text Books:

1. Rod Ellis, English for Engineers and Technologists (Combined edition, Vol. 1 and 2) Orient Blackswan, 2010
2. Ashraf, M Rizvi. Effective Technical Communication. Tata McGraw-Hill, 2006
3. Meenakshi Raman and Sangeetha Sharma. Technical Communication: Principles and Practice Oxford University Press, 2011, Second Edition
4. Tan, Zhongchao. Academic Writing for Engineering Publications: A Guide for Non-native English Speakers. Springer, 2022

BT 1161 **2-0-0(2)**

Biology for Engineers

Pre-Requisites: NONE

Course Outcomes:

CO-1	Realize the significance of biomolecules for sustaining life
CO-2	Identify the difference between unicellular to multi-cellular organisms
CO-3	Understand heredity, variation and central dogma of life
CO-4	Apply the concepts of biology for engineering the cell

Course Articulation Matrix:

	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6	PO-7	PO-8	PO-9	PO-10	PO-11	PO-12	PSO-1	PSO-2
CO-1	3	2	2	–	–	2	2	–	–	2	–	3	3	3
CO-2	3	2	2	–	–	2	–	–	–	–	–	3	3	3
CO-3	3	2	2	–	–	2	–	–	–	–	–	3	3	3
CO-4	3	3	2	2	1	2	2	1	–	2	–	3	3	3

1 - Slightly; **2 - Moderately;** **3 - Substantially**

Syllabus:

Molecules of Life: Chemical basis of life, Proteins, Nucleic acids, Carbohydrates, Lipids, Membranes and First cell, Inside the cell, Cell cycle and Division.

Information processing in living system: Central dogma, Concept of Gene, Genetic code, Transcription, Translation, Biological signal transduction, Quorum sensing and Biofilm formation.

Biomolecular machines and motors: Cytoskeletal motor proteins, ATP synthase, Cell motility.

Applied Biotechnology: Biocomputing, Synthetic biology, Biosensors, Biomedical instrumentation in disease diagnosis, Biomimicry, Biomechanics, Biomaterials, Nanobiotechnology, Industrial and Environmental Biotechnology.

Learning Resources:

Text Books:

1. Quillin, Allison Scott Freeman, Kim Quillin and Lizabeth Allison, Biological Science, Pearson Education India, 2016
2. Reinhard Renneberg, Viola Berkling and Vanya Loroch, Biotechnology for Beginners, Academic Press, 2017

CS 1103 **0-1-2(2)**

Programming and Data Structures Lab

Pre-Requisites: NONE

Course Outcomes:

CO-1	Design and test programs to solve mathematical and scientific problems
CO-2	Develop and test programs using control structures
CO-3	Implement modular programs using functions
CO-4	Develop programs using classes
CO-5	Develop ADT for stack and queue applications

Course Articulation Matrix:

	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6	PO-7	PO-8	PO-9	PO-10	PO-11	PO-12	PSO-1	PSO-2
CO-1	3	2	2	1	2	1	-	-	-	-	-	-	3	3
CO-2	1	1	2	1	2	2	-	-	-	-	-	-	3	3
CO-3	1	2	3	2	2	1	-	-	-	-	-	-	3	3
CO-4	2	2	2	2	2	3	-	-	-	-	-	-	2	3
CO-5	2	2	2	2	2	3	-	-	-	-	-	-	2	3

1 - Slightly; **2 - Moderately;** **3 - Substantially**

Syllabus:

List of Experiments conducted in this lab:

1. Programs on conditional control constructs.
2. Programs on loops (while, do-while, for).
3. Programs using user defined functions and library functions.
4. Programs on arrays, matrices (single and multi-dimensional arrays).
5. Programs using pointers (int pointers, char pointers).
6. Programs on structures.
7. Programs on classes and objects.
8. Programs of Stack and Queue.

Learning Resources:

Text Books:

1. Walter Savitch, "Problem Solving with C++", Ninth Edition, Pearson, 2014.
2. Cay Horstmann, Timothy Budd, "Big C++", Wiley, 2nd Edition, 2009.
3. R.G. Dromey, "How to solve it by Computer", Pearson, 2008.
4. Mark Allen Weiss, "Data Structures and Algorithm Analysis in C++", Third Edition, Pearson Education, 2006

ME 1102 **3-0-0(3)**

Engineering Mechanics

Pre-Requisites: NONE

Course Outcomes:

CO-1	Determine the resultant force and moment for a given system of forces
CO-2	Analyze planar and spatial systems for determining the forces in members of trusses, frames and problems related to friction
CO-3	Calculate the motion characteristics of a body subjected to a given force system
CO-4	Determine the deformation of a shaft and identify the relationship between different material constants
CO-5	Determine the centroid and second moment of area

Course Articulation Matrix:

	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6	PO-7	PO-8	PO-9	PO-10	PO-11	PO-12	PSO-1	PSO-2
CO-1	3	3	2	-	-	1	-	-	-	-	-	-	3	2
CO-2	3	3	2	-	-	1	-	-	-	-	-	-	3	2
CO-3	3	3	2	-	-	1	-	-	-	-	-	-	3	2
CO-4	3	3	2	-	-	1	-	-	-	-	-	-	3	2
CO-5	3	3	2	-	-	1	-	-	-	-	-	-	3	2

1 - Slightly; **2 - Moderately;** **3 - Substantially**

Syllabus:

Introduction: Specification of force vector, Formation of Force Vectors, Moment of Force – Cross product – Problems, Resultant of a general force system in space, Degrees of freedom - Equilibrium Equations, Kinematics – Kinetics – De' Alemberts principle, Degree of Constraints– Free body diagrams.

Spatial Force systems: Concurrent force systems - Equilibrium equations – Problems, Problems (Vector approach) – Tension Coefficient method, Problems (Tension Coefficient method), Parallel force systems - problems, Center of Parallel force system – Problems.

Coplanar Force Systems: Introduction – Equilibrium equations – All systems, Problems on Coplanar Concurrent force system, Coplanar Parallel force system, Coplanar General force system – Point of action, Method of joints, Method of sections, Method of sections, Method of members, Friction – Coulombs laws of dry friction – Limiting friction, Problems on Wedge friction, Belt Friction-problems.

Mechanics of Deformable Bodies: Stress & Strain at a point- Normal and shear stresses, Axial deformations – Problems on prismatic shaft, tapered shaft and deformation due to self- weight, Deformation of Stepped shaft due to axial loading, Poisson's Ratio – Bulk Modulus - Problems, change in dimensions and volume.

Centroid & Moment of Inertia: Centroid and M.I – Arial – Radius of Gyration, Parallel axis– Perpendicular axis theorem – Simple Problems.

Dynamics of Particles: Rectilinear Motion – Kinematics Problems, Kinetics – Problems, Work & Energy – Impulse Moment, Curvilinear Motion – Normal and tangential components.

Learning Resources:

Text Books:

1. S. Timoshenko, D.H. Young, J.V. Rao and Sukumar Pati, Engineering Mechanics (In SI Units), McGraw Hill Publishers, 2017,5th edition.
2. Ferdinand P. Beer, E. Russell Johnston Jr., et al., Vector Mechanics for Engineers - Statics and Dynamics, McGraw Hill Publishers, 2019, 12th edition.
3. Gere and Timoshenko, Mechanics of Materials, CBS Publishers, 2011, 2nd edition.

Reference Books:

1. R. C. Hibbeler, Mechanics of Materials (SI edition), Pearson publication, 2018.
2. J. L. Meriam, L. G. Kraige, et al., Engineering Mechanics: Statics, SI Version, 2017, Wiley India Edition.
3. J.L. Meriam , L.G. Kraige, et al., Engineering Mechanics: Dynamics, SI Version, 2018 , Wiley India edition,
4. S S Bhavikatti, Engineering Mechanics, New Age International Private Limited, 2021, Eighth edition.

Online Resources:

1. NPTEL Lectures:
   a. https://nptel.ac.in/courses/122/104/122104015/,
   b. https://nptel.ac.in/courses/112/106/112106180/

3rd Semester

ME 1201 **3-0-0 (3)**

Mechanics of Solids

Pre-Requisites: **None**

Course Outcomes:

CO-1	Distinguish statically determinate and indeterminate problems
CO-2	Determine the resistance and deformation in machine members subjected to axial, flexural and torsional loads
CO-3	Apply the concept of failure theories for design
CO-4	Analyse and design thin, thick cylinders and springs

Course Articulation Matrix:

	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6	PO-7	PO-8	PO-9	PO-10	PO-11	PO-12	PSO-1	PSO-2
CO-1	3	3	2	1	–	–	2	–	–	–	–	1	2	1
CO-2	3	3	2	2	–	–	2	–	–	–	–	1	2	1
CO-3	3	3	2	1	–	–	2	–	–	–	–	1	2	1
CO-4	3	3	3	1	–	–	2	–	–	–	–	1	2	1

1 - Slightly; **2 - Moderately;** **3 - Substantially**

Syllabus:

Resistance and Deformation: Concept of Resistance and deformation - Determinate and Indeterminate problems in Tension and Compression - Thermal Stresses - 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 - Strain energy in tension and compression - Impact loading.

Shear Force and Bending Moment: Types of supports - Types of beams - Types of loads - articulated beams - Shear Force and Bending Moment diagrams.

Theory of Simple Bending: Assumptions - Bending stresses in beams - Efficiency of various cross sections - Composite beams.

Shear Stress Distribution: Flexural shear stress distribution in different cross sections of beams.

Deflection of Beams: Slope and deflection of beams - Double Integration method- Macaulay's method - strain energy method.

Torsion of Circular cross sections: Theory of pure torsion - transmission of Power in Solid and Hollow circular shafts - Combined bending and torsion.

Springs: Axial load and torque on helical springs - stresses and deformations - strain energy - compound springs - leaf springs.

Principal Stresses and Strains: Analysis of Biaxial state of stress with and without shear - Mohr's Circle.

Theories of failure: Dilation - Distortion - Maximum Principal Stress Theory - Maximum Principal Strain Theory - Maximum Shear Stress Theory - Strain Energy Theory - Distortion energy theory.

Thin and Thick Cylinders: Thin and Thick Cylinders - spherical shells subjected to internal fluid pressure - Wire wound thin cylinders - Compound cylinders - Shrink fit.

Learning Resources:

Text Books:

1. Timoshenko and Gere, Mechanics of Materials, CBS Publishers, 2011, 2nd Edition
2. E.P.Popov, Engineering Mechanics of Solids, Pearson, 2015, 2nd Edition
3. S. B. Junarkar, Mechanics of Structures, Charotar Publishers, 2012

Reference Books:

1. Pytel & Singer, Strength of Materials, Harper & Row Publishers, 2018, 4th Edition.
2. L.S Srinath, Advanced Mechanics of Solids, McGraw Hill Education, 2017, 3rd Edition.
3. Beer and Johnston, Mechanics of Materials, McGraw Hill India Pvt. Ltd., 2020, 8th Edition (SI Units).

Other Suggested Readings:

1. https://nptel.ac.in/courses/112/102/112102284/
2. https://nptel.ac.in/courses/105/105/105105108/
3. https://nptel.ac.in/courses/105/106/105106172/

ME 1203 **3-0-2 (4)**

Kinematics of Machinery

Pre-Requisites: None

Course Outcomes:

CO-1	Understand the principles of kinematic pairs, chains and their classification, degree of freedom, inversions, equivalent chains and planar mechanisms
CO-2	Analyze the planar mechanisms for position, velocity and acceleration
CO-3	Synthesize planar four bar and slider crank mechanisms for specified design requirements
CO-4	Design suitable gears for the given application
CO-5	Synthesize cams and followers for specified motion profiles

Course Articulation Matrix:

	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6	PO-7	PO-8	PO-9	PO-10	PO-11	PO-12	PSO-1	PSO-2
CO-1	3	2	2	–	2	–	–	–	–	–	–	2	3	2
CO-2	2	3	2	3	–	–	–	–	–	–	–	2	3	2
CO-3	2	2	3	3	2	–	–	–	–	–	–	2	3	2
CO-4	2	2	3	2	–	–	–	–	–	–	–	2	3	2
CO-5	2	2	2	–	2	–	–	–	–	–	–	2	3	2

1 - Slightly; **2 - Moderately;** **3 - Substantially**

Syllabus:

Introduction to Mechanisms: Basic terminology, kinematic chains, Mechanisms, Degrees of freedom, Four-bar chain - equivalents, inversions and their applications. Case studies on Straight line mechanisms, steering gear mechanisms and other general mechanisms.

Kinematic Analysis of Planar Mechanisms: Position analysis of single degree of freedom mechanisms, range of motion, extreme positions, transmission angle. Graphical and Analytical methods for the velocity and acceleration analysis of four bar, slider crank and other single degree of freedom mechanisms.

Synthesis of Mechanisms: Dimensional synthesis, function generation, path generation and motion generation, Synthesis of single degree freedom closed loop mechanisms for specified Instantaneous conditions, basics of analytical synthesis.

Gears and Gear trains: Classification, Terminology, Law of Gearing, Interference and methods to avoid interference in spur gears. Simple, compound, reverted and cycloidal gear trains.

Cams: Classification of cams and followers, applications, SVAJ (Plot position (s), velocity (v), acceleration (a) and jerk (j) versus cam angle) diagrams. Overview of motion programs and

Laboratory Component:

Session 1: Inversions of four-bar chain and slider crank mechanisms

Session 2: Lower pairs

Session 3**:** Gears and Gear trains

Session 4**:** Belt drives

Session 5 Velocity and Acceleration diagrams-I

Session 6: Velocity and Acceleration diagrams-II

Session 7: Velocity and Acceleration diagrams-III

Exercise 8**:** Graphical Synthesis -I

Exercise 9: Graphical Synthesis -II

Exercise 10: Graphical Synthesis -III

Exercise 10**:** Simulation/Design of complex mechanisms-I

Exercise 11: Simulation/Design of Complex Mechanisms II

Exercise 12**:** Simulation/Design of Complex Mechanisms-III

Learning Resources:

Text Books:

1. R V Chalm and J Shruthi, Kinematics and Dynamcis of machinery, Blue rose one publishers (2023)
2. Amitabha Ghosh and Ashok Kumar Mallik, Theory of Mechanisms and Machines, East West Press Pvt. Ltd., New Delhi, 2017, 3rd edition.
3. S.S. Rattan, Theory of Machines, McGraw-Hill Publications, New Delhi, 2017, 3rd edition.
4. Shigley J. E. and John Joseph Uicker, Theory of Machines and Mechanisms, McGraw-Hill international edition, 2014, 2nd edition.

Reference Books:

1. David H Myshka, Machines and Mechanisms: Applied Kinematic Analysis, Pearson, 2011, 4th edition.
2. Kenneth J Waldron, Gary L Kinzel, Kinematics, Dynamics and Design of Machinery, Wiley India Pvt Ltd, 2007, 2nd edition.
3. Norton, R.L., Design of Machinery: An introduction to Synthesis and Analysis of Mechanisms and Machines, McGraw Hill International editions, New York, 2019, 6th edition

MM 1213 **3-0-0 (3)**

Materials Engineering

Pre-Requisites: None

Course Outcomes:

CO-1	Identify crystal structures and crystal defects of materials.
CO-2	Analyze the binary alloy phase diagrams.
CO-3	Correlate the microstructure and mechanical properties of materials.
CO-4	Differentiate the types of steels and cast irons.
CO-5	Describe the properties and applications of non-ferrous alloys, ceramics and polymers.

Course Articulation Matrix:

	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6	PO-7	PO-8	PO-9	PO-10	PO-11	PO-12	PSO-1	PSO-2
CO-1	2	3	2	1	1	-	1	-	-	-	-	1	2	1
CO-2	2	3	2	1	1	-	1	-	-	-	-	1	2	1
CO-3	2	3	2	1	1	-	1	-	-	-	-	1	2	1
CO-4	2	3	2	1	1	-	3	-	1	1	-	1	2	1
CO-5	2	1	1	1	1	-	3	-	1	1	-	1	2	1

1 - Slightly; **2 - Moderately;** **3 - Substantially**

Syllabus:

Introduction: Atomic bonding, Classification of materials

Crystal geometry and imperfections: Space lattices, Unit cells, Crystal structure, Crystal directions and planes, Crystal imperfections- Point defects, Line defects, Surface defects, Volume defects;

Constitution of alloys: Types of solid solutions- substitutional and interstitial; Hume-Rothery rules for solid solutions; Solidification and microstructural evolution in metals and alloys; Construction and interpretation of binary equilibrium diagrams-isomorphous, eutectic and peritectic-type phase diagrams, Intermediate phases, Gibb's phase rule, lever rule;

Mechanical properties: Elasticity and plasticity in materials, Stress-strain curve, tensile properties, hardness and hardness measurement, impact properties, fatigue, creep.

Steels and Cast Irons: Iron-carbon phase diagram, Types of steels- low, medium and high carbon steels, stainless steels, alloy steels and their applications; Heat treatment- annealing, normalizing, hardening, tempering, surface hardening; Cast irons, types- white, grey, malleable and nodular, Properties and applications of cast irons

Non-ferrous Metals and Alloys: Properties and applications of - Cu and its alloys, Al and its alloys, Age hardening, Ti and its alloys, Ni-based alloys.

Ceramics, Polymers and Composites: Structure and unique properties of important ceramics, polymers and composites; rule of mixtures;

Learning Resources:

Text Books:

1. W.D. Callister (Adapted by R. Balasubramaniam), Materials Science and Engineering, 2nd ed. (2014), Wiley India, New Delhi (ISBN: 978-8126541607)
2. S. H. Avner, Introduction to Physical Metallurgy, 2nd ed. (1997), McGraw-Hill Education Publishers, New York, USA (ISBN: 978-0074630068)
3. V. Raghavan, Physical Metallurgy: Principles and Practice, 2nd ed. (2012) Prentice Hall of India Learning Pvt. Ltd., Delhi (ISBN: 978-8120330122)
4. V. Raghavan, Materials Science and Engineering: A First Course, 6th ed.(2015), Prentice Hall of India Learning Pvt. Ltd., Delhi (ISBN: 978-8120350922)
5. D.S. Clark and W. Varney, Physical Metallurgy for Engineers, 2nd ed. (2004) CBS Publishers and Distributors, New Delhi (ISBN: 978-8123911786)

Reference Books:

1. M.F. Ashby and D.R.H. Jones, Engineering Materials 1-An Introduction to Properties, Applications and Design, 4th ed. (2011), Butterworth-Heinemann Publishers, Massachusetts, USA (ISBN: 978-0080966656)
2. M.F. Ashby and D.R.H. Jones, Engineering Materials 2-An Introduction to Microstructures and Processing, 4th ed. (2012), Butterworth-Heinemann Publishers, Massachusetts, USA (ISBN: 978-0080966687)

Other Suggested Readings:

1. NPTEL Courses: https://nptel.ac.in/courses/113102080

ME 1205 **3-1-0 (4)**

Thermodynamics

Pre-Requisites: **None**

Course Outcomes:

CO-1	Understand the concepts of continuum, system, thermodynamic properties, thermodynamic equilibrium, work and heat.
CO-2	Apply the laws of thermodynamics to thermal machines.
CO-3	Evaluate the ideal and real gas relations
CO-4	Evaluate the quality of steam and properties of pure substances
CO-5	Analyze air standard and vapor cycles

Course Articulation Matrix:

	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6	PO-7	PO-8	PO-9	PO-10	PO-11	PO-12	PSO-1	PSO-2
CO-1	3	2	2	2	2	2	2		2	2		2	3	3
CO-2	3	3	2	2	2	2	3		2	2		2	3	3
CO-3	3	3	2	2	2		3		2	3		2	2	2
CO-4	3	2	2	2	2		3			3		2	2	2
CO-5	3	3	3	2	2	2	3		2	2		2	3	2

1 - Slightly; **2 - Moderately;** **3 - Substantially**

Syllabus:

Fundamental Concepts and Definitions: Scope and applications of thermodynamics, Concept of continuum, microscopic and macroscopic approach, system, control volume, properties, state, path, process, thermodynamic equilibrium, temperature scale, Zeroth law of thermodynamics, numerical problems.

Pure Substance Behavior: Pure substance, two-property rule, vapor-liquid-solid phase equilibrium in a pure substance, independent properties of a pure substance, Tables of thermodynamic properties and property diagrams, thermodynamic surfaces, quality of steam, numerical problems.

Energy Transfers: Thermodynamic work, forms of work transfer, heat transfer, heat transfer and work transfer in different processes, numerical problems.

First Law of Thermodynamics: First law applied to a system undergoing a cyclic process and a change of state, concept of energy, first law applied to a control volume, general energy equation, steady state steady flow energy equation (SSSFEE) on unit mass and time basis, application of SSSFEE, specific heat, numerical problems.

Second Law of Thermodynamics: Limitations of the first law, Kelvin-Planck and Clausius statements of the second law, Carnot theorems and corollaries, Carnot cycle. Reversible process, irreversible process, factors responsible for making a process irreversible, thermodynamic temperature scale. Entropy, Clausius theorem, Clausius inequality, Principle of increase of entropy, entropy equation for a control volume, T-ds relations, available and unavailable energy, irreversibility, availability and Second - Law efficiency, Third law of thermodynamics, absolute entropy, numerical problems.

Ideal Gas and Real Gas: Ideal gas, relation among the specific heats, internal energy, enthalpy. Analysis of isochoric, isobaric, isothermal, isentropic, isenthalpic processes, representation of the above processes on P-v, T-s planes. Determination of work, heat, entropy and enthalpy changes during the above processes, Characteristic gas equations of a real gas, P-V-T behavior of low and moderate density gases, virial coefficients, compressibility factor, generalized compressibility chart, Equations of state, numerical problems.

Thermodynamic Property Relations: The Clapeyron equation, mathematical relations for a homogeneous phase, The Maxwell relations, volume expansivity and Isothermal and adiabatic compressibility, numerical problems.

Air Standard Cycles: Assumptions for air standard cycles, Analysis of Otto, Diesel, Dual cycles, Joule/Brayton cycles, air-refrigeration cycle, property diagrams, numerical problems.

Vapor cycles: Rankine cycle, Simple vapor compression refrigeration cycle, property diagrams, numerical problems.

Learning Resources:

Text Books:

1. P.K.Nag, Engineering Thermodynamics, McGraw Hill Education - 6 th Edition, 2017
2. G.J.Vanwylen and R.E.Sonntag, Fundamentals of Thermodynamics, Wiley India Pvt. Limited, 7th Edition, 2009

Reference Books:

1. A.Venkatesh, Basic Engineering Thermodynamics, Universities Press- reprint, 2007
2. Yonus A Cengel and Michale A Boles, Thermodynamics: An Engineering Approach, McGraw Hill Education, 9th Edition 2019

Other Suggested Readings:

1. NPTEL Courses:https://nptel.ac.in/courses/112/108/112108148/

ME 1207 **3-0-0 (3)**

Fluid Mechanics and Hydraulic Machines

Pre-Requisites: **None**

Course Outcomes:

CO-1	Apply conservation laws to fluid flow problems in engineering applications.
CO-2	Design experimental procedure for physical model studies.
CO-3	Design the working proportions of hydraulic machines.
CO-4	Compute drag and lift coefficients using the theory of boundary layer flows.
CO-5	Analyze and design pipe flows

Course Articulation Matrix:

	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6	PO-7	PO-8	PO-9	PO-10	PO-11	PO-12	PSO-1	PSO-2
CO-1	3	3	2	2	-	-	-	-	-	-	-	2	2	1
CO-2	3	3	3	3	-	-	-	-	-	-	-	2	2	1
CO-3	2	1	3	1	1	-	-	-	-	-	-	1	2	1
CO-4	2	1	3	2	-	-	-	1	-	-	-	1	2	1
CO-5	3	2	3	2	1	-	-	-	-	-	-	1	2	1

1 - Slightly; **2 - Moderately;** **3 - Substantially**

Syllabus:

Introduction: Purpose of study of fluid mechanics for design and operation of engineering systems in the fields of Mechanical Engineering, Aeronautical Engineering, Metallurgical Engineering, Civil Engineering, Biomedical Engineering, Chemical Engineering. Fundamental difference between a solid and fluid, constituent relationships for solids and fluids, conservation principles applied in fluid mechanics, Surface Tension and Capillary Effect

Fluid statics: Pressure at a Point, Standard Atmosphere, Measurement of Pressure: Manometry, Mechanical and Electronic Pressure-Measuring Devices, Hydrostatic Force on a Plane and Curved Surface, Buoyancy, Flotation, and Stability

Description of fluid flow: with reference to translation, rotation and deformation concept of continuum, control mass & control volume approach, Reynolds transport theorem. Steady flow and uniform flow. Velocity field, one & two-dimensional flow analysis, circulation and vorticity, stream function and velocity potential function, potential flow, standard flow patterns, combination of flow patterns, flow net.

Continuity equation, Euler's equation of motion, Bernoulli's equation and its applications in flow measurement, Impulse momentum equation and applications.

Dimensional Analysis as a tool in design of experiments, identification of non-dimensional numbers and their significance, dimensional analysis methods.

Equations of motion for laminar flow of a Newtonian fluid - Viscous flow - Navier-Stoke's equations, simple exact solutions for Hydrodynamic lubrication.

Boundary Layer Theory-Formation, growth and separation of boundary layer-Integral momentum principles to compute drag and lift forces-Mathematical models for boundary layer flows. smooth rough and transitional turbulent flow in pipes, pipe resistance equation for pipes design of pipe networks

Application of fluid Principles in Hydraulic Machinery: Turbines - Impulse and Reaction Turbines - Pelton Turbine - Francis Turbine - Kaplan Turbine, working principles, design principles; Centrifugal pumps - Axial flow pumps, working principles, design principles.

Learning Resources:

Text Books:

1. Philip M. Gerhart, John I. Hochstein, Andrew L. Gerhart, “Fundamentals of Fluid Mechanics”, 9th Edition, Wiley, 2021
2. Fluid Mechanics Franck .M White Tata Mc GrawHill Publication 2011.

Reference Books:

1. Shames, “Mechanics of Fluids”, McGraw Hill Book Co., New Delhi, 1988
2. Streeter V.L., Benjamin Wylie, “Fluid Mechanics”, Mc Graw Hill Book Co., New Delhi, 1999

ME 1209 **0-1-2 (2)**

Strength of Materials Lab

Pre-Requisites: **None**

Course Outcomes:

CO-1	Determine the principal stresses and strains in structural members.
CO-2	Analyze columns and struts
CO-3	Apply the concept of failure theories
CO-4	Analyze and design springs and thick cylinders

Course Articulation Matrix:

	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6	PO-7	PO-8	PO-9	PO-10	PO-11	PO-12	PSO-1	PSO-2
CO-1	3	3	3	3	-	1	-	1	1	-	-	-	-	3
CO-2	2	3	3	2	-	1	-	1	1	-	-	-	-	3
CO-3	1	3	1	1	-	1	-	1	1	-	1	-	-	3
CO-4	2	3	2	3	-	1	-	1	1	-	1	-	-	3

1 - Slightly; **2 - Moderately;** **3 - Substantially**

Syllabus:

List of Experiments conducted in this lab:

1. To study the stress -strain characteristics of (a) Mild Steel and (b) Tor steel by conducting tension test on U.T.M.
2. To find the Brinnell's and Vicker's hardness numbers of (a) Steel (b) Brass (c) Aluminium (d) Copper by conducting hardness test.
3. To determine the Modulus of rigidity by conducting Torsion test on (a) Solid shaft (b) Hollow shaft.
4. To find the Modulus of rigidity of the material of a spring by conducting Compression test.
5. To determine the Young's modulus of the material by conducting deflection test on a simply supported beam.
6. To determine the Modulus of elasticity of the material by conducting deflection test on a Propped Cantilever beam.
7. To determine the Modulus of elasticity of the material by conducting deflection test on a continuous beam.
8. To determine the impact resistance of mild steel and cast-iron specimen by conducting Charpy Impact test.
9. Shear test on Mild Steel rods.

Learning Resources:

Text Books:

1. Timoshenko and Gere, Mechanics of Materials, CBS Publishers, New Delhi, 2004, 2nd Edition.
2. H. J. Shah and S. B. Junarkar, Mechanics of Structures Vol.II, Charotar Publishers, Anand, 2017.

Reference Books:

1. Pytel & Singer, Strength of Materials, Harper & Row Publishers, 2018, 4th Edition.
2. R. C. Hibbeler,Mechanics of Materials (SI Edition), Pearson Publications, 2018.
3. L.S Srinath, Advanced Mechanics of Solids, McGraw Hill Education, 2017, 3rd Edition.
4. N. Krishna Raju, Advanced Mechanics of Solids and Structures, McGraw Hill Education, 2018.

ME 1211 **0-1-2 (2)**

Fluid Mechanics & Hydraulic Machines Laboratory

Pre-Requisites: **None**

Course Outcomes:

CO-1	Develop procedure for standardization of experiments.
CO-2	Calibrate flow discharge measuring device used in pipes and tanks.
CO-3	Determine fluid and flow properties
CO-4	Characterize laminar and turbulent flows
CO-5	Compute drag coefficients
CO-6	Test the performance of pumps and turbines

Course Articulation Matrix:

	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6	PO-7	PO-8	PO-9	PO-10	PO-11	PO-12	PSO-1	PSO-2
CO-1	2	2	-	3	-	-	-	-	1	-	-	1	2	1
CO-2	2	2	2	3	-	-	-	-	1	-	-	1	2	1
CO-3	-	-	1	3	-	-	-	-	-	-	-	-	2	1
CO-4	2	2	2	3	1	-	-	-	1	-	-	1	2	1
CO-5	2	2	2	3	2	-	-	-	1	-	-	1	2	1
CO-6	2	2	2	3	2	-	-	-	1	-	1	1	2	1

1 - Slightly; **2 - Moderately;** **3 - Substantially**

Syllabus:

List of Experiments:

1. Calibration of Venturi meter, Orifice meter (discharge measuring device in pipes)
2. Calibration of Orifice and mouthpiece (discharge measuring device in Tanks).
3. Measurement of Viscosity of water, SAE - 10 Oil by Hazen Poiseuille method and that of glycerin by Stoke's method.
4. Determination of Darcy Friction Factor, relative roughness for laminar and turbulent flows.
5. Application of momentum equation for determination of coefficient of impact of jets on flat and curved blades and Pelton bucket.
6. Computation of pressure drag coefficient for flow past a cylinder in a subsonic wind tunnel.
7. Performance Characteristics of single stage centrifugal pump, multi stage centrifugal pump.
8. Submersible pumps, and varying speed centrifugal pump.
9. Performance Characteristics of Pelton turbine, Francis turbine, and Kaplan turbine.

Learning Resources:

Text Books:

1. K.L.Kumar. "Engineering Fluid Mechanics" Experiments, Eurasia Publishing House, 1997
2. Jagdish Lal, Hydraulic Machines, Metropolitan Book Co, Delhi, 1995

Reference Books:

1. Philip M. Gerhart, John I. Hochstein, Andrew L. Gerhart, “Fundamentals of Fluid Mechanics”, 9th Edition, Wiley, 2021
2. Fluid Mechanics Franck .M White Tata Mc GrawHill Publication 2011.

4th Semester

MS 1262 **3-0-0 (3)**

Business Essentials for Engineers

Pre-Requisites: **None**

Course Outcomes:

CO-1	Understand the basic concepts of management and its functions
CO-2	Apply the functions of management for taking effective decisions.
CO-3	Analyze factors influencing management in competitive business environment
CO-4	Identify business opportunities and challenges
CO-5	Integrate functions of management for building a better organization.

Course Articulation Matrix:

	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6	PO-7	PO-8	PO-9	PO-10	PO-11	PO-12	PSO-1	PSO-2
CO-1	1	1	1	2	1	3	2	3	3	3	3	3	3	3
CO-2	1	1	1	2	1	3	2	3	3	3	3	3	3	3
CO-3	1	1	1	2	1	3	2	3	3	3	3	3	3	3
CO-4	1	1	1	2	1	3	2	3	3	3	3	3	3	3
CO-5	1	1	1	2	1	3	2	3	3	3	3	3	3	3

1 - Slightly; **2 - Moderately;** **3 - Substantially**

Syllabus:

Introduction: The evolution of management theory, Business functions and their roles, Organizations and types, Levels of management, Types of markets and pillars of management- planning, organizing, leading and controlling.

People Management: Catalysts for organizational performance – Motivation & Leadership, Organization culture & Change, Human resource functions in a dynamic business environment and evolving dynamics in Industrial Relations.

Marketing Management: Nature and scope of marketing, Company's orientation towards market place, Importance of marketing concept, Marketing environment, 4p's of marketing, market segmentation, target market selection and positioning.

Financial Management: Financial accounting, Financial statements and analysis for decisions, Financial planning, Capital, Working capital, Capital structure and Sources of corporate finance, Investment decisions.

Quality & Strategy: Quality, Principles, Quality Awards, Standards of Quality culture, Quality metrics programs, Strategy, Vision and Mission, Porter's 5–forces, McKinsey's 7S Model, BCG Matrix, Competitive advantage - Value chain analysis & Resource based view.

Learning Resources:

Text Books:

1. Ronald J. Ebert, Ricky W. Griffin,, Business Essentials, Global Edition , Pearson, 2019, 12th Edition.
2. Harold Koontz, Heinz Weihrich, Mark V. Cannice, Essentials of Management, McGraw hill, 2020, 11th Edition

Reference Books:

1. G. Shainesh Philip Kotler, Kevin lane Keller, Alexander Chernev, Jagdish N. Sheth, Marketing Management, Pearson, 2022, 16th Edition.
2. Dessler, G., & Varkkey, B, Human Resource Management, Pearson Education, 2018.
3. Prasanna Chandra, Financial Management: Theory & Practice, Mc Graw Hill, 2022, 11th Edition.
4. Poornima M Charantimath, Total Quality Management, Pearson, 2022, 4th Edition.
5. IM Pandey, Financial Management, Vikas Publications, 2021, 12th Edition.

ME 1202 **3-0-2 (4)**

Dynamics of Machinery

Pre-Requisites: None

Course Outcomes:

CO-1	Understand free and forced vibrations of single degree freedom systems.
CO-2	Analyze balancing problems in rotating and reciprocating machinery.
CO-3	Characterize and design flywheels.
CO-4	Illustrate the gyroscopic effects in ships, aero planes and road vehicles.
CO-5	Analyze centrifugal governors.

Course Articulation Matrix:

	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6	PO-7	PO-8	PO-9	PO-10	PO-11	PO-12	PSO-1	PSO-2
CO-1	3	3	3	3	2		3					2	2	2
CO-2	3	3	3	3	3	3	2					2	3	2
CO-3	3	3	3	3	1		2					2	2	2
CO-4	3	3	3	3	1		2					2	2	2
CO-5	3	3	3	3	3	3	2					2	3	2

1 - Slightly; 2 - Moderately; 3 - Substantially

Syllabus:

Flywheels: Introduction, turning moment of a crankshaft, Development of turning moment diagram for multi-cylinder engines, Design procedure for flywheel, maximum fluctuation of energy, problems

Balancing of Rotating systems: Introduction, bearing reactions, single plane balancing, static and dynamic balancing in multi-plane rotating systems, -graphical and analytical methods, field balancing

Balancing of Reciprocating Systems: Primary and secondary balancing of single and multi-cylinder inline engines.

Gyroscope: Principle of gyroscope, roll, pitch, and yaw motions, gyroscopic effect in airplanes and naval ships

Vibrations: Introduction, properties of the vibration system, mathematical treatment, problems on free vibrations of pendulums and rigid bodies, degree of freedom, energy methods, forced vibrations of undamped 1-dof systems, resonance, free vibrations of damped 1-dof systems, forced vibrations of damped 1-dof systems, vibration measuring instruments, Introduction to 2-dof systems and coupled pendulum.

Laboratory Component:

1. Estimate the acceleration due to gravity using bifilar pendulum.
2. Determine the mass moment of inertia of a given object using a TriFilar pendulum.
3. Verify the natural frequency of a bar resting on a Cylindrical surface
4. Verify the natural frequency of a semi cylindrical shell resting on a horizontal surface.
5. Find the location of the center of mass G and the moment of inertia about IG of a given

connecting rod (Compound pendulum).

6. Determine the viscous damping coefficient of a given viscous damper
7. Estimate the damping in given vibrating system through Logarithmic decrement.
8. Determine the viscous damping coefficient of a viscous damper by observing free vibrations of Spring-Mass-Damper system.
9. Determine the coefficient of friction between two surfaces.
10. Determine the natural frequencies of the Coupled pendulum (Two-degree freedom) through (a) Normal mode vibrations (b) Beat phenomenon and then calculate the stiffness of the coupling spring
11. Verify the natural frequencies of a Cantilever beam (Vibration of Continuous system)
12. Estimate the Critical speed of shafts
13. Determine imbalance and perform balancing operation using Balancing apparatus

Learning Resources:

Text Books:

1. R. Venkatachalam, Mechanical Vibrations, PHI, 2014
2. R Venkatachalam & RJ Shruthi, Kinematics and Dynamics of Machinery, BlueRoseOne, 2023.

Reference Books:

1. Norton, R.L., Design of Machinery - An introduction to Synthesis and Analysis of Mechanisms and machines, McGraw Hill International Editions, New York, 2000, 2nd Edition.
2. S.S. Rattan, Theory of Machines, McGraw-Hill Publications, New Delhi, 2023, 5th edition.

MA 1263 **3-0-0 (3)**

Partial Differential Equations, Statistics and Numerical Methods

Pre-Requisites: MA 1164

Course Outcomes:

CO-1	Determine the solution of a PDE by variable separable method
CO-2	Interpret an experimental data using interpolation / curve fitting
CO-3	Solve algebraic/transcendental equations and ordinary differential equations
CO-4	Understand the concepts of probability and statistics
CO-5	Perform testing of hypothesis

Course Articulation Matrix:

	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6	PO-7	PO-8	PO-9	PO-10	PO-11	PO-12	PSO-1	PSO-2
CO-1	3	3	1	2	1	-	-	-	-	-	-	-	-	1
CO-2	3	3	1	2	1	-	-	-	-	-	-	-	-	1
CO-3	3	3	1	2	1	-	-	-	-	-	-	-	-	1
CO-4	3	3	1	2	1	-	-	-	-	-	-	-	-	1
CO-5	3	3	1	2	1	-	-	-	-	-	-	-	-	1

1 - Slightly; **2 - Moderately;** **3 - Substantially**

Syllabus:

Partial Differential Equations: Introduction to Fourier series **(**including half range)**,** Method of separation of variables - Solution of one-dimensional wave equation, one dimensional heat conduction equation

Numerical Methods: Gauss-Seidal iteration method to solve a system of equations - Numerical solution of algebraic and transcendental equations by Regula-Falsi method and Newton-Raphson's method - Lagrange interpolation, Forward and backward differences, -Newton's forward and backward interpolation formulae - Numerical differentiation with forward and backward differences - Numerical Integration with Trapezoidal rule, Simpson's 1/3 rule and Simpson's 3/8 rule - Taylor series method, Euler's method, 4th order Runge-Kutta method for solving first order ordinary differential equations

Probability and Statistics: Random variables, discrete and continuous random variables, Mean and variance of Binomial, Poisson and Normal distributions and applications. Testing of Hypothesis — Null and alternate hypothesis, level of significance and critical region - Z-test for single mean and difference of means, t-test for single mean and difference of means - F-test for comparison of variances.

Learning Resources:

Text Books:

1. R. K. Jain and S. R. K. Iyengar, Advanced Engineering Mathematics, Narosa Publishing House, 2016, Fifth Edition.
2. Erwin Kreyszig, Advanced Engineering Mathematics, John Wiley and Sons, 2015, Tenth Edition.

Reference Books:

1. Richard A. Johnson, Miller & Freund's Probability and Statistics for Engineers, Pearson, 2018, Ninth Edition.
2. Dennis G. Zill, Advanced Engineering Mathematics, Jones & Bartlett Learning, 2018, Sixth Edition
3. B. S. Grewal, Higher Engineering Mathematics, Khanna Publishers, 2012, Forty- Second Edition

ME 1204 **3-0-0 (3)**

Manufacturing Science

Pre-Requisites: **None**

Course Outcomes:

CO-1	Design core, core print and gating system in metal casting processes.
CO-2	Design near net shaped components from metal and ceramic powders
CO-3	Examine weld joints fabricated through solid state and fusion joining, brazing and soldering techniques
CO-4	Develop process-maps for metal forming processes using plasticity principles

Course Articulation Matrix:

	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6	PO-7	PO-8	PO-9	PO-10	PO-11	PO-12	PSO-1	PSO-2
CO-1	3	3	3	2	2	2	2	-	-	-	-	-	3	2
CO-2	3	3	3	2	2	2	2	-	-	-	-	-	3	2
CO-3	3	3	3	-	-	-	-	-					3	2
CO-4	3	3	3	2	2	2	2	-	-	-	-	-	3	2

1 - Slightly; **2 - Moderately;** **3 - Substantially**

Syllabus:

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

Near-Net and Net Shaped Manufacturing:

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

Joining Processes: 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.

Learning Resources:

Text Books:

1. Amitabha Ghosh and Mallick A. K, Manufacturing Science. Affiliated East-West Press Pvt. Ltd. 2010.

2. Doru Michael Stefanescu, Science and Engineering of Casting Solidification, Springer, 2009
3. Sindo Kao, Welding Metallurgy,2nd Edition, Wiley, 2002.
4. G. K. Lal and S. K. Choudhury,Fundamentals of Manufacturing Process, 2009, CRC Press, 2011
5. P. C. Angelo and R. Subramanian, Powder Metallurgy- Science, Technology and Applications, PHI, New Delhi, 2010.

Reference Books:

1. Paul Degarmo E, Black J.T and Ronald A. Kosher, Materials and Processes, in Manufacturing, Eight Edition, Prentice –Hall of India, 1997.
2. Brian Cantor, Keyna O'Reilly, Solidification and Casting, Taylor and Francis, 2002.
3. Dorel Banabic, Formability of Metallic Materials: Plastic Anisotropy, Formability Testing, Forming Limits, Springer, 2010.

ME 1206 **3-1-0 (4)**

Fundamentals of Prime Movers

Pre-Requisites: None

Course Outcomes:

CO-1	Understand the working principles of different types of prime movers.
CO-2	Describe the combustion and emission formation from Engines and Turbines.
CO-3	Analyze the performance of gas and steam turbines
CO-4	Analyze the performance of electric/hybrid vehicles.

Course Articulation Matrix:

	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6	PO-7	PO-8	PO-9	PO-10	PO-11	PO-12	PSO-1	PSO-2
CO-1	2	3	3	3	3	3	3	2	3	2	1	2	3	3
CO-2	2	3	3	3	3	3	3	3	3	2	3	2	3	3
CO-3	2	3	3	3	3	3	3	2	3	2	2	1	3	3
CO-4	2	3	3	3	3	3	3	2	3	2	2	1	3	3

1 - Slightly; **2 - Moderately;** **3 - Substantially**

Syllabus:

Introduction to IC Engines: Classification of Prime Movers; IC Engines as Prime Movers; IC Engines-Classification of Engines and brief details.

Combustion in SI and CI Engines: SI Engines: Brief treatment on Flame Propagation, Combustion phenomena (Normal and Abnormal), Ignition quality (Octane rating), CI Engines: Normal and abnormal combustion - Ignition Quality (Cetane rating) ; Combustion Chambers for SI and engines.

Supercharging of IC Engines: Need of Supercharging and advantages, Configurations of Supercharging-Numerical problems on turbocharging.

Pollutant emissions from IC Engines: Pollutants from SI and CI Engines: Carbon monoxide, UBHCs, Oxides of nitrogen (NO-NOX) and Particulate Matter, Mechanism of formation of pollutants, Factors affecting pollutant formation. Driving cycles, Emission norms.

Performance of IC Engines: Classification of engine performance parameters-Measurement of brake power, indicated power and friction power. Engine dynamometers, , Factors affecting performance, Heat loss, Air-fuel ratio, Energy Balance: Pi diagram, Numerical problems.

Steam Nozzles: Steam Nozzles- Introduction, Area- velocity relationship, Mass flow rate, Choking of Nozzles.

Fundamentals of Rotating Machines: Energy Equation, Dimensional Analysis, Ideal Gas Turbine Cycles: Analysis of Ideal Gas Turbine Cycles, Simple Cycle, Regeneration Cycle, Reheat Cycle, Inter cooling Cycle.

Practical Gas Turbine Cycles: Analysis of Practical Gas Turbine Cycles, Methods of accounting for component losses, Efficiencies, change in the composition of the working fluid.

Propulsion: Propulsive devices - Criteria of performance, Gas turbine cycles for turbojet, turbofan, turboprop and turbo-shaft engines, Thrust augmentation techniques.

Steam Power plant: Layout, Rankine Cycle- Analysis, Modified Rankine Cycle, and Combined Cycle.

Steam Turbines: Impulse and reaction Turbines, compounding of steam turbines, multistage reaction Turbines, Reheat factor and Efficiency.

Electric Vehicles: Rechargeable batteries, History of EVs, EV system, basic structure- Electric vehicle drive train-advantages and limitations, Components of EV Battery run EVs and Electric Motor run EVs, Hybrid Vehicles: Configurations of hybrids, advantages and limitations- basic structure of series, parallel and series-parallel configurations, Fuel Cell vehicles.

Learning Resources:

Text Books:

1. H.N.Gupta, Fundamentals of Internal Combustion Engines, PHI,2012.
2. Ehsani, M., Gao, Y., Longo, S., Ebrahimi, K., Modern Electric, Hybrid Electric, and Fuel Cell Vehicles, CRC Press, 2018 II Edition.
3. Sarvanamuttoo, H.I.H., Rogers, G. F. C. and Cohen, H., Gas Turbine Theory, Pearson Prentice Hall, 2017, 7th Edition.
4. Ganesan, V., Gas Turbines, Tata McGraw Hill, 3rd Edition 2017

Reference Books:

1. Heywood, John.B., , Internal Combustion Engine Fundamentals, McGraw Hill Co.2nd 2018 Edition.
2. Pulkrabek, W.W., Engineering Fundamentals of IC Engine, PHI Pvt.Ltd 2nd Edition, 2002
3. John Lowry and James Larmine, Electric vehicle technology explained, John Wiley and Sons, 2012.
4. Yahya, S. M, Turbines, Compressors and Fans, Tata McGraw Hill, 2017, 4th Edition.

ME 1208 **0-1-2 (2)**

Manufacturing Science Laboratory

Pre-Requisites: None

Course Outcomes:

CO-1	Test the properties of moulding sands.
CO-2	Fabricate weldments using gas and arc welding.
CO-3	Evaluate the quality of welded joints and cast components using non-destructive testing methods.
CO-4	Study the metallurgical changes in welded joints.
CO-5	Perform formability studies on sheet metals.

Course Articulation Matrix:

	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6	PO-7	PO-8	PO-9	PO-10	PO-11	PO-12	PSO-1	PSO-2
CO-1	3	2	2	2	-	-	-	-	3	3	-	2	3	3
CO-2	3	2	-	-	-	-	-	-	3	3	-	2	3	3
CO-3	3	2	-	-	-	-	-	-	3	3	-	2	3	3
CO-4	3	2	2	2	-	-	-	-	3	3	-	2	3	3
CO-5	3	2	2	2	2	2	-	-	3	3	-	2	3	3

1 - Slightly; 2 - Moderately; 3 - Substantially

Syllabus:

List of Experiments:

Casting

1. Demonstration on sweep pattern and core making in mould preparation
2. Calculate the amount of the clay content in the given moulding sand
3. Find the grain fineness number of the given moulding sand
4. Find the green and dry shear strength, compression strength and permeability of the given moulding sand.
5. Find shatter index of the given moulding sand

Welding

1. Fabricate the butt joint in the given samples by using shielded metal arc welding in the given samples
2. Fabricate butt joint in the given samples by using gas welding, SAW, TIG and MIG welding.
3. Join metal plates in the given samples using resistance spot welding
4. Join rectangular cross section plates in the given samples by flash butt welding
5. Identify welding defects by liquid penetration test in the welded sample
6. Microstructural evolution of weldments

Forming

1. Forming of deep drawing components – Erichsen cupping test
2. Component developments using sheet metal
3. Experiments in rolling

Learning Resources:

Text Books:

1. Amitabha Ghosh and A. K. Mallick, Manufacturing Science, Affiliated East-West Press Pvt. Ltd. 2010.
2. M. P. Groover, Fundamentals of Modern Manufacturing: Materials, Processes, and Systems, Wiley India Private Limited, 3rd edition, 2009.

Reference Books:

1. P.L. Jain, Principles of Foundry Technology, TMH, 2014
2. P.N. Rao, Manufacturing Technology Foundry, Forming and Welding, TMH, 2nd Edition, 2017

ME 1210 **0-1-2 (2)**

Computer Aided Machine Drawing

Pre-Requisites: **None**

Course Outcomes:

CO-1	Build 2D and 3D objects using a modeling software.
CO-2	Draw the two-dimensional machine elements using a modeling software.
CO-3	Construct a three-dimensional assembly drawing of machine component.
CO-4	Generation of two-dimensional drawing from three-dimensional for manufacturing.

Course Articulation Matrix:

	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6	PO-7	PO-8	PO-9	PO-10	PO-11	PO-12	PSO-1	PSO-2
CO-1	2	2	1		3				2	2		2	2	2
CO-2	2	3	2		3				2	3		2	2	2
CO-3	2	2	2		3				2	3		2	2	3
CO-4	2	2	2		3				2	3		2	2	3

1 - Slightly; **2 - Moderately;** **3 - Substantially**

Syllabus:

List of Experiments conducted in this lab:

1. Introduction to Modeling software, draw tools and constrains
2. Working with features like Extrude & Revolve.
3. Model solids with features like Hole, Round, Chamfer and Rib.
4. Model solids with features like Copy, Rotate, Move and Mirror.
5. Working with features like dimension pattern, axis patter, etc.,
6. Advanced modeling tools, Sweep, Blend.
7. Advanced modeling tools, Variable section Sweep, Helical Sweep.
8. Modelling with Cosmetic Threads.
9. Part Modelling of machine components.
10. Assembly modelling of machine components.
11. Case study of Assembly-1.
12. Case study of Assembly-2.
13. Case study of Assembly-3.
14. Generation of 2D drawings using 3D models for Manufacturing.
15. Minor course project on modelling of machine component.

Learning Resources:

Text Books:

1. Lab instruction manual
2. Bhatt, N.D., Machine Drawing, Charotar Publishing House, 50th Edition 2016.
3. Sidheswar, N., Kannaiah, P. and Sastry, V.V.S., Machine Drawing, Tata McGraw Hill Book Company, New Delhi, 2000.
4. Kannaiah, P., Production Drawing, New Age International, 2009

5th Semester

ME 1301 **3-1-0 (4)**

Machine Design

Pre-Requisites: **None**

Course Outcomes:

CO-1	Identify the preferred sizes and codes and selection of proper material for designing machine elements.
CO-2	Design the machine element under static and dynamic loading conditions.
CO-3	Design the temporary and permanent joints required to assemble the machine elements.
CO-4	Design the required spring for the given application.

Course Articulation Matrix:

	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6	PO-7	PO-8	PO-9	PO-10	PO-11	PO-12	PSO-1	PSO-2
CO-1	3	3	3	2	2							2	3	1
CO-2	3	3	3	2	2							2	3	1
CO-3	3	3	3	2	2							2	3	1
CO-4	3	3	3	2	2							2	3	1

1 - Slightly; **2 - Moderately;** **3 - Substantially**

Syllabus:

Introduction: Engineering Design and classification, Basic design procedure, requirement of machine element, traditional design methods, standards and codes, selection of preferred sizes, Engineering material and its classification, Mechanical properties of engineering materials, Selection of materials, Manufacturing considerations and their selection.

Static Loading: Basics- Stresses in members subjected to different types of loads, Modes of failure, Principal stresses, Theories of failure- Rankine theory, Guests theory and Von Mises theory, Selection of failure theories to design simple machine parts.

Dynamic Loading: Stress concentration and its Importance in design, Methods to reduce stress concentration, Stress concentration factor-Theoretical and actual stress concentration factors, Notch sensitivity, Design of stress concentrated members subjected to various loads- Problems, Types of variable/Cyclic loads, Mean & amplitude Stresses, Fatigue Failure, Endurance Limit & Strength, S-N Diagram, Goodman and Soderberg criterion, Modifying factors: Size effect, surface effect, Reliability, Stress concentration effects etc., Problems on design of members for finite & infinite life in members subjected to individual & combined loading, Cumulative damage in fatigue.

Design of Bolted Joints: Forms of screw threads, Nomenclature of screw thread, Thread series and its designation, Power screws, Stress in screwed threads, Design of bolts based on uniform strength, Empirical relation for initial tightening, Eccentrically bolted joints in shear, Turnbuckle, Design of power screw-Problems.

Design of Riveted and Welded Joints: Rivet heads, Terminology, Caulking and fullering, Analysis of riveted joint, Efficiency of a riveted joint, Design of boiler joints and structural joints, eccentrically loaded riveted joints, welding process, merits and demerits of welded joint over riveted joints, weld symbols, Strength of parallel and fillet weld, eccentrically loaded welded joints, Weld subject to bending moment and torsional moment, Problems.

Design of Springs: Types of Springs, Spring materials, terminology - Stresses in Helical coil springs of

circular and non-circular cross sections, Compression-spring surge, Springs under eccentric loading and fluctuating loads, - Energy stored in springs, torsion, Belleville springs. Leaf Springs: Stresses in leaf springs, Nipping. Equalized stresses.

Learning Resources:

Text Books:

1. V B Bhandari, Design of Machine Elements, Tata McGraw Hill Education Private Limited, 2020, Fifth edition.
2. Robert L Norton, Machine design an integrated approach, Pearson Education, 2018, Fifth edition.

Reference Books:

1. Richard G. Budynas, J Keith Nisbett, Mechanical Engineering Design, Shigley's. McGraw Hill, 2011, Ninth edition.
2. Black and Adams, Machine Design, McGraw Hill and Co, New Delhi, 2002.

ME 1303 **3-0-0 (3)**

Machine Tools and Metrology

Pre-Requisites: **None**

Course Outcomes:

CO-1	Design kinematic motions in a machine tool.
CO-2	Design speed and feed gear boxes.
CO-3	Design machine tool structures for strength and rigidity.
CO-4	Analyze machine tool vibration and chatter.
CO-5	Select alignment tests to be performed on a machine tool for quality assurance.

Course Articulation Matrix:

	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6	PO-7	PO-8	PO-9	PO-10	PO-11	PO-12	PSO-1	PSO-2
CO-1	2	2	-	-	-	-	-	-	-	-	-	-	3	2
CO-2	2	2	-	-	-	-	-	-	-	-	-	-	3	2
CO-3	3	2	-	2	-	-	-	-	-	-	-	-	2	-
CO-4	3	2	2	2	-	-	-	-	-	-	-	-	3	-
CO-5	2	2	3	-	-	-	-	-	-	2		2	3	2

1 - Slightly; **2 - Moderately;** **3 - Substantially**

Syllabus:

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
Finishing Processes: Grinding, Lapping, Honing & Broaching Processes.
Regulation of Speed and Feed Rates: Introduction, Methods of Speed and Feed Regulation, Ray Diagrams and Design Considerations, Design of Speed Gearboxes, Feed Drives.

Metrology:

Linear and Angular Measurements: Linear Measuring Instruments, Angle measuring instruments, Comparators, Calibration of Instruments.
Limits, Fits, Tolerances and Gauging: Interchangeability, Types of fits, Basic-Hole System, Basic-Shaft System, Types of Assemblies, Design of limit gauges, Introduction to GD&T.

Gear and Screw Thread Measurements:

- Gear measurement: Introduction and Classification of gears; Forms of gear teeth; Gear tooth terminology; Methods of measuring tooth thickness, tooth profile & pitch, Gear Errors;
- Screw Thread Measurement: Terminology, Forms of thread, Errors in threads, Measurement of major, minor and effective diameters (2-wire and 3-wiremethods).

Surface Roughness Measurement: Components of surface texture, Need for surface roughness measurement, Measurement of surface roughness, Roughness characterization, Roughness grades.
Interferometry: Principle of Interference, Optical Flat, Fringe Patterns, NPL Interferometer.
Geometric Form Measurement: Straightness, Flatness, Roundness, Coordinate Measuring Machine.

Learning Resources:

Text Books:

1. Kalpakjian, S. and Steven R. Schmid, Manufacturing, Engineering & Technology, Pearson Education, 2013
2. P.N. Rao, Manufacturing Technology–Metal Cutting and Machine Tools, Tata McGraw Hill, New Delhi, 2000.
3. N.K. Mehta, Machine Tool Design, Tata McGraw Hill, 2012
4. I.C. Gupta, Engineering Metrology, Dhanpat Rai & Sons,2003
5. R. K. Jain, Engineering Metrology, Khanna Publishers, 19/e, 2005.

Reference Books:

1. D. James, and S, Meadow, Geometric Dimensioning and Tolerancing, Marcel Dekker Inc.,1995.
2. S.K. Hajra Chowdary, and A.K. Hajra Chowdary, Elements of Workshop Technology, Vol. II, Asia Publishing House, Bombay, 2003.

Online Resources:

NPTEL Courses

1. https://nptel.ac.in/courses/112/105/112105127/
2. https://nptel.ac.in/courses/112/106/112106179/

ME 1305 **3-0-0 (3)**

Heat Transfer

Pre-Requisites: **None**

Course Outcomes:

CO-1	Understand the basic modes of heat transfer
CO-2	Compute temperature distribution in steady-state and unsteady-state heat conduction
CO-3	Estimate heat transfer through forced and free convection
CO-4	Calculate the radiation heat transfer in multi body enclosure
CO-5	Design heat exchangers using LMTD and NTU methods.

Course Articulation Matrix:

	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6	PO-7	PO-8	PO-9	PO-10	PO-11	PO-12	PSO-1	PSO-2
CO-1	2	2	-	3	-	-	-	-	1	-	-	1	2	1
CO-2	2	2	2	3	-	-	-	-	1	-	-	1	2	1
CO-3	-	-	1	3	-	-	-	-	-	-	-	-	2	1
CO-4	2	2	2	3	1	-	-	-	1	-	-	1	2	1
CO-5	2	2	2	3	2	-	-	-	1	-	-	1	2	1

1 - Slightly; **2 - Moderately;** **3 - Substantially**

Syllabus:

Introduction: Heat Transfer - Different Modes, Governing Laws, Applications to Heat Transfer, Numerical Problems.

General Heat Conduction Equation: Derivation of the equation in (i) Cartesian, (ii) Polar and (iii) Spherical Coordinate Systems.

Steady-state one-dimensional heat conduction: Steady-state one-dimensional heat conduction problems (i) with and without heat generation and (ii) with and without varying thermal conductivity - in Cartesian system, Polar System, and Spherical System with various possible boundary conditions, Thermal Resistances in Series and in Parallel, Numerical Problems.

Critical Thickness of Insulation: Concept, Derivation and Numerical Problems.

Extended Surfaces or Fins: Classification, Straight Rectangular and Circular Fins, Temperature Distribution and Heat Transfer Calculations, Fin Efficiency and Effectiveness, Applications, Numerical Problems.

Transient [Unsteady-state] heat conduction: Definition, Different cases - Negligible internal thermal resistance, negligible surface resistance, comparable internal thermal and surface resistance, Lumped body, Infinite Body and Semi-infinite Body, Numerical Problems, Heisler and Grober charts: Solutions to various one-dimensional problems using the charts, Numerical problems.

Forced Convection: Boundary Layer Theory, Velocity and Thermal Boundary Layers, Prandtl number, Governing Equations - Continuity, Navier-Stokes and Energy equations, Boundary layer assumptions, Integral and Analytical solutions to above equations, Turbulent flow, Various empirical solutions, Numerical

Problems, Forced convection flow over cylinders and spheres, Internal flows -laminar and turbulent flow solutions, Numerical Problems.

Free convection: Laminar and Turbulent flows, Vertical Plates, Vertical Tubes and Horizontal Tubes, Empirical solutions, Numerical Problems.

Thermal Radiation: Fundamental principles - Gray, White, Opaque, Transparent and Black bodies, Spectral emissive power, Wien's, Rayleigh-Jeans' and Planck's laws, Hemispherical Emissive Power, Stefan-Boltzmann law for the total emissive power of a black body, Emissivity and Kirchhoff's Laws, View factor, View factor algebra, Net radiation exchange in a two-body enclosure, Typical examples for multi-body enclosures, Radiation Shield, Numerical problems.

Heat Exchangers: Definition, Classification, LMTD method, Effectiveness - NTU method, Analytical Methods, Numerical Problems, Chart Solution for Heat Exchanger Problems: Correction Factor Charts and Effectiveness-NTU Charts, Numerical Problems.

Boiling and Condensation: Basics of Pool Boiling, Flow Boiling, Film condensation and dropwise condensation

Learning Resources:

Text Books:

1. Incropera, F. P. and De Witt, D. P., Fundamentals of Heat and Mass Transfer, John Wiley and Sons, New York, 8th edition, 2019.
2. Holman, J. P., Bhattacharyya Souvik, Heat Transfer, Tata McGraw Hill, New Delhi, 10th edition 2017.

Reference Books:

1. M. Necati Ozisik, Heat Transfer - A Basic Approach, McGraw Hill, New York, 1985
2. Alan J. Chapman, Heat Transfer, Macmillan, Pearson Education India; Fourth edition, 2016..

ME 1307 **3-0-0 (3)**

Management Science and Productivity

Pre-Requisites: **None**

Course Outcomes:

CO-1	Understand the role of production systems to support a given competitive strategy
CO-2	Understand the role of productivity in streamlining a production system.
CO-3	Apply the inventory management tools in managing inventory.
CO-4	Apply quality engineering tools in designing products and process controls.
CO-5	Apply PERT and CPM in the management of projects.

Course Articulation Matrix:

	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6	PO-7	PO-8	PO-9	PO-10	PO-11	PO-12	PSO-1	PSO-2
CO-1	2	2	2	2		2		2	2		2	2	3	3
CO-2	2	2											2	2
CO-3	2	3	2	3				2	2			2	3	3
CO-4	2	3	2	3				2	2				3	3
CO-5	2		2				2	2	2	2	3		2	3

1 - Slightly; **2 - Moderately;** **3 - Substantially**

Syllabus:

Production Systems: Evolution of production systems, Classification and characterization, Competitive strategies, Production and Inventory control strategies, Process management, Facility Design.

Productivity and Work study: Productivity and its role in the economy, Techniques for improving productivity, Method study, Principles of motion economy, Stopwatch time study, Work sampling, Predetermined Time Standards.

Quality Management: Dimensions of quality, Process control charts, Acceptance sampling, Quality function deployment, Taguchi's Quality Engineering, Introduction to TQM.

Inventory Management: Purpose of inventories, Inventory costs, ABC classification, Economic Order Quantity (EOQ), P and Q systems of inventory control.

Project Management: Project activities, Network diagrams, CPM, PERT, Project Feasibility studies.

Learning Resources:

Text Books:

1. Chase, Operations and Supply Chain Management, Tata McGraw Hill, 2024, 17th Edition.

2. Krajewski L.J. and Ritzmen L.P, Operations Management: Strategy and Analysis, Pearson Education, 2021, 11th Edition.
3. Mahadevan. B, Operations Management: Theory and Practice, Pearson Education, 2015, 3rd Ed.

Reference Books:

1. Hopp W. J. and Spearman M. L., Factory Physics: Foundations of Manufacturing Management, McGraw Hill International Edition, 2008, 3rd Edition.

ME 1309 **0-1-2 (2)**

Machine Tools and Metrology Laboratory

Pre-Requisites: **None**

Course Outcomes:

CO-1	Perform machining operations on a lathe.
CO-2	Evaluate the effect of process parameters on shear angle, cutting forces and surface finish in machining.
CO-3	Evaluate the effect of process parameters on MRR and surface finish in EDM.
CO-4	Perform indexing to machine spur and helical gears on milling machine.
CO-5	Evaluate internal and external taper angles, straightness and flatness of a given surface.
CO-6	Evaluate dimensional and form accuracies of thread and gear profiles.

Course Articulation Matrix:

	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6	PO-7	PO-8	PO-9	PO-10	PO-11	PO-12	PSO-1	PSO-2
CO-1	2	-	-	3	2	3	-	-	2	2	-	2	3	-
CO-2	2	-	-	3	2	3	-	-	2	2	-	2	3	-
CO-3	2	-	-	3	2	3	-	-	2	2	-	2	3	-
CO-4	2	-	-	3	2	3	-	-	2	2	-	2	3	-
CO-5	2	-	-	3	2	3	-	-	2	2	-	2	3	-
CO-6	2	-	-	3	2	3	-	-	2	2	-	2	3	-

1 - Slightly; **2 - Moderately;** **3 - Substantially**

Syllabus:

List of Experiments:

Machining Cycle:

1. Turning, Taper turning, Facing, Thread cutting and chamfering on lathe (Demo: Split-half nut).
2. Eccentric turning (Demo: Different types of chucks, Belt, Chain and Gear drives).
3. Spur Gear and Helical milling (Demo: Indexing).
4. Chip reduction coefficient on shaper (Demo: 1. Quick-return mechanism, 2. Pawl and Ratchet mechanism, 3. Rack & Pinion mechanism).
5. Measurement of cutting forces and surface finish in turning (Demo: Dynamometer and its setup).

Metrology Cycle:

1. Internal and external taper measurement.
2. Thread measurement using floating carriage diameter measuring machine.
3. Straightness measurement using auto-collimator.
4. Measurement of Thread and Gear profiles for their form and geometrical accuracies.
5. Demonstration Coordinate Measuring Machine for the evaluation of form errors.

Learning Resources:

Text Books:

1. Kalpakjian S. and Steven R. Schmid, Manufacturing, Engineering & Technology, Pearson, 2007
2. I.C. Gupta, Engineering Metrology, Dhanpat Rai and Sons, 2003.

ME 1311 **0-1-2 (2)**

Heat Transfer and Energy Systems Laboratory

Pre-Requisites: None

Course Outcomes:

CO-1	Estimate heat transfer coefficient of air in Free and forced convection modes and compare with theoretical and empirical values.
CO-2	Estimate the efficiency and effectiveness of a pin-fin, heat exchanger and equivalent thermal resistance of a composite slab.
CO-3	Demonstration and performance evaluation of heat pipe, thermal radiation principles and two-phase heat transfer phenomenon.
CO-4	Analyse the performance of solar collectors.
CO-5	Demonstration and performance evaluation of fuel cells.

Course Articulation Matrix:

	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6	PO-7	PO-8	PO-9	PO-10	PO-11	PO-12	PSO-1	PSO-2
CO-1	2	2	-	3	-	-	-	-	1	-	-	1	2	1
CO-2	2	2	2	3	-	-	-	-	1	-	-	1	2	1
CO-3	-	-	1	3	-	-	-	-	-	-	-	-	2	1
CO-4	2	2	2	3	1	-	-	-	1	-	-	1	2	1
CO-5	2	2	2	3	2	-	-	-	1	-	-	1	2	1

1 - Slightly; **2 - Moderately;** **3 - Substantially**

Syllabus:

List of Experiments:

1. **Forced Convection Apparatus:** Determination of theoretical, experimental and empirical values of forced convection heat transfer coefficient for flow through a circular pipe.
2. **Natural Convection Apparatus:** Determination of experimental and empirical values of free convection heat transfer coefficient from a Heated Vertical Cylinder.
3. **Pin-Fin Apparatus:** Determination of temperature distribution, efficiency and effectiveness of a pin fin working in a forced convection environment.
4. **Composite Slab Apparatus:** Determination of theoretical and experimental values of equivalent thermal resistance of a composite slab.
5. **Heat Pipe Demonstrator:** Demonstration of isothermal characteristics exhibited by a heat pipe in comparison to other pipes.
6. **Parallel and Counter flow Heat Exchanger:** Determination of LMTD of parallel and counter flow heat exchanger.
7. **Emissivity Apparatus:** Determination of the surface emissivity of a given test plate at a given absolute temperature.
8. **Stefan-Boltzmann Apparatus:** Determination of the Stefan-Boltzmann constant and comparison with the theoretical value

9. **Film Boiling and Condensation Apparatus:** Determination of the heat transfer coefficient in film boiling and condensation.
10. **Solar flat plate collector:** Performance evaluation of solar flat plate collector in natural and forced circulation modes.
11. **Parabolic concentric solar collector:** Performance evaluation of parabolic concentric solar collector.
12. **Solar PV Module:** Identifying and measuring the parameters of a solar PV Module in the field.
13. **Solar Simulator:** Dark and Illuminated Current-Voltage characteristics of solar cell.
14. **Fuel Cells:** Performance evaluation of DMFC and PEM fuel cells.

Learning Resources:

Text Books:

1. M. Necati Ozisik, Heat Transfer - A Basic Approach, McGraw Hill, New York., 1985
2. Incropera, F. P. and De Witt, D. P., Fundamentals of Heat and Mass Transfer, John Wiley and Sons, New York, 8th Edition, 2019.
3. Frano Barbir, PEM Fuel Cells-Theory and Practice, Elsevier Academic Press, 2005, 2nd Edition.

Reference Books:

1. Holman, J. P., Bhattacharyya Souvik, Heat Transfer, Tata McGraw Hill, New Delhi, 10th edition 2017
2. Sukhatme, S. P. and Nayak, J. K., Solar Energy, McGraw Hill Education, 2017, 4th Edition.
3. Holman, J., Experimental Methods for Engineers, McGraw Hill Education, 2017, 7th Edition.

Online Resources:

1. Solar Energy Laboratory, IIT Roorkee, https://www.iitr.ac.in/departments/HRE/pages/Facilities+Solar_Energy_Laboratory.html

6th Semester

ME 1302 **3-0-0 (3)**

Refrigeration & Air conditioning

Pre-Requisites: None

Course Outcomes:

CO-1	Demonstrate the working principles of various refrigeration systems using thermodynamic principles.
CO-2	Evaluate the performance of basic refrigeration and air-conditioning machines.
CO-3	Identify the Psychrometric processes for different applications and design the parameters of the air-conditioning system as per standards.
CO-4	Analyze the performance of compressors using thermodynamic concepts, principles of design and their control during its operation.

Course Articulation Matrix:

	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6	PO-7	PO-8	PO-9	PO-10	PO-11	PO-12	PSO-1	PSO-2
CO-1	2	2	-	3	-	-	-	-	1	-	-	1	2	1
CO-2	2	2	2	3	-	-	-	-	1	-	-	1	2	1
CO-3	-	-	1	3	-	-	-	-	-	-	-	-	2	1
CO-4	2	2	2	3	1	-	-	-	1	-	-	1	2	1

1 - Slightly; 2 - Moderately; 3 - Substantially

Syllabus:

Introduction: Basic Definitions of Refrigeration and Air-Conditioning, History of Refrigeration, Natural and Artificial Refrigeration Methods, Techniques to produce low temperatures, refrigerants.

Thermodynamic analysis of Refrigeration cycles: Working principles and thermodynamic analysis of Refrigeration cycles such as air refrigeration, VCRS, VARS, Steamjet, Vortex tube refrigeration etc. Methods to improve performance of VCRS, concept of MultiStage VCRS and Cascade Refrigeration systems.

Psychrometry and air-conditioning: Psychrometry - Air-water vapor mixtures, Psychrometric Properties, Psychrometric or Air-Conditioning processes, Psychrometric Chart, Thermal Comfort. Analysis of psychrometric processes for the purpose of comfort air-conditioning. Mathematical Analysis of Air-Conditioning Systems. Overview of Cooling and Heating Load Estimation.

Compressors: Reciprocating compressors - Construction, P-V diagram, Clearance volume, Multi-stage compressors, Efficiency. Centrifugal and Axial Flow Compressors - Principle of Operation, T-s diagram, Performance Characteristics

Learning Resources:

Text Books:

1. Arora Ramesh Chandra, Refrigeration and Air Conditioning, PHI Learning Pvt. Ltd., India, 2012
2. Arora, C. P., Refrigeration and Air-Conditioning, Tata McGraw - Hill, New Delhi, 2000.

Reference Books:

1. Roy J. Dossat, Principles of Refrigeration, Wiley Limited, 1978
2. Stoecker, W. F., and Jones, J. W., Refrigeration and Air-Conditioning, McGraw - Hill, New Delhi, 1983.
3. Yahya, S.M., Compressors and Fans, Turbines, 4th Edition, McGraw Hill Education, 2017.

Data Books:

1. M. L. Mathur, and F. S. Mehta,Refrigerant and Psychrometric Properties - Tables and Charts [SI Units], Jain Brothers, 2020 (Revised Edition).

Online Resources:

1. Refrigeration and Air-Conditioning by Prof. R.C Arora and Prof. M. Ramgopal (IIT Kharagpur), NPTEL Course (Link: https://nptel.ac.in/courses/112/105/112105128/)
4. Refrigeration and Air-Conditioning by Prof. Ravi Kumar (IIT Roorkee), NPTEL Course (Link: https://nptel.ac.in/courses/112/107/112107208

ME 1304 **4-0-0 (4)**

Machining Science

Pre-Requisites: None

Course Outcomes:

CO-1	Develop interrelations among ASA, ORS and NRS systems of tool geometry.
CO-2	Analyze the stresses, cutting forces, temperature, power and specific energy in metal cutting with a single point cutting tool.
CO-3	Select cutting fluids, tool materials and coatings for improving tool life and machinability.
CO-4	Estimate optimum cutting speed with respect to production cost and production rate.
CO-5	Select a modern machining process based on the effect of various process parameters.

Course Articulation Matrix:

	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6	PO-7	PO-8	PO-9	PO-10	PO-11	PO-12	PSO-1	PSO-2
CO-1	3												2	
CO-2	3	3	2	3			2						3	
CO-3	3						2	2					3	
CO-4	3	3											2	
CO-5	3												3	2

1 - Slightly; **2 - Moderately;** **3 - Substantially**

Syllabus:

Introduction: Classification of Manufacturing Processes, History of Machining, Scope and Significance of Machining.

Geometry of Cutting Tools: Geometry of single-point turning tool: Tool-in hand system, ASA system, Significance of various angles of SPTT, Orthogonal Rake System (ORS), Normal Rake System (NRS), Conversions between ASA and ORS systems.

Mechanics of Machining: Processes - Orthogonal and Oblique cutting, Mechanics of Chip formation: Types of chips, chip-breakers, Chip reduction coefficient, shear angle, shear strain, Built-Up-Edge and its effect in metal cutting, Merchant's analysis of metal cutting process–Various forces, power and specific energy in cutting, Effect of tool geometry on cutting forces and surface finish.

Thermal aspects in machining: Sources of heat generation, Effects of temperature, Determination of cutting temperature using analytical methods, Determination of cutting temperature using experimental methods, Methods of Controlling Cutting Temperature.

Tool wear, Tool life, Machinability: Wear Mechanisms, Types of tool wear, Tool Life and Machinability.

Cutting Tool Materials: Desirable Properties of tool materials, Characteristics of Cutting Tool Materials, Indexable inserts, coated tools.

Cutting Fluids: Functions, characteristics and types, Selection of cutting fluids.

Machining Economics: A brief treatment for single pass turning operations.

Advanced Machining Processes: An overview of modern machining processes–Classification, Mechanical energy-based machining processes: Abrasive jet machining, Ultrasonic machining, Water jet

machining, Abrasive water jet machining.

Thermo-electric energy-based machining processes: Electric discharge machining, Laser Beam machining.

Chemical energy-based machining processes: Chemical machining, Electro-Chemical machining

Learning Resources:

Text Books:

1. A. B. Chattopadhyay, Machining and Machine Tools, Wiley, 2nd Edition, 2017.
2. B L Juneja and G S Sekhon, Fundamentals of metal cutting and machine Tools, New Age International publishers, Revised 2nd Edition, 2017.

Online Resources:

1. NPTEL Lectures: https://nptel.ac.in/courses/112/105/112105126/
2. NPTEL Lectures: https://nptel.ac.in/courses/112/105/112105127/

ME 1306 **0-1-4 (3)**

Product Development

Pre-Requisites: **ME 1101**

Course Outcomes:

CO-1	Express Product Design Ideas using 2D or 3D sketches
CO-2	Model the components with geometric (engineering) specifications and appropriate materials
CO-3	Develop a prototype of the product
CO-4	Evaluate the entire product and the product based on testing with user
CO-5	Explore the scope for protecting novelty of the product through patent

Course Articulation Matrix:

	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6	PO-7	PO-8	PO-9	PO-10	PO-11	PO-12	PSO-1	PSO-2
CO-1			2	3	3	3	2	2	3	3	2	3		
CO-2			2	3	3	3	2	2	3	3	2	3		
CO-3			2	3	3	3	2	2	3	3	2	3		
CO-4			2	3	3	3	2	2	3	3	2	3		
CO-5			2	3	3	3	2	2	3	3	2	3		

1 - Slightly; **2 - Moderately;** **3 - Substantially**

Syllabus:

Design Thinking process for Product Development: Review of five step design thinking process of Empathize- Define- Ideate- Prototype- Test.

Project Selection: Identification of the problem through empathy, formulate and ideate to solve the problem.

Product Development:
Sketching: 2D and 3D sketching: Students will sketch the concept on drawing sheets/ digital screens. The drawings will contain the specifications of the geometric form.
3D Modelling*:* Develop the 3D model features including free form surfaces, final product design specifications, Parametric design.
Physical Component Development*:* Development of components: fabrication of actual components of the product using the materials and tools available in the lab, Iterations.

Iterative improvement of the product and Report writing: Development of assemblies/mock-up models/ working models/ prototypes/functional models/products, Testing and design review, Report writing.

IPR: Different forms of innovations emanating from the human mind and their protection using different tools of IPR, Basic introduction to Patents, Trademarks, Copyright, Industrial Designs Registrations, Geographical Indications Trade Secrets. Filing of IPR, implications, Ethics and societal implications of

Intellectual Property Rights.

Learning Resources:

Text Books:

1. Sullivan, Brian, The design studio method: creative problem solving with UX sketching, Focal Press, 2016.
2. Karl T. Ulrich, Steven D. Eppinger, Maria C. Yang, Product Design and Development, McGraw Hill, 2020, 7th Edition.
3. Verma G., Autodesk Fusion 360 Black Book, CADACAMCAE Works, 2021, 2nd edition.
4. Class Junghans and Adam Levy, Intellectual Property Management: A guide for Scientists, Engineers, Financers and Managers, Willey (2006).

Reference Books:

1. Kevin N. Otto, Kristin L. Wood, Product Design: Techniques in Reverse Engineering and New Product Development, Pearson Education, 2004.
2. George E Dieter, Engineering Design, Publisher, McGraw Hill, 2013, 5th edition.

Online Resources:

1. Self-Paced Tutorials: https://help.autodesk.com/view/fusion360/ENU/courses/
2. Product Documentation: https://help.autodesk.com/view/fusion360/ENU/?guid=GUID1C665B4D-7BF7-4FDF-98B0-AA7EE12B5AC2
3. NPTEL: https://archive.nptel.ac.in/courses/112/107/112107217/
4. Functional and Conceptual Design: https://www.youtube.com/playlist?list=PLygSpOzTE6M88PUx4AtV1WWNeKYVIvPAl

ME 1308 **0-1-2 (2)**

Thermal Engineering Lab

Pre-Requisites: None

Course Outcomes:

CO-1	Evaluate the performance and emission characteristics of IC engines by conducting constant speed performance tests.
CO-2	Determine the friction power of an IC engine by motoring, Morse and retardation tests.
CO-3	Evaluate the properties of fuels and oil.
CO-4	Evaluate the performance of turbomachines and refrigerators.

Course Articulation Matrix:

	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6	PO-7	PO-8	PO-9	PO-10	PO-11	PO-12	PSO-1	PSO-2
CO-1	3	3	3	3	2	2	3	2	3	2	2	1	3	3
CO-2	3	3	3	3	2	2	3	2	3	2	2	1	3	3
CO-3	3	3	3	3	2	2	3	2	3	2	2	1	3	3
CO-4	3	3	3	3	2	2	3	2	3	2	2	1	3	3

1 - Slightly; 2 - Moderately; 3 - Substantially

Syllabus:

List of Experiments:

1. Determination of flash and fire points of a given oil sample and determination of distillation characteristic of a given sample of gasoline.
2. Determination of viscosity of a given oil sample.
3. Two-Stage Reciprocating Air-Compressor: Determination of volumetric efficiency of the compressor as a function of receiver pressure.
4. Valve timing diagram of a single cylinder diesel engine.
5. Performance test on twin cylinder air cooled diesel engine and computer interfaced engine.
6. Determination of friction power of an engine.
7. Heat balance test on single cylinder engine.
8. Performance characteristics of an Axial flow fan.
9. Performance characteristics of a single stage centrifugal blower.
10. Demonstration of a Steam Power Plant.
11. Flow characteristics of an aerofoil.
12. Performance test on Vapour Compression Refrigeration Test -rig.

Learning Resources:

Text Books:

1. Gupta, H.N.,Fundamentals of Internal Combustion Engines, , PHI, 2021.
2. Ganesan,V., Gas Turbines, Tata McGraw Hill Book Co., New Delhi, 3rd Edition, 2019.

Other Suggested Readings:

1. https://www.me.iitb.ac.in/?q=individual-research-group/Internal%20Combustion%20Engines%20and%20Combustion%20Laboratory

ME 1310 **0-1-2 (2)**

CAE Laboratory

Pre-Requisites: **None**

Course Outcomes:

CO-1	Draw complex geometries of parts in sketch mode.
CO-2	Develop MATLAB codes for analytical and synthetic curves.
CO-3	Create complex engineering assemblies using appropriate assembly constraints.
CO-4	Practice on CAD data exchange formats used in design and analysis of Engineering components.
CO-5	Finite Element Analysis 2D/3D component using a FEA software

Course Articulation Matrix:

	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6	PO-7	PO-8	PO-9	PO-10	PO-11	PO-12	PSO-1	PSO-2
CO-1	3	2				2								
CO-2	3	2	2	3	2	2								
CO-3	3	2	2			2								
CO-4	3	3	2	2	2	2								
CO-5	3	3	2	3	2	2								

1 - Slightly; **2 – Moderately;** **3 - Substantially**

Syllabus:

1. Introduction to Solid Modeling Packages
2. Working with sketch mode of Solid modeling Package
3. Working with creating features (Extrude & Revolve)
4. Develop MATLAB Code for various analytical curves
5. Develop MATLAB Code for various synthetic curves
6. Working with various editing tools in Solid Modelling
7. Working with advanced modeling tools (Sweep, Blend & Swept Blend)
8. Assembly modeling using appropriate assembly constrains
9. Working with CAD Data Exchange formats: IGES, ACIS, DXF STL, AMF, STEP
10. Analysis of simple 2D/3D component using a FEA software

Learning Resources:

Text Books:

1. Steven Chapra, Applied Numerical Methods with MATLAB for Engineers & Scientists, McGraw-Hill, 2018, 4th Edition.
2. Sham Tickoo, AutoCAD 2017 for Engineers & Designers, Dreamtech Press, 23rd Edition, 2016.
3. Verma G., Autodesk Fusion 360 Black Book, CAD CAM CAE Works, 2021, 2nd Edition.

Reference Books:

1. Kunwoo Lee, Principles of CAD/CAM/CAE, Pearson, 1999.
2. David Smith, Engineering Computation with MATLAB, Pearson, 2013, 3rd Edition.

Online Resources:

1. Self-Paced Tutorials: https://help.autodesk.com/view/fusion360/ENU/courses/
2. Product Documentation: https://help.autodesk.com/view/fusion360/ENU/?guid=GUID-1C665B4D-7BF7-4FDF-98B0-AA7EE12B5AC2
3. https://sites.ualberta.ca/~wmoussa/AnsysTutorial/
4. https://www.ansys.com/en-in/academic/learning-resources
5. http://engineering.nyu.edu/mechatronics/vkapila/matlabtu

7th Semester

ME 1401 **3-0-2 (4)**

CAD/CAM – Theory and Practice

Pre-Requisites: None

Course Outcomes:

CO-1	Understand conceptual design and geometric transformation techniques in CAD
CO-2	Develop mathematical models to represent curves, surfaces and solids
CO-3	Develop CNC programs to manufacture industrial components
CO-4	Understand the elements of an automated manufacturing environment
CO-5	Apply CAD/CAM tools for the given engineering application

Course Articulation Matrix:

	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6	PO-7	PO-8	PO-9	PO-10	PO-11	PO-12	PSO-1	PSO-2
CO-1	2	2			2								3	2
CO-2	2	3			2								3	2
CO-3	2	3		3	2								3	2
CO-4	2	2		3	2								3	2
CO-5	2	3		3	2								3	2

1 - Slightly; **2 - Moderately;** **3 - Substantially**

Syllabus:

Introduction to CAD/CAM: Introduction to CAD/CAM/CIM, Design Process, Product Lifecycle Management (PLM), CAD/CAM Input and Output Devices, Software Tools for CAD/CAM. **Transformations of Geometry:** Rigid-body transformations. Deformations. Computer Implementation.

Geometric Modelling of Curves: 3-D Wire Frame Modelling, Parametric representation, Curve modelling using Ferguson's, Bezier and B-spline methods. Computer Implementation.

Geometric Modelling of Surfaces: Basic Surfaces Entities, Parametric Representation, Modelling of Analytical and Synthetic Surfaces. Developing Computer Codes for Design of Surfaces.

Geometric Modelling of Solids: Fundamentals of solid modelling, B-rep of Solid Modelling, CSG Approach of Solid Modelling, CAD/CAM Data Exchange Formats.

Computer Aided Manufacturing (CAM): Introduction to Computer Numerical Control (CNC), Designation of Axes, Drives and Actuation Systems, Feedback Devices, CNC Tooling and Work Holding Devices, CNC Control Systems, Adaptive Control, DNC.

CNC Programming: Part Programming Fundamentals, Developing Manual Part Programming, APT Programming, Geometric and Motion Commands, Post Processor Commands, Practice using Software Tools.

Group Technology and Computer Aided Process Planning (CAPP): Group Technology (GT), Part Classification and Coding Systems, CAPP Methods, Advantages of CAPP.

Automated Material Handling and Storage: Material Handling Equipment, Automated Guided Vehicle Systems (AGVS), Robots, Automated Storage and Retrieval Systems (AS/RS), Automated Identification System.

Flexible Manufacturing System (FMS): Components of FMS, FMS Equipment and Control, FMS Case Studies.

Computer Aided Inspection and Quality Control: Inspection and Testing Coordinate Measuring Machine, Non-Contact Inspection, and Machine Vision.

Computer Integrated Manufacturing (CIM): Elements of CIM, CIM Case Studies

CAD/CAM Applications: Finite Element Analysis, Reverse Engineering, Virtual Prototyping, Rapid Prototyping, Additive Manufacturing, Integration of CAD/CAM Tools with Industry 4.0 Technologies. Practice using Software Tools.

List of Laboratory Experiments:

1. Develop MATLAB Codes for various synthetic curves.
2. Working with CAD Data Exchange formats.
3. Simulation of turn components on CNC Simulator.
4. Turning of components on spinner.com Lathe.
5. Turning of components on VDF lathe.
6. Milling simulation of 2D profiles on CNC Simulator.
7. Milling Simulation of Turbine blade on CNC Simulator.
8. Milling of 2D profiles on Max Mill CNC milling Machine.
9. Milling of 2D/3D profiles using MasterCam.
10. Milling of 2D/3D profiles using EdgeCam.
11. Generate and visualize CNC code using Virtual CNC Software.
12. Design and fabrication of components using 3D printer.

Learning Resources:

Text Books:

1. Ibrahim Zeid and Sivasubramanian, R., CAD/CAM Theory and Practice, TataMcGraw Hill Publications, New Delhi, 2009.
2. P.N. Rao, CAD/CAM: Principles and Applications, Tata McGraw Hill, 2002.
3. Vikram Sharma, Vikrant Sharma and Om Ji Shukla, Principles and Practices of CAD/CAM,CRC Press, 2024.

Reference Books:

1. David F. Rogers, J. A. Adams, Mathematical Elements for Computer Graphics, Tata McGrawHill, 2008.
2. Mikell P. Groover, Automation, Production Systems, and Computer-Integrated Manufacturing, Prentice-Hall, 2003.
3. Chang, T.C, Wysk, R.A. and Wang, H.P, Computer Aided Manufacturing, Prentice Hall, 2006.
4. Michael E. Mortenson, Geometric Modelling, McGrawHill, 2013.
5. Anupam Saxena and Birendra Sahay, Computer Aided Engineering Design, Springer, 2005.

ME 1403 **0-1-2 (2)**

CFD Laboratory

Pre-Requisites: **None**

Course Outcomes:

CO-1	Formulate problems in fluid flow and heat transfer
CO-2	Analyze the influence of non-dimensional parameters in solving the governing equations.
CO-3	Solve real life thermal engineering problems using software packages.
CO-4	Model and analyze thermal engineering equipment using CFD

Course Articulation Matrix:

	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6	PO-7	PO-8	PO-9	PO-10	PO-11	PO-12	PSO-1	PSO-2
CO-1	3	3	2	3	2								2	2
CO-2	3	3	2	3	2								2	3
CO-3	2	3	3	3	3					2			3	3
CO-4	2	3	3	3	3					2			3	3

1 - Slightly; **2 - Moderately;** **3 - Substantially**

Syllabus:

List of Experiments:

1. Heat conduction through a slab
2. Lumped heat capacity model
3. Laminar pipe Flow
4. Lid driven Cavity
5. Natural convection in a cavity (steady state)
6. Natural convection in a cavity (Unsteady)
7. Turbulent Pipe Flow
8. Flow over cylinder
9. Heat transfer in porous media
10. Conjugate heat transfer problem

Learning Resources:

Text Books:

1. J.D Anderson (Jr), Computational Fluid Dynamics, McGraw-Hill Book Company, 2017.
2. K.A. Hoffman, and S.T. Chiang, Computational Fluid Dynamics, Vol. I, II and III, Engineering Education System, Kansas, USA, 2000.

Reference Books:

1. T.J. Chung, Computational Fluid Dynamics, 2nd Edition, Cambridge University Press, 2014.
2. D.A. Anderson, J.C. Tannehill and R.H. Pletcher, Computational Fluid Mechanics and Heat Transfer,3rd Edition, CRC Press, 2013.
3. H.K. Versteeg, and W. Malalasekara, An Introduction to Computational Fluid Dynamics, Pearson Education, 2010.

ME 1489 **0-0-0 (2)**

SEMINAR AND TECHNICAL WRITING

Pre-Requisites: **None**

Course Outcomes:

CO-1	Consolidate ideas based on expert talks attended
CO-2	Prepare a well-organized report employing elements of critical thinking and technical writing
CO-3	Demonstrate the ability to describe, interpret and analyze the subject matter and develop competence in presenting

Course Articulation Matrix:

	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6	PO-7	PO-8	PO-9	PO-10	PO-11	PO-12	PSO-1	PSO-2
CO-1	2		2			3	3		2	3		3		
CO-2	2		2			3	3		2	3		3		
CO-3	2		2			3	3		2	3		3		

1 - Slightly; **2 - Moderately;** **3 - Substantially**

Description:

In Seminar and Technical Writing, every student is expected to prepare a well-organized report based on one / all of the following:

- by attending at least 5 expert lectures/ invited talks/ Seminar/ Popular lectures etc. organized by the institute/any of the departments, ideally in a specific domain or with the same theme.
- prepare a business or marketing plan based on patent search

The student is expected to consolidate the ideas from these lectures/patent searches and may even include material from other sources to strengthen the content of the report. The student should prepare a well-organized report based on the above and present it to the panel constituted by the department, for evaluation.

Evaluation Criteria:

The student will be evaluated by the panel based on the below criteria.

Criteria	Description	Weightages
I	Clarity on the topic	10
II	List of lectures attended	30
III	Report	30
IV	Presentation	20
V	Response to questions	10

Evaluation Criteria-CO Mapping

CO / Criteria	CO1	CO2	CO3
I	X		
II	X		
III		X	
IV			X
V			X

ME 1495 **0-0-0 (2)**

Minor Project

Pre-Requisites: **None**

Course Outcomes:

CO-1	Apply engineering principles to real-world projects
CO-2	Plan and monitor project tasks individually or as a team
CO-3	Demonstrate practical experience in project execution
CO-4	Communicate project findings clearly through reports and presentations

Course Articulation Matrix:

	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6	PO-7	PO-8	PO-9	PO-10	PO-11	PO-12	PSO-1	PSO-2
CO-1	3	3	3	3	3				2	1		3		
CO-2	2	2	2	2	2				3	2	3	3		
CO-3	2	2	2	2	2				3	2	3	3		
CO-4	1	1	1	1	1				3	3				

1 - Slightly; **2 - Moderately;** **3 - Substantially**

Description:

Students are expected to choose real world or relevant problems and apply the engineering principles learned, to solve the problem through building prototypes or simulations or writing codes or establishing processes/synthesis/correlations etc. The department constituted panel can decide the suitability and worthiness of the project

Evaluation Criteria:

The student will be evaluated by the panel based on the below criteria. Weightage for each criterion will be determined by the panel and will be informed to the students.

Criteria	Description	Weightages
I	Identification of Problem Domain	10
II	Study of Existing Systems and establishing clear objectives	30
III	Planning of project and work distribution within the team	40
IV	Proper Documentation and Technical Writing	10
V	Presentation and Response to questions	10

Evaluation Criteria-CO Mapping

CO / Criteria	CO-1	CO-2	CO-3	CO-4
I	X			
II	X			
III		X	X	
IV				X
V				X

ME 1491 0-0-0 (2)

SHORT TERM INDUSTRIAL / EPICS / RESEARCH EXPERIENCE

Pre-Requisites: **None**

Course Outcomes:

CO-1	Apply engineering principles to real-world problems, gaining practical experience
CO-2	Plan, manage and execute the work with ethical consideration
CO-3	Review the social and environmental impact of the work
CO-4	Communicate the learnings through report and presentation

Course Articulation Matrix:

	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6	PO-7	PO-8	PO-9	PO-10	PO-11	PO-12	PSO-1	PSO-2
CO-1	3	3	3	3	3							3		
CO-2	2	2	2	2	2			3	3		3	3		
CO-3						3	3					3		
CO-4										3		3		

1 - Slightly; 2 - Moderately; 3 - Substantially

Description:

Every student has to undergo either a Summer Internship / EPICS / Research project. The summer internship may be undergone in an Industry/Research organization or any premier academic Institution, including NIT Warangal for 6-8 weeks. The EPICS/research project shall be registered under the guidance of any faculty member in the institute. The student is required to submit a report and present the work before an evaluation committee, nominated by the Head of the Department.

Evaluation Criteria:

The student will be evaluated by the panel based on the below criteria. Weightage for each criterion will be determined by the panel and will be informed to the students.

Criteria	Description	Weightages
I	Relevance of the area of work	10
II	Performance of the Task	30
III	Crucial learnings from the work	30
IV	Report Preparation	20
V	Presentation and Response to questions	10

Evaluation Criteria-CO Mapping

CO / Criteria	CO-1	CO-2	CO-3	CO-4
I	X			
II		X		
III			X	
IV				X
V				X

8th Semester

ME 1498 **0-0-0 (6)**

MAJOR PROJECT

Pre-Requisites: **None**

Course Outcomes:

CO-1	Identify a domain specific and contemporary topic
CO-2	Review literature to identify gaps and define objectives & scope of the work.
CO-3	Develop a prototype/model, experimental set-up or software systems to meet the objectives
CO-4	Analyze the results to draw valid conclusions

Course Articulation Matrix:

	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6	PO-7	PO-8	PO-9	PO-10	PO-11	PO-12	PSO-1	PSO-2
CO-1	3	2			2	1		1	3	1	1	2		
CO-2	2	2			1	2	1	1	2	2		3		
CO-3	2	2	3	3	3	2	2	2	2	1	3	2		
CO-4	2	2		3	3				2	2		3		

1 - Slightly; **2 - Moderately;** **3 - Substantially**

Description:

Students are expected to choose real-world contemporary problem and apply the engineering principles learned, to solve the problem through building prototypes or simulations or writing codes or establishing processes/synthesis/correlations etc. The department constituted panel will decide the suitability and worthiness of the project

The method of evaluation should be as per the guidelines stipulated for the B.Tech. Project evaluation. The template for preparation of the project report may be downloaded from (https://www.nitw.ac.in/path/?dept=/nitwForms) under UG Forms. The students are required to submit a report showing that plagiarism is within 30%. The B.Tech. Project work will be evaluated for 100 marks, with the following weightages:

Component	**Weightage**
Periodic evaluation by Guide	40 marks
Mid-term review	20 marks
End Semester viva-voce examination	40 marks
Total	100 marks

The midterm review and the end semester viva-voce examination will be conducted by a committee constituted by the Head of the Department. If the performance of a student is not satisfactory, he/ she can be awarded 'F' grade. Such a student will be given a maximum time of three months to improve his/her performance. If the performance of such a student is not satisfactory even after the extended time period, he/ she will have to repeat the project work in the next academic year.

Evaluation Criteria:

The student will be evaluated by the panel based on the below criteria. Weightage for each criterion will be determined by the panel and will be informed to the students.

Criteria	Description	Weightages
I	Selection of Topic	10
II	Literature Survey	10
III	Objectives and Solution Methodology	20
IV	Performance of the Task and clarity on the work	40
V	Report Preparation	10
VI	Presentation and Response to questions	10

Evaluation Criteria-CO Mapping

CO / Criteria	CO1	CO2	CO3	CO4
I	X			
II		X		
III		X		
IV			X	
V				X
VI				X

Professional Elective - I

ME 1321 **3-0-0 (3)**

Computational Fluid Dynamics

Pre-Requisites: **None**

Course Outcomes:

CO-1	Explain the differential equations for flow phenomena and numerical methods for their solution.
CO-2	Analyze different mathematical models and computational methods for fluid flow and heat transfer simulations.
CO-3	Solve computational problems related to fluid flows and heat transfer.
CO-4	Analyze the accuracy of a numerical solution by comparison to known solutions of simple test problems and by mesh refinement studies.
CO-5	Determine forces in both internal and external flows.

Course Articulation Matrix:

	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6	PO-7	PO-8	PO-9	PO-10	PO-11	PO-12	PSO-1	PSO-2
CO-1	3	3	2	–	–	–	–	–	–	–	–	–	3	2
CO-2	3	3	2	–	–	–	–	–	–	–	–	–	3	2
CO-3	3	3	2	–	–	–	–	–	–	–	–	–	3	2
CO-4	2	2	3	–	–	–	–	–	–	–	–	–	2	2
CO-5	2	2	3	–	–	–	–	–	–	–	–	–	2	2

1 - Slightly; **2 - Moderately;** **3 - Substantially**

Syllabus:

Introduction: History and Philosophy of computational fluid dynamics, CFD as a design and research tool, Applications of CFD in engineering, Programming fundamentals, MATLAB programming, Numerical Methods

Governing equations of fluid dynamics: Models of the flow, The substantial derivative, Physical meaning of the divergence of velocity, The continuity equation, The momentum equation, The energy equation, Navier-Stokes equations for viscous flow, Euler equations for inviscid flow, Physical boundary conditions, Forms of the governing equations suited for CFD, Conservation form of the equations, shock fitting and shock capturing, Time marching and space marching.

Mathematical behavior of partial differential equations: Classification of quasi-linear partial differential equations, Methods of determining the classification, General behavior of Hyperbolic, Parabolic and Elliptic equations.

Basic aspects of discretization: Introduction to finite differences, Finite difference equations using Taylor series expansion and polynomials, Explicit and implicit approaches, Uniform and unequally spaced grid points.

Grids with appropriate transformation: General transformation of the equations, Metrics and Jacobians, The transformed governing equations of the CFD, Boundary fitted coordinate systems, Algebraic and elliptic grid generation techniques, Adaptive grids.

Parabolic partial differential equations: Finite difference formulations, Explicit methods - FTCS, Richardson and DuFort-Frankel methods, Implicit methods - Lasonen, Crank-Nicolson and Beta formulation methods, Approximate factorization, Fractional step methods, Consistency analysis, Linearization.

Stability analysis: Discrete Perturbation Stability analysis, von Neumann Stability analysis, Error analysis, Modified equations, Artificial dissipation and dispersion.

Elliptic equations: Finite difference formulation, solution algorithms: Jacobi-iteration method, Gauss-Siedel iteration method, point- and line-successive over-relaxation methods, alternative direction implicit methods.

Hyperbolic equations: Explicit and implicit finite difference formulations, splitting methods, multi-step methods, applications to linear and nonlinear problems, linear damping, flux corrected transport, monotone and total variation diminishing schemes, TVD formulations, entropy condition, first-order and second-order TVD schemes.

Scalar representation of Navier-Stokes equations: Equations of fluid motion, numerical algorithms: FTCS explicit, FTBCS explicit, Dufort-Frankel explicit, McCormack explicit and implicit, BTCS and BTBCS implicit algorithms, applications.

Grid generation: Algebraic Grid Generation, Elliptic Grid Generation, Hyperbolic Grid Generation, Parabolic Grid Generation.

Finite volume method for unstructured grids: Advantages, Cell Centred and Nodal point Approaches, Solution of Generic Equation with tetrahedral Elements, 2-D Heat conduction with Triangular Elements.

Learning Resources:

Text Books:

1. Anderson, J.D. (Jr), Computational Fluid Dynamics, McGraw-Hill Book Company, 1995.
2. Hoffman, K.A., and Chiang, S.T., Computational Fluid Dynamics, Vol. I, II and III, Engineering Education System, Kansas, USA, 2000.

Reference Books:

1. Chung, T.J., Computational Fluid Dynamics, Cambridge University Press, 2003.
2. Anderson, D.A., Tannehill, J.C., and Pletcher, R.H., Computational Fluid Mechanics and Heat Transfer, McGraw Hill Book Company, 2002

ME 1323 **3-0-0 (3)**

Automobile Engineering

Pre-Requisites: **None**

Course Outcomes:

CO-1	Understand the basic layout of an automobile.
CO-2	Understand the operation of engine cooling, lubrication, ignition, electrical and air conditioning systems.
CO-3	Analyze the vehicle transmission, suspension, steering and braking systems.
CO-4	Understand automotive electronics.
CO-5	Explore latest developments in automobiles.

Course Articulation Matrix:

	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6	PO-7	PO-8	PO-9	PO-10	PO-11	PO-12	PSO-1	PSO-2
CO-1	2	–	2	3	3	2	–	–	–	–	–	–	2	2
CO-2	3	3	2	3	3	3	–	–	–	–	–	–	2	2
CO-3	3	2	3	2	3	3	–	–	–	–	–	–	1	2
CO-4	2	3	3	3	3	2	–	–	–	–	–	–	1	2
CO-5	2	3	3	3	3	2	–	–	–	–	–	–	2	2

1 - Slightly; **2 - Moderately;** **3 - Substantially**

Syllabus:

Introduction: Overview of the course, Examination and Evaluation patterns, History of Automobiles, Classification of Automobiles.

Power Plant: Classification, Engine Terminology, Types of Cycles, working principle of an IC engine, advanced classification of Engines- Multi cylinder engines, Engine balance, firing order.

Fuel System and Ignition System and Electrical system: spark Ignition engines- Fuel tank, fuel filter, fuel pump, air cleaner/filter, carburettor, direct injection of petrol engines. Compression Ignition engines, Fuel Injection System- air & solid injection system, Pressure charging of engines, super charging and turbo charging, Components of Ignition systems, battery ignition system, magneto ignition system, electronic ignition and ignition timing. Main electrical circuits, generating & stating circuit, lighting system, indicating devices, warning lights, speedometer.

Lubricating system and cooling systems: Functions & properties of lubricants, methods of lubrication-splash type, pressure type, dry sump, and wet sump & mist lubrication. Oil filters, oil pumps, oil coolers. Characteristics of an effective cooling system, types of cooling system, radiator, thermostat, air cooling & water cooling.

Chassis: Systems in an automobile, body, chassis frame, parts of the automobile body, terminology, automobile frames, functions, constructions, sub frames, materials and defects in frames.

Transmission, axles, clutches, propeller shafts and differential: Types of gear boxes, automatic transmission, electronic transmission control, functions and types of front and rear axles, types and

functions of the clutches, design considerations of Hotchkiss drive torque tube drive, function and parts of differential and traction control.

Steering System: functions of steering mechanism, steering gear box types, wheel geometry.

Braking and suspension system: functions and types of brakes, operation and principle of brakes, constructional and operational classification and parking brake. Types of springs shock observers, objectives and types of suspension system, rear axles suspension, electronic control and proactive suspension system.

Automotive air conditioning: ventilation, heating, air condition, refrigerant, compressor and evaporator.

Wheels and tyres: Wheel quality, assembly, types of wheels, wheel rims. Construction of tyres and tyre specifications.

Learning Resources:

Text Books:

1. K.M. Gupta.l, Automobile Engineering, Vol.I & II, Umesh Pub, 2010.
2. W.H. Crouse and D.L. Anglin, Automotive Mechanics, Tata McGraw Hill, New Delhi,2005.
3. J. Heitner, Automotive Mechanics, Affiliated South West Press, New Delhi, 2000.
4. Anderson, J. D., Fundamentals of Aerodynamics,McGraw-Hill Education, 2016, 6th edition

Reference Books:

1. G.B. Narang, Automobile Engineering, Khanna Publishers, New Delhi, 2001.
2. Kamaraju Ramakrishna, Automobile Engineering,PHI Learning pvt. Ltd., New delhi-2012.
3. D. Crolla, D. E. Foster, T. Kobayashi and N. Vaughan (Editors-in-Chief), Encyclopedia of Automotive Engineering, Parts 1-6, Wiley, 2015.
4. R. Stone and J. K. Ball, Automotive Engineering Fundamentals,SAE International, 2004.

Other Suggested Readings:

1. Fundamentals of Automotive Systems - Course (nptel.ac.in)

ME 1325 **3-0-0 (3)**

Advanced Welding Technology

Pre-Requisites: **None**

Course Outcomes:

CO-1	Understand the weldability of metals
CO-2	Apply laser beam welding for joining ferrous, non-ferrous and dissimilar material
CO-3	Understand the mechanism of solid state joining processes
CO-4	Classify different hybrid welding process
CO-5	Understand the allied welding process for joining of metals and plastics

Course Articulation Matrix:

	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6	PO-7	PO-8	PO-9	PO-10	PO-11	PO-12	PSO-1	PSO-2
CO-1	3	3	3	2	2	2							2	3
CO-2	3	3	3	2	2	2							2	2
CO-3	3	3	3	2	2	2							3	2
CO-4	3	3	3	2	2	2							3	2
CO-5	3	2	2	2	2	2							2	3

1 - Slightly; **2 - Moderately;** **3 - Substantially**

Syllabus:

Weldability of Metals: Weldability of Plain Carbon Steels, stainless steel problems in welding of stainless steel and their remedy, and aluminium alloys solidification cracking, hydrogen induced porosity, partial melting zone and liquation cracking, HAZ softening, precautions in the welding of age hardenable alloy. Challenges associated with welding of dissimilar alloy system

Heat Flow in Welding: Calculation of peak temperature; width of Heat Affected Zone; cooling rate and solidification rates; weld thermal cycles

Laser Beam welding (LBW): Welding Efficiency; Mechanism of Laser Welding: Conduction Mode Welding, Keyhole Welding; Laser Welding Parameters: Joint Configuration; Material Considerations; ferrous, Nonferrous alloys, Ceramics, Polymers, Dissimilar Materials; Weldment Discontinuities: Porosity, Humping, Spiking; Advantages and Disadvantages of Laser Welding; Special Techniques; Heat Treatment; Specific Applications.

Friction stir welding and processing: Classification of solid-state welding processes, Review of Friction stir welding, Selection of tool design, Fixture design, modification of tool and features, stir welding, submerged friction stir welding. Friction stir processing, Process variables, Surface modification by friction stir processing, Production of composite by friction stir processing.

Ultrasonic welding: Ultrasonic welding system and process variation, mechanism and working, process parameters, weldability of metal, dissimilar alloys, plastics and metal-plastics. advantages and limitations applications.

Magnetic Pulse Welding: Introduction, process parameters, interface structure and joint Department of Mechanical Engineering formation mechanism, dissimilar material welding using magnetic pulse welding

Hybrid welding processes: GTAW and laser welding, GMAW and Laser welding, Underwater welding, Vibration assisted welding, process, advantages and Limitations, A-TIG welding, Cold Metal Transfer welding process, advantages, limitations and applications.

Allied Welding Process: Soldering, Brazing Adhesive bonding, vacuum brazing, diffusion bonding, Induction welding of plastics, process description, application, advantages and limitations.

Learning Resources:

Text Books:

1. R. S. Parmar, Welding Engineering and Technology, Khanna Publishers, 2014
2. S.V. Nadkarni, Modern Welding Technology, Oxford IBH Publishers, 2015.
3. W. Messler Robert Jr., Joining of Materials and Structures, Elsevier Butterworth–Heinemann, 2004

Reference Books:

1. L. Li, ASM Handbook: Welding Fundamentals and Processes, Volume 6A.
2. A. O'Brien, Welding handbook, volume 4-material and application. American welding society, 2011
3. Mather's Gene, The welding of aluminium and its alloys, Woodhead publishing, 2002.

ME 1327 **3-0-0 (3)**

MECHATRONICS

Pre-Requisites: **None**

Course Outcomes:

CO-1	Model and analyze mechatronic systems for an engineering application
CO-2	Identify sensors, transducers and actuators for monitoring and controlling the behavior of processes and products.
CO-3	Develop PLC programs for an engineering application.
CO-4	Evaluate the performance of mechatronic systems.

Course Articulation Matrix:

	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6	PO-7	PO-8	PO-9	PO-10	PO-11	PO-12	PSO-1	PSO-2
CO-1	3	3	3	2	2				2			2	3	3
CO-2	3	2	2	3	2				2		2		3	2
CO-3	3	3	2	2	3		2	2	2				3	3
CO-4	3	2	2	2	3		2	2	2			2	3	2

1 - Slightly; **2 - Moderately;** **3 - Substantially**

Syllabus:

Introduction: Overview of the course, Examination and Evaluation patterns, History of Mechatronics, Scope and Significance of Mechatronics systems, elements of mechatronic systems, needs and benefits of mechatronics in manufacturing

Sensors & Actuators: Proximity Sensor, force sensors, sensors used in mechatronics systems. Electrical Actuators: Solenoids, relays, DC motor, Servo motor, BLDC Motor, AC Motor, stepper motors. Hydraulic & Pneumatic devices – Power supplies, different control valves, cylinder sequencing. Design of Hydraulic & Pneumatic circuits. Piezoelectric actuators, Shape memory alloys actuators.

Basic System Models & Analysis: Modelling of one and two degrees of freedom Mechanical, Electrical, Fluid and thermal systems, Block diagram representations for these systems.

Dynamic Responses of System: Transfer function, Modelling Dynamic systems, first order systems, second order systems, Time Domain Analysis, Stability analysis using Routh- Hurwitz criteria .

Digital Electronics: Number systems, BCD codes and arithmetic, Gray codes, self- complimenting codes, Error detection and correction principles. Boolean functions using Karnaugh map, Design of combinational circuits, Design of arithmetic circuits. Design of Code converters, Encoders and decoders.

Signal Conditioning: Operational amplifiers, inverting amplifier, differential amplifier, Protection, comparator, filters, Multiplexer, Pulse width Modulation Counters, decoders. Data acquisition – Quantizing theory, Analog to digital conversion, digital to analog conversion.

Controllers: Classification of control systems, Feedback, closed loop and open loop systems,

Continuous and discrete processes, control modes, Two step Proportional, Derivative, Integral, PID controllers.

PLC Programming: PLC Principles of operation PLC sizes PLC hardware components I/O section Analog I/O section Analog I/O modules, digital I/O modules CPU Processor memory module Programming. Ladder Programming, ladder diagrams, timers, internal relays and counters, data handling, analogue input and output. Application on real time industrial automation systems.

Case studies of Mechatronics systems: Pick and place robot, Bar code, Engine Management system, Washing machine etc.

Industry 4.0 Concepts & Principles: Introduction, AI, Cyber physical System, Cloud computing, machine learning

Learning Resources:

Text Books:

1. W. Bolton, Mechatronics, Addison Wesley Longman Ltd, 2010, 5thEdition
2. Devdas Shetty & Richard Kolk, Mechatronics System Design, PWS Publishing, 2009, 3rd Edition

Reference Books:

1. Alciatore David G and Histand Michael B, Introduction to Mechatronics and Measurement systems, Tata McGraw Hill, 2012, 4th Edition.
2. Clarence W. de Silva, Mechatronics : A foundation course, CRC Press, 2010.

ME 1329 **3-0-0 (3)**

MECHANICAL VIBRATIONS

Pre-Requisites: **None**

Course Outcomes:

CO-1	Develop schematic models for physical systems and formulate governing equations of motion.
CO-2	Analyze the vibration characteristics including critical speed of rotating and reciprocating systems
CO-3	Design machine supporting structures, vibration isolators and absorbers.
CO-4	Calculate free and forced vibration responses of multi degree freedom systems using modal analysis.

Course Articulation Matrix:

	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6	PO-7	PO-8	PO-9	PO-10	PO-11	PO-12	PSO-1	PSO-2
CO-1	3	3	3	1	1							2	2	2
CO-2	3	3	2	2	2							2	2	2
CO-3	3	3	2	3	2							3	2	2
CO-4	3	3	2	2	3							3	2	2

1 - Slightly; **2 - Moderately;** **3 - Substantially**

Syllabus:

Introduction: Causes and effects of vibration, Classification of vibrating system, Discrete and continuous systems, degrees of freedom, Identification of variables and Parameters, Linear and nonlinear systems, linearization of nonlinear systems, Physical models, Schematic models and Mathematical models.

SDF systems: Formulation of equation of motion: Newton -Euler method, De Alembert's method, Energy method, Undamped Free vibration response and Damped Free vibration response, Case studies on formulation and response calculation.

Forced vibration response: Response to harmonic excitations, solution of differential equation of motion, Vector approach, Complex frequency response, Magnification factor Resonance, Rotating/reciprocating unbalances, Force Transmissibility, Motion Transmissibility, Vehicular suspension, Vibration measuring instruments, Case studies on forced vibration.

Two degree of freedom systems: Introduction, Formulation of equation of motion: Equilibrium method, Lagrangian method, Case studies on formulation of equations of motion. Free vibration response, Eigen values and Eigen vectors, Normal modes and mode superposition, Coordinate coupling, decoupling of equations of motion, Natural coordinates, Response to initial conditions, free vibration response case studies, Forced vibration response, undamped vibration absorbers, Case studies on undamped vibration absorbers.

Multi degree of freedom systems: Introduction , Formulation of equations of motion, Free vibration response, Natural modes and mode shapes, Orthogonally of model vectors, normalization of model vectors, Decoupling of modes, model analysis, mode superposition technique, Free vibration response

through model analysis, Forced vibration analysis through model analysis, Model damping, Rayleigh's damping, Introduction to experimental model analysis.

Continuous systems: Introduction to continuous systems, Exact and approximate solutions, free vibrations of strings, bars and beams.

Learning Resources:

Text Books:

1. L. Meirovich, Elements of Vibration analysis, Tata Mc-Grawhill, 2007, 2nd Ed.
2. Singiresu S Rao, Mechanical Vibrations, Pearson education, 2011, 4th Ed.

Reference Books:

1. W.T., Thompson, Theory of Vibration, CBS Publishers.
2. Clarence W. de Silva , Vibration: Fundamentals and Practice, CRC Press LLC, 2000.

ME 1331 **3-0-0 (3)**

GEOMETRIC MODELLING FOR CAD

Pre-Requisites: **None**

Course Outcomes:

CO-1	Apply geometric transformations and projection methods in CAD.
CO-2	Develop geometric models to represent curves.
CO-3	Design surface and solid models for engineering design.
CO-4	Apply mesh generation method for engineering analysis.

Course Articulation Matrix:

	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6	PO-7	PO-8	PO-9	PO-10	PO-11	PO-12	PSO-1	PSO-2
CO-1	3	2	2	2	2		2					2	2	3
CO-2	3	2	2	2	2		2					2	2	3
CO-3	3	2	3	2	2		2					2	2	3
CO-4	3	2	2	2	2		2					2	2	3

1 - Slightly; **2 - Moderately;** **3 - Substantially**

Syllabus:

Introduction: Introduction to CAE, CAD. Role of CAD in Mechanical Engineering, Design process, Requirements of Modelling, Geometric modelling, Software tools for CAD, Input and Output Devices for CAD System.

Transformations in Geometric Modeling: Introduction, Translation, Scaling, Reflection, Rotation in 2D and 3D. Homogeneous representation of transformation, Concatenation of transformations. Computer-Aided assembly of rigid bodies, applications of transformations in design and analysis of mechanisms, etc. Implementation of the transformations using computer codes.

Projections: Projective geometry, transformation matrices for Perspective, Axonometric projections, Orthographic and Oblique projections. Implementation of the projection formulations using computer codes.

Curves in Geometric Modeling for Design: Differential geometry of curves**,** Analytic Curves, PC curve, Ferguson's Cubic Curve, Composite Ferguson, Curve Trimming and Blending. Bezier segments, de Castegliau's algorithm, Bernstein polynomials, Bezier- subdivision, Degree elevation, Composite Bezier. B-spline basis functions, Properties of basic functions, Knot Vector generation, NURBS. Conversion of one form of curve to other. Implementation of the all the curve models using computer codes in an interactive manner.

Surfaces in Geometric Modeling for Design: Differential geometry of surfaces, parametric representation, Curvatures, Developable surfaces. Surface's entities (planar, surface of revolution, lofted etc). Free-form surface models (Hermite, Bezier, B-spline surface). Boundary interpolating surfaces (Coon's). Implementation of the all the surface models using computer codes.

Solids in Geometric Modeling for Design: Solid entities, Boolean operations, Topological aspects,

Invariants. Write-frame modeling, B-rep of Solid Modelling, CSG approach of solid modelling. Popular modeling methods in CAD software. Data Exchange Formats and CAD Applications**.**

Introduction to Engineering Analysis: Finite Element Analysis, Criteria of Mesh Quality, Mesh Generation Methods (Mapped Mesh Generation, Triangulation etc.).

Learning Resources:

Text Books:

1. Michael E. Mortenson, Geometric Modeling, Tata McGraw Hill, 2013.
2. A. Saxena and B. Sahay, Computer-Aided Engineering Design, Anamaya Publishers, New Delhi, 2005.
3. Rogers, David F., An introduction to NURBS: with historical perspective, Morgan Kaufmann Publishers, USA, 2001.
4. David F. Rogers, J. A. Adams, Mathematical Elements for Computer Graphics, TMH, 2008.

Reference Books:

1. Kunwoo Lee, Principles of CAD/CAM/CAE, Pearson, 1999.

Professional Electives - II and III

ME 1322 **3-0-0 (3)**

Mechanical Measurements

Pre-Requisites: **None**

Course Outcomes:

CO-1	Understand the measurement terminologies and the concept of a generalized measurement system.
CO-2	Estimate errors and uncertainty in measurements using statistical analysis.
CO-3	Analyze the zeroth, first and second order measurement systems.
CO-4	Select sensors for measurement of specific parameters with required accuracy.
CO-5	Calibrate measuring instruments with given standards.
CO-6	Design experiments by combining measuring devices to obtain desired outputs.

Course Articulation Matrix:

	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6	PO-7	PO-8	PO-9	PO-10	PO-11	PO-12	PSO-1	PSO-2
CO-1	2	3	3	3	–	2	–	–	–	–	–	–	2	2
CO-2	2	3	3	2	–	2	–	–	3	3	–	2	2	2
CO-3	2	3	3	3	–	2	–	–	–	3	–	–	2	2
CO-4	3	3	3	2	–	3	–	–	3	3	–	2	2	2
CO-5	3	2	3	2	–	3	–	–	3	3	–	2	3	3

1 - Slightly; **2 - Moderately;** **3 - Substantially**

Syllabus:

Basics of Measurements: Introduction, Generalized measurement system, Signal flow diagram of measurement system, Inputs and their methods of correction, Dynamic response – zeroth, first and second order measuring systems.

Presentation of experimental data: Errors in measurement, Propagation of errors, Uncertainty analysis, Regression analysis.

Pressure measurement: Different pressure measurement instruments and their comparison, Transient response of pressure transducers

Thermometry: Overview of thermometry, Thermo-electric temperature measurement, Resistance thermometry, Pyrometer, Other methods, issues in measurements.

Flow Measurement: Flow obstruction methods, Magnetic flow meters, Interferometer, LDA, Other methods.

Thermal and transport property measurement: Measurement of thermal conductivity, diffusivity, viscosity, humidity and gas composition.

Nuclear, thermal radiation measurement: Measurement of reflectivity, transmissivity, emissivity, nuclear radiation, neutron detection, etc.

Other measurements: Basics in measurement of torque, force, strain

Advanced topics: Issues in measuring thermos-physical properties of micro and Nano fluidics

Design of Experiments: Basic ideas of designing experiments, Experimental design protocols with some examples.

Learning Resources:

Text Books:

1. Thomas G Beckwith, Mechanical Measurements, Pearson publications, 2006, 6th Edition
2. Ernest O Doebelin, Measurement systems, Tata McGraw Hill publications, 2019, 7th Edition
3. J P Holman, Experimental Methods for Engineers, Tata McGraw Hill publications, 2011, 7th Edition

Reference Books:

1. John R. Taylor, An Introduction to Error Analysis,University Science Books, 1997, 2nd Edition
2. S P Venkateshan, Mechanical Measurements, Ane Books Pvt. Ltd., 2015, 2nd Edition.

Other Suggested Readings:

1. Mechanical Measurements and Metrology by Prof. S P Venkateshan (IIT Madras), NPTEL Course (Link: https://nptel.ac.in/courses/112/106/112106138/).
2. Principles of Mechanical Measurement by Prof. Dipankar N Basu (IIT Guwahati), NPTEL Course (Link: https://nptel.ac.in/courses/112/103/112103261/).

ME 1324 **3-0-0 (3)**

Alternate Fuels

Pre-Requisites: **None**

Course Outcomes:

CO-1	Categorize, interpret and understand the essential properties of fuels for IC engines
CO-2	Identify the need for alternate fuels and characterize prospective alternate fuels
CO-3	Evaluate the storage and dispensing facility requirements
CO-4	Analyze the implement limitations with regard to performance, emission and materials compatibility
CO-5	Develop strategies for control of emissions as per the legislation standards

Course Articulation Matrix:

	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6	PO-7	PO-8	PO-9	PO-10	PO-11	PO-12	PSO-1	PSO-2
CO-1	3	2	2	–	–	1	–	–	–	–	–	1	2	3
CO-2	–	–	3	–	–	2	2	–	–	–	–	1	3	2
CO-3	2	1		–	–	–	–	–	–	–	–	1	3	3
CO-4	3	3	2	2	–	2	2	–	–	–	–	1	2	2
CO-5	3	2	2	–	–	1	–	–	–	–	–	1	2	3

1 - Slightly; **2 - Moderately;** **3 - Substantially**

Syllabus:

Reactive Systems: Introduction, Need for alternate fuels, Desirable characteristics of good alternate fuel, Properties of air, Combustion with air, Equivalence ratio, Enthalpy of formation, Adiabatic combustion temperature, Dissociation

Introduction: Estimation of petroleum reserve – Need for alternate fuels – Availability and properties of alternate fuels, ASTM standards

Alcohols: General Use of Alcohols – Properties as Engine fuel – Gasoline and alcohol blends – Performance in SI Engine – Methanol and Gasoline blend – Combustion Characteristics in engine – emission characteristics

Vegetable oils: Soya been Oil, Jatropha, Pongamia, Rice bran, Mahua etc as alternate fuel and their properties, Esterification of oils

Natural Gas, LPG: Availability of CNG, properties, modification required to use in engines – performance and emission characteristics of CNG using LPG in SI & CI engines.

Hydrogen: hydrogen production, Hydrogen as an alternative fuel, fuel cells

Automobile emissions & its control: Evaluating vehicle emissions – EURO standards – Indian standards

Learning Resources:

Text Books:

1. L. Richard, P.E. Bechhold, Alternate Fuels Guide Book, Society of Automotive Engineers, 1997
2. Norbeck, M. Joseph, Hydrogen fuel for surface transportation, Society of Automotive Engineers, 1996
3. S.C. Bhatia, Air Pollution and its Control, Atlantic Publications, 2007

Reference Books:

1. Anil Agarwal, Sunita Narain, Global Warming in an unequal world, Centre for Science and Environment, New Delhi, 2003
2. Sunggyu Lee, James G. Speight, Sudarshan K. Loyalka, Handbook of Alternate Fuels Technology, CRC Press, 2007

ME 1326 **3-0-0 (3)**

Advanced Metal Casting and NDT

Pre-Requisites: **None**

Course Outcomes:

CO-1	Apply solidification principles in designing the casting processes
CO-2	Identify defects in castings.
CO-3	Model components for castings using CAD tools.
CO-4	Selection of NDT and understand their capabilities

Course Articulation Matrix:

	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6	PO-7	PO-8	PO-9	PO-10	PO-11	PO-12	PSO-1	PSO-2
CO-1	3	3	3	2	2	2	2	-	-	-	-	-	3	3
CO-2	3	3	3	2	2	2	2	-	-	-	-	-	3	3
CO-3	3	3	3	-	-	-	-	-					3	3
CO-4	3	3	3	2	2	2	2	-	-	-	-	-	3	3

1 - Slightly; **2 - Moderately;** **3 - Substantially**

Syllabus:

Processing of Castings:

Design of Casting Components:

Pattern, mould and core design: Orientation and parting, mould parting analysis, pattern design, cored features, core print design and analysis, mould cavity layout.

Feeder design and analysis: Casting solidification, solidification time and rate, feeder location and shape, feeder and neck design, feed aid design, solidification analysis, vector element method, optimization and validation.

Gating design and analysis: Mould filling, gating system and types, gating channel layout, optimal filling time, gating element design, mould filling analysis, numerical simulation, optimization and validation.

Introduction to NDT, Liquid penetrant test: Physical Principles, Procedure for penetrant testing, penetrant testing materials, Penetrant testing methods, sensitivity, Applications and limitations, typical examples

Ultrasonic testing: Basic properties of sound beam, Ultrasonic transducers, Inspection methods, Techniques for normal beam inspection , Techniques for angle beam inspection, Flaw characterization techniques, Applications of ultrasonic testing , Advantages and limitations.

Thermography: Basic principles, Detectors and equipment, techniques, applications

Radiography: Basic principle, Electromagnetic radiation sources, radiographic imaging, Inspection techniques, applications, limitations, typical examples

Eddy current test: Principles, instrumentation for ECT, techniques, sensitivity, advanced eddy Current test methods, applications, limitations

Acoustic emission: Principle of AET, Technique, instrumentation, sensitivity, applications, Acoustic emission technique for leak detection

Magnetic particle inspection: Principle of MPT, Procedure used for testing a component, sensitivity, limitations.

Learning Resources:

Text Books:

1. Peter J. Shull , Nondestructive Evaluation: Theory, Techniques and Applications, Marcel Dekkar, 2002.
2. P. Mclntire (Ed.), Non Destructive Testing Hand Book, Vol. 4, American Society for Non Destructive Society, 2010
3. ASM Metals Hand Book, Non Destructive Testing and Quality Control, Vol. 17, ASM, 1989.
4. B. Ravi, Metal casting: CAD and Analysis, PH Publication, 2014.
5. Hasse Fredriksson, Ulla Akerlind, Materials Processing during Casting, John Wiley and Sons Ltd, 2006

Reference Books:

1. John Campbell, Complete Casting Handbook Metal Casting Processes, Techniques and Design, Elsevier, 2011.

ME 1328 **3-0-0 (3)**

Advanced Metal Forming

Pre-Requisites: None

Course Outcomes:

CO-1	Evaluate workability of different ductile materials
CO-2	Develop process maps for metal forming processes using plasticity principles.
CO-3	Analyze the deformation process parameters for different engineering components.
CO-4	Estimate formability limits for sheets and bulk metals.
CO-5	Identify the practical applications of metal forming

Course Articulation Matrix:

	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6	PO-7	PO-8	PO-9	PO-10	PO-11	PO-12	PSO-1	PSO-2
CO-1	3	3	3	2	2	2	2	-	-	-	-	-	3	3
CO-2	3	3	3	2	2	2	2	-	-	-	-	-	3	3
CO-3	3	3	3	-	-	-	-	-					3	3
CO-4	3	3	3	2	2	2	2	-	-	-	-	-	3	3
CO-5	3	3	3	2	2	2	2	-	-	-	-	-	3	3

1 - Slightly; **2 - Moderately;** **3 - Substantially**

Syllabus:

Introduction: Introduction of metal forming as a manufacturing process and its relation with other processes, Advantages of metal forming as a manufacturing process, Classifications of metal forming processes – Bulk and sheet forming, Forming equipment, Presses (mechanical, hydraulic).

Description of Material properties: Tensile test, effect of properties on forming. Sheet deformation processes: Uni-axial tension, general sheet forming processes, yielding, flow rule, work hardening hypothesis, work of plastic deformation, isotropic and anisotropic yield functions, Bauschinger effect modeling, effective stress and strain. Sheet deformation in plane stress: strain distributions, strain diagram, deformation modes, effective stress-strain laws, principal tensions.

Bulk Forming Processes: Load estimation - Rolling - Forging; open-die forging, closed-die forging, Rod, wire and tube drawing, extrusion, problems.

Sheet Forming Processes: Deep drawing, Blanking, piercing, stretch forming, formability tests, forming limit diagrams, strain path diagrams, process simulation for deep drawing.

Recent advances: Hydroforming, tailor welded blanks, friction stir welding of sheets, incremental sheet forming, electric assisted forming

Case studies: Case studies on the manufacturing aspects of products using the lessons learnt

Learning Resources:

Text Books:

1. D. Banabic, Sheet metal forming processes Constitutive modeling and numerical simulation, Springer-Verlag Berlin Heidelberg, 2010

2. Z. Marciniak, J.L.Duncan, S.J.Hu, Mechanics of sheet metal forming, Elsevier, Butterworth-Heinemann, 2002
3. R. H. Wagoner, J. L. Chenot, Fundamentals of metal forming, John Wiley and Sons, 1997
4. W. F. Hosford, R. M. Caddell, Metal forming Mechanics and Metallurgy, Prentice Hall, 2007

Reference Books:

1. J. Chakrabarty, Theory of Plasticity, McGraw Hill, 1998.
2. D. W. A. Rees, Basic engineering plasticity, Elsevier, 2000
3. R. Narayanasamy, R Ponalagusamy, Theory of Engineering Plasticity, Ahuja Book Company, 2000.
4. Henry S. Valberg, Applied Metal Forming - Including FEM Analysis, Cambridge University Press, 2010.
5. G.K. Lal, P.M. Dixit and N.Venkat Reddy, Modeling Techniques for Metal Forming Processes, Alpha Science, 2011

ME 1330 **3-0-0 (3)**

FINITE ELEMENT METHOD

Pre-Requisites: **None**

Course Outcomes:

CO-1	Model the solid mechanics and Heat transfer problems for applying finite element method.
CO-2	Solve problems in one dimensional structures including trusses, beams and frames.
CO-3	Formulate FE characteristic equations for two dimensional elements for evaluating plain stress, plain strain, and axi-symmetric and plate bending problems.
CO-4	Solve the finite element formulations using MATLAB.

Course Articulation Matrix:

	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6	PO-7	PO-8	PO-9	PO-10	PO-11	PO-12	PSO-1	PSO-2
CO-1	2	2			3							2	2	2
CO-2	3	3	2	2	3							2	2	2
CO-3	3	3	2	2	3							2	2	2
CO-4	2	2			3							2	2	3

1 - Slightly; **2 - Moderately;** **3 - Substantially**

Syllabus:

Introduction: Overview of the course, examination and evaluation patterns, history and basic concept of finite element method and direct FEM.

Fundamental concepts: Calculus of variation and solving differential equations, Ritz method, Galerkin method, Least squares, collocation and subdomain methods, Case studies for Ritz and Galerkin methods, Ritz FEM formulation, Galerkin FEM formulation.

One-Dimensional Problems: Finite element formulation for 1-D problems, elimination method, penalty method, computer implementation and case studies.

Trusses: Introduction, fem formulation, plane trusses, three dimensional trusses, frames and case studies.

Two-Dimensional Problems: Finite element formulation for 2-D problems, constant strain triangle, various elements, iso parametric, sub parametric and super parametric elements, interpolation functions, computer implementation and case studies.

Numerical Integration and 2-D problems of Elasticity: Introduction to numerical integration, two dimensional integrals, plane stress, plane strain, axisymmetric, plate bending problems.

Thermal Applications: Two - dimensional heat conduction analysis, formulation of functional, element matrices and case studies.

Fluid Mechanics Applications: Stream function formulation, velocity potential formulation and torsional analysis of a prismatic bar.

Three Dimensional Problems: Finite element formulation for 3-D problems, mesh preparation, hexahedral elements, shell elements and case studies.

Learning Resources:

Text Books:

1. P. Seshu, Textbook of Finite Element Analysis, PHI, 2009.
2. U.S. Dixit, Finite Element Methods for Engineers, Cengage Learning, New Delhi and Singapore, 2009.
3. J.N. Reddy, Finite Element Method in Engineering, Tata McGraw Hill, 2007.

Reference Books:

1. Rao, S. Singiresu,The finite element method in engineering, Butterworth-heinemann, 2017.
2. Cook, D. Robert, Concepts and applications of finite element analysis, John wiley & sons, 2007.
3. Bathe, Klaus-Jürgen, Finite element procedures, Klaus-Jurgen Bathe, 2006.
4. Hughes, Thomas JR. The finite element method: linear static and dynamic finite element analysis, Courier Corporation, 2012.
5. Zeincowicz, The Finite Element Method for Solid and Structural Mechanics, Elsevier, 2007, 4th Edition.

ME 1332 **3-0-0 (3)**

Optimization for Engineering Design

Pre-Requisites: **None**

Course Outcomes:

CO-1	Formulate a design task as an optimization problem
CO-2	Solve unconstrained and constrained optimization problems
CO-3	Solve the nonlinear optimization problems with evolutionary methods.
CO-4	Apply data-driven techniques for solving optimization problems.

Course Articulation Matrix:

	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6	PO-7	PO-8	PO-9	PO-10	PO-11	PO-12	PSO-1	PSO-2
CO-1	3	3	3	3	3					2		3	3	3
CO-2	3	3	3	3	3					2			3	3
CO-3	3	3	3	3	3					2			3	3
CO-4	3	3	3	3	3					2			3	3

1 - Slightly; **2 - Moderately;** **3 - Substantially**

Syllabus:

Introduction to optimization in design: Introduction to Engineering Design, Identification of Customer Requirements, Mapping Customer Requirements to Engineering Characteristics, Problem formulation, Optimization problems in Mechanical Engineering, Classification of methods for optimization

Single-variable Optimization: Optimal criteria, Derivative-free methods (bracketing, region elimination), Derivative based methods, root-finding methods.

Multiple-variable Optimization: Optimal criteria, direct search methods (Box's, Simplex, Hooke-Jeeves, Conjugate methods), Gradient-based methods (Steepest Descent, Newton's, Marquardt's, DFP method). Formulation and Case studies.

Constrained Optimization: KKT conditions, Penalty method, and Sensitivity analysis, direct search methods for constrained optimization, quadratic programming, GRG method, Formulation and Case studies.

Evolutionary Optimization algorithm: Genetic algorithms, simulated annealing, Anti-colony optimization, Particle swarm optimization.

Multi-objective Optimization: Terminology and concepts, the concepts of Pareto optimality and Pareto optimal set, formulation of multi-objective optimization problem, NSGA.

Data-driven Techniques in Optimization: Machine Learning Methods (Decision Tree, KNN algorithm, Gradient boosting algorithm etc.).

Case studies and Computer Implementation: Representative case studies for important methods and development of computer code for the same to solve problems.

Learning Resources:

Text Books:

1. Jasbir Arora, Introduction to Optimum Design, Academic Press, 2004
2. Kalyanmoy Deb, Optimization for Engineering Design: Algorithms and Examples, PHI, 2004.
3. Kalyanmoy Deb, Multi-Objective Optimization using Evolutionary Algorithms, Wiley, 2001.

Reference Books:

1. Gilbert Strang, Linear Algebra and Learning from Data, Wellesley-Cambridge Press, 2019.

ME 1334 **3-0-0 (3)**

GAS DYNAMICS

Pre-Requisites: **None**

Course Outcomes:

CO-1	Solve flow equations for quasi one-dimensional flow through variable area ducts.
CO-2	Analyze the flow through constant area ducts with friction and heat transfer.
CO-3	Analyze flows with normal and oblique shocks.
CO-4	Solve flow problems with supersonic velocities using shock-expansion theory.
CO-5	Solve linearized velocity potential equation for multi-dimensional flows.

Course Articulation Matrix:

	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6	PO-7	PO-8	PO-9	PO-10	PO-11	PO-12	PSO-1	PSO-2
CO-1	3	3	2	1	–	–	–	–	–	–	–	–	2	2
CO-2	3	3	3	1	–	–	–	–	–	–	–	–	2	2
CO-3	3	3	2	3	–	–	–	–	–	–	–	–	2	2
CO-4	3	1	2	3	–	–	–	–	–	–	–	–	2	2
CO-5	3	3	3	2	–	–	–	–	–	–	–	–	2	2

1 - Slightly; **2 - Moderately;** **3 - Substantially**

Syllabus:

Introduction: Review of basic fluid dynamic and thermodynamic principles, Conservation equations for inviscid flows.

One Dimensional flow: One-dimensional wave motion, normal shock waves, Oblique shock waves, Prandtl-Meyer expansions and applications, generalized one-dimensional flow

Nozzle Flow: Isentropic flow with area change, Flow with friction (Fanno flow), Flow with heat addition (Rayleigh flow), Method of characteristics (application to one-dimensional unsteady isentropic flow)

Supersonic Flow: Velocity Potential Equation, Numerical Techniques for Steady Supersonic Flow, Time Marching Technique for Supersonic Blunt Bodies and Nozzles

Learning Resources:

Text Books:

1. Anderson, J.D Jr., Modern Compressible Flows, Tata McGraw Hill, 2017
2. Yahya, S.M., Fundamentals of Compressible Flow, New age International Pub., 2018
3. Zucrow, M., Gas Dynamics, Wiley India, 2013

Other Suggested Readings:

1. NPTEL Courses
2. MIT Open Course Ware, etc.

ME 1336 **3-0-0 (3)**

Non-Conventional Energy Sources

Pre-Requisites: **None**

Course Outcomes:

CO-1	Identify renewable energy sources and their utilization.
CO-2	Analyze the working of solar PV and thermal systems.
CO-3	Understand principles of energy conversion from alternate sources including wind, geothermal, ocean, biomass, biogas and hydrogen.
CO-4	Understand the concepts of fuel cells, thermoelectric convertor and MHD generator.
CO-5	Identify methods of energy storage for specific applications

Course Articulation Matrix:

	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6	PO-7	PO-8	PO-9	PO-10	PO-11	PO-12	PSO-1	PSO-2
CO-1	3	3	3	2	1	2	1	2	–	–	2	1	-	3
CO-2	3	3	2	3	1	2	–	2	–	–	2	3	2	3
CO-3	3	2	1	1	1	1	–	2	–	–	2	3	3	3
CO-4	3	3	3	1	1	1	–	2	–	–	2	2	3	3
CO-5	3	3	1	1	1	2	–	2	–	–	2	2	2	3

1 - Slightly; **2 - Moderately;** **3 - Substantially**

Syllabus:

Energy Storage: Introduction; Necessity of Energy Storage; Energy Storage Methods

Solar Energy: Fundamentals; Solar Radiation; Estimation of solar radiation on horizontal and inclined surfaces; Measurement of solar radiation data

Solar Thermal systems: Introduction; Basics of thermodynamics and heat transfer; Flat plate collector; Evacuated Tubular Collector; Solar air collector; Solar concentrator; Solar distillation; Solar cooker; Solar refrigeration and air conditioning; Thermal energy storage systems

Solar Photovoltaic systems: Introduction; Solar cell Fundamentals; Characteristics and classification; Solar cell: Module, panel and Array construction; Photovoltaic thermal systems

Wind Energy: Introduction; Origin and nature of winds; Wind turbine siting; Basics of fluid mechanics; Wind turbine aerodynamics; wind turbine types and their construction; Wind energy conversion systems

Fuel cells: Overview; Classification of fuel cells; Operating principles; Fuel cell thermodynamics

Biomass Energy: Introduction; Photosynthesis Process; Biofuels; Biomass Resources; Biomass conversion technologies; Urban waste to energy conversion; Biomass gasification.

Other forms of Energy: Introduction: Nuclear, ocean and geothermal energy applications; Origin and their types; Working principles

Learning Resources:

Text Books:

1. B.H.Khan, Non-conventional Energy Resources,Tata McGraw Hill, New Delhi, 2017, 3rd edition
2. S.P.Sukhatme and J.K.Nayak, Solar Energy-Principles of Thermal Collection and Storage, TMH, 2008, 3rd edition

Reference Books:

1. J.A.Duffie and W.A.Beckman, Solar Energy Thermal Processes, John Wiley, 2010, 2nd edition
2. S.Rao and B.B. Parulekar, Energy Technology (Non Conventional, Renewable and Conventional), Khanna Publishers, 2010, 1st Edition

Other Suggested Readings:

1. Non-conventional Energy Resources by Prof. Prathap Haridoss (IIT Madras), NPTEL Course (Link: https://nptel.ac.in/courses/121/106/121106014/)

ME 1338 **3-0-0 (3)**

Operations Planning and Control

Pre-Requisites: **None**

Course Outcomes:

CO-1	Explain production systems and their characteristics.
CO-2	Evaluate MRP and JIT systems against traditional inventory control systems.
CO-3	Evaluate basics of variability and its role in the performance of a production system.
CO-4	Analyze aggregate planning strategies.
CO-5	Apply forecasting and scheduling techniques to production systems.
CO-6	Apply theory of constraints for effective management of production systems.

Course Articulation Matrix:

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PS02
CO1	2	2	2						2		2	2	2	2
CO2	3	3	3		3	2			2	2	2	2	2	2
CO3	2	3	3						2		2	3	2	2
CO4	3	3	3	3	3				2	2	2	2	2	3
CO5	3	3	3	3	3	2			2		2	2	2	3
CO6	2	3	3	2					2		2	2	2	2

1 - Slightly; **2 - Moderately;** **3 - Substantially**

Syllabus:

Introduction: Milestones in the evolution of production systems, Overview of Production Planning and Control Hierarchy, product design.

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

Material Requirements Planning: Review of EOQ and Inventory control systems, Concept of Dependent Demand; Structure of MRP system, MRP Calculations, Planning Issues, Implementation Issues.

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.

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.

Factory Physics: Basic factory dynamics, Variability basics, Push and pull production systems, CONWIP.

Theory of Constraints: TOC and Drum-Buffer-Rope, TOC process as applied to Marketing, Production and Project Management.

Learning Resources:

Text Books:

1. L.J. Krajewski and L.P Ritzmen, Operations Management: Strategy and Analysis, Pearson Education, 2021, 13th Edition.
2. R.B. Chase, F.R. Jacobs and N.J. Aquilano, Operations Management for Competitive Advantage, Tata McGraw Hill Book Company, New Delhi, 2021, 15th Edition.
3. Hopp W. J. and Spearman M. L., Factory Physics: Foundations of Manufacturing Management, McGraw Hill International Edition, 2008, 3rd Edition.
4. Mahadevan. B., Operations Management: Theory and Practice, Pearson, Edition 3rd, 2008

Reference Books:

1. Eliyahu M Goldratt, The Goal – A process of ongoing improvement, Gower Book, 2004 3rd Edition
2. Eliyahu M Goldratt, Critical Chain, Gower Book, 1997.

Other Suggested Readings:

1. https://www.dbrmfg.co.nz – for understanding TOC implementation.

ME 1340 **3-0-0 (3)**

Operation Research

Pre-Requisites: **None**

Course Outcomes:

CO-1	Develop critical thinking and problem-solving skills.
CO-2	Learn to model and analyze complex systems for optimization.
CO-3	Gain proficiency in using computational tools for operations research.
CO-4	Apply theoretical knowledge to real-world engineering problems.
CO-5	Develop practical skills in using OR software tools such as Python and Excel to solve optimization problems.

Course Articulation Matrix:

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PS02
CO1	3	2	1		3							3		
CO2	3	3	1		3							3		
CO3	3	3	3		3							3		
CO4	3	3	3	3	3							3		
CO5	3	3	2	3	3				1	3		3		
CO6	3	2	1		3							3		

1 - Slightly; **2 - Moderately;** **3 - Substantially**

Syllabus:

Introduction of operation research: Definition and scope of OR, Historical development of OR, Application of OR in engineering, OR tools and techniques,

Linear programming: Formulation of linear programming problems (LPP), Graphical method solving LPP

Simplex Algorithm: Algebraic form, Tabular form, Types of LPs, Matrix method

Duality: Writing the dual of an LP, Primal-Dual relationships, Duality theorems, complimentary slackness theorem

Dual: Basic understanding, significance, interpretation, Dual Simplex algorithm

Transportation Problem: Introduction to the transportation problem, formulation and solve transportation problems using methods like the Northwest Corner Rule, Least Cost Method, and Vogel's Approximation Method

Assignment Problem: Special features of assignment problems, Hungarian method for solving assignment problems, dual of the assignment problem, optimality of the Hungarian algorithm

Multi-Objective Programming, Dynamic Programming, Transportation Problem, Assignment Problem, Case studies

OR Software and Tools: Introduction to OR software (e.g., Python and Excel)

Learning Resources:

Text Books:

1. Mohan, C. and Deep, Kusum: “Optimization Techniques”, New Age, 2009.
2. Mittal, K. V. and Mohan, C. “Optimization Methods in Operations Research and Systems Analysis”, New Age, 2003.
3. Taha, H.A. : “Operations Research – An Introduction”, Prentice Hall, (7th Edition), 2002.
4. Ravindran, A. , Phillips, D. T and Solberg, J. J. “Operations Research: Principles and Practice”, John Willey and Sons, 2nd Edition, 2009.

Other Suggested Readings:

1. NPTEL Courses: Introduction to Operations Research by Prof. G. Srinivasan

ME 1342 **3-0-0 (3)**

Mechanics of Composite Materials

Pre-Requisites: **None**

Course Outcomes:

CO-1	Understand the industrial need for composite materials.
CO-2	Identify suitable processes to develop fiber reinforced composite materials.
CO-3	Apply the micro and macro mechanics for fiber reinforced composite materials.
CO-4	Develop governing equation for Bending, Buckling, and Vibration of Laminated plates.
CO-5	Design the composite structures with the help of computers.

Course Articulation Matrix:

	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6	PO-7	PO-8	PO-9	PO-10	PO-11	PO-12	PSO-1	PSO-2
CO-1		2				2	3	2		3		2		2
CO-2		2	3	3	3	2	3	2		3		2		
CO-3	3	3						2				2	3	2
CO-4	3	3						2				2	3	
CO-5			3		3		3	2				2	3	3

1 - Slightly; **2 - Moderately;** **3 - Substantially**

Syllabus:

Introduction to composite materials: Introduction, What is a composite material, Current and potential advantages of fibre reinforced composites, Applications of composite materials, Military, civil, space, automotive and commercial applications

Macro and micro mechanical behaviour of a lamina: Stress strain relations for anisotropic materials, Restrictions on engineering constants, Strengths of an orthotropic lamina, biaxial strength criteria for orthotropic lamina

Micro mechanical behaviour of lamina and laminates: Mechanical of material approach to stiffness, Elasticity approach to stiffness, Classification lamination theory, Special cases, strength of laminates

Bending, Buckling and Vibration of laminated plates: Governing equations for bending buckling and vibration of laminated plates, Deflection of simply supported laminated plates, Vibration of simply supported laminated plates

Design of composite structures: Introduction, design philosophy, Anisotropic analysis, Bending extension coupling, Micromechanics, Nonlinear behaviour, Inter-laminar stresses, transverse shearing, Laminate optimization

Learning Resources:

Text Books:

1. Ronald F. Gibson, Principles of composite material mechanics, CRC Press, 2011.
2. Robert M Jones, Mechanics of Composite Materials, Taylor & Francis, 2000.

Reference Books:

1. Lawrence E. Nielsen, Nielson, Paul Nielsen, Mechanical Properties of Polymers and Composites, Second Edition, CRC press, 2000

ME 1344 **3-0-0 (3)**

Design of Mechanical Elements

Pre-Requisites: **None**

Course Outcomes:

CO-1	Design the required size of shaft, key and coupling for the given application.
CO-2	Design an appropriate gear for the given operating conditions.
CO-3	Design a suitable bearing for the given application.
CO-4	Design clutches, brakes and I.C. engine parts.

Course Articulation Matrix:

	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6	PO-7	PO-8	PO-9	PO-10	PO-11	PO-12	PSO-1	PSO-2
CO-1		2				2	3	2		3		2		2
CO-2		2	3	3	3	2	3	2		3		2		
CO-3	3	3						2				2	3	2
CO-4	3	3						2				2	3	
CO-5			3		3		3	2				2	3	3

1 - Slightly; **2 - Moderately;** **3 - Substantially**

Syllabus:

Introduction to composite materials: Introduction, What is a composite material, Current and potential advantages of fibre reinforced composites, Applications of composite materials, Military, civil, space, automotive and commercial applications

Macro and micro mechanical behaviour of a lamina: Stress strain relations for anisotropic materials, Restrictions on engineering constants, Strengths of an orthotropic lamina, biaxial strength criteria for orthotropic lamina

Micro mechanical behaviour of lamina and laminates: Mechanical of material approach to stiffness, Elasticity approach to stiffness, Classification lamination theory, Special cases, strength of laminates

Bending, Buckling and Vibration of laminated plates: Governing equations for bending buckling and vibration of laminated plates, Deflection of simply supported laminated plates, Vibration of simply supported laminated plates

Design of composite structures: Introduction, design philosophy, Anisotropic analysis, Bending extension coupling, Micromechanics, Nonlinear behaviour, Inter-laminar stresses, transverse shearing, Laminate optimization

Learning Resources:

Text Books:

1. V B Bhandari, Design of Machine Elements, Tata McGraw Hill Education Private Limited, 2020, Fifth edition.
2. Robert L Norton, Machine design an integrated approach, Pearson Education, 2018, Fifth edition.

Reference Books:

1. Richard G. Budynas, J Keith Nisbett, Mechanical Engineering Design, Shigley's. McGraw Hill, 2011, Ninth edition.
2. Black and Adams, Machine Design, McGraw Hill and Co, New Delhi, 2002.

Professional Electives - IV and V

ME 1421 **3-0-0 (3)**

Convective Heat Transfer

Pre-Requisites: **None**

Course Outcomes:

CO-1	Understand principles of forced and free convection heat transfer processes.
CO-2	Formulate and solve convective heat transfer problems.
CO-3	Estimate heat dissipation from heat transfer devices.
CO-4	Evaluate energy requirements for operating a flow system with heat transfer.
CO-5	Understand current challenges in the field of convective heat transfer.

Course Articulation Matrix:

	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6	PO-7	PO-8	PO-9	PO-10	PO-11	PO-12	PSO-1	PSO-2
CO-1	2	1	1	2	2	–	–	–	–	–	–	-	3	3
CO-2	3	3	3	2	3	–	–	–	–	–	–	1	2	2
CO-3	3	2	2	1	3	–	–	–	–	–	–	1	2	2
CO-4	3	2	3	1	3	–	–	–	–	–	–	1	2	3
CO-5	3	2	1	2	3	–	–	–	–	–	–	2	2	1

1 - Slightly; **2 - Moderately;** **3 - Substantially**

Syllabus:

Introduction: Course structure, Basics of Thermodynamics, Fluid mechanics and Heat transfer.

Fundamental Principles: Continuity, momentum and energy equations, Reynolds transport theorem, Second law of TD, Rules of Scale analysis, Concept of Heat line visualization.

Laminar forced convection: External flows: Boundary layer concept, velocity and thermal boundary layer, Governing equations, Similarity solutions, various wall heating conditions, Flow over sphere, wedge and stagnation flow.

Laminar forced convection: Internal flows: Fully developed laminar flow: Constant heat flux, Constant wall temperature, developing length.

External Natural convection: Governing equations for natural convection, Boussinesq approximation, Dimensional Analysis, Boundary layer equations, Scale analysis, Low and high Prandtl number fluids, vertical walls, horizontal walls, sphere.

Internal Natural Convection: Natural convection in enclosures: isothermal and constant heatflux. Sidewalls, triangular enclosures, heated from below, inclineden closures, annular space between horizontalcylinders.

Turbulent boundary layer flow: Boundary layer equations, mixing length model, flow over single cylinder, crossflow over array of cylinders, Natural convection along vertical walls, turbulent duct flow.

Learning Resources:

Text Books:

1. Bejan, A., Convection Heat Transfer, John Willey and Sons, New York, 2001.
2. Louis, C. Burmeister, Convective Heat Transfer, John Willey and Sons, New York, 2003.

Reference Books:

1. Kays, W.M. and Crawford, M. E., Convective Heat and Mass Transfer, McGraw Hill, 2001.

ME 1423 **3-0-0 (3)**

Automotive Safety

Pre-Requisites: **None**

Course Outcomes:

CO-1	Identify different safety systems and its role in automobiles
CO-2	Understand the active and passive safety systems
CO-3	Describe the working principles of air-bag, ABS, seat-belt controls, comfort and convenience systems
CO-4	Understand engine maintenance and its trouble shooting as well as remedial measures.
CO-5	Understand maintenance of transmission, steering, braking, air conditioning and electrical systems

Course Articulation Matrix:

	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6	PO-7	PO-8	PO-9	PO-10	PO-11	PO-12	PSO-1	PSO-2
CO-1	2	3	2	3	–	–	–	–	–	–	–	2	2	1
CO-2	3	3	3	3	–	–	–	–	–	–	–	2	2	1
CO-3	2	2	2	1	**3**	–	–	–	–	–	–	2	2	1
CO-4	2	2	3	2	–	–	–	**1**	–	–	–	1	2	1
CO-5	2	3	2	2	–	–	–	–	–	–	–	1	2	1

1 - Slightly; **2 - Moderately;** **3 - Substantially**

Syllabus:

INTRODUCTION

Design of the vehicle body for safety, energy equation, engine location, deceleration of vehicle inside passenger compartment, deceleration on impact with stationary and movable obstacle, concept of crumble zone, safety sandwich construction.

SAFETY CONCEPTS

Safety Concepts: Active safety, driving safety, conditional safety, perceptibility safety, operating safety, passive safety: exterior safety, interior safety, deformation behaviour of vehicle body, speed and acceleration characteristics of passenger compartment on impact.

Active Safety: Cruise control system, Lane departure warning, Safety equipment: Seat belt, regulations, automatic seat belt tightened system, Anti-locking braking system(ABS), Speed limiting device(SLD),Fire detection and suppression system(FDSS), automatic traction control, automatic vehicle stability control, Collapsible steering system, tilt able steering system, air bags, electronic system for activating air bags, bumpers design for safety.

PASSIVE SAFETY EQUIPMENTS

Seat belt, regulations, automatic seat belt tightener system, collapsible steering column, tiltable steering wheel, air bags, electronic system for activating air bags, bumper design for safety.

COLLISION WARNING AND AVOIDANCE

Collision warning system, causes of rear end collision, frontal object detection, rear vehicle object detection system, object detection system with braking system interactions.

COMFORT AND CONVENIENCE SYSTEM

Steering and mirror adjustment, central locking system, Garage door opening system, tyre pressure control system, rain sensor system, environment information system.

PREVENTIVE MAINTENANCE OF ENGINE AND TRANSMISSION LINE

Maintenance of cooling and lubricating systems, engine management service - fault diagnosis- servicing emission controls.

Clutch, transmission, axles: general checks, adjustment and service, fault diagnosis.

STEERING, BRAKE, SUSPENSION, WHEEL MAINTENANCE

Inspection, Maintenance and Service of Hydraulic brake, Drum brake, Disc brake, Parking brake. Bleeding of brakes. Inspection, Wheel alignment and balance, removing and fitting of tyres, tyre wear and tyre rotation. Inspection, Maintenance and Service of steering linkage.

Learning Resources:

Text Books:

1. Robert Bosch GmbH, Automotive Handbook, SAE publication, 2011, 8th Edition
2. Srinivasan S, Automotive Mechanics, Tata McGraw- Hill, Publisher, 2015, 2nd Edition
3. Jullian Happian-Smith, An Introduction to Modern Vehicle Design, SAE, 2002
4. Johnson W, and Mamalis A G, Crashworthiness of Vehicles, MEP – London, 1995
5. Vehicle Service Manuals of reputed manufacturers

ME 1425 **3-0-0 (3)**

DESIGN AND ANALYSIS OF EXPERIMENTS

Pre-Requisites: **None**

Course Outcomes:

CO-1	Formulate objective(s) and identify key factors in designing experiments for a given Problem.
CO-2	Develop appropriate experimental design to conduct experiments for a given problem.
CO-3	Analyze experimental data to derive valid conclusions.
CO-4	Optimize process conditions by developing empirical models using experimental data.
CO-5	Design robust products and processes using parameter design approach.

Course Articulation Matrix:

	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6	PO-7	PO-8	PO-9	PO-10	PO-11	PO-12	PSO-1	PSO-2
CO-1	3	3	2						2	2	2	2	3	2
CO-2	3	3	3	3	2				2		2	2	3	3
CO-3	3	3	2	3	2				2	3		2	3	3
CO-4	3	3	3	3	3				2		2	2	3	2
CO-5	3	3	3	3	3				2		3	2	3	3

1 - Slightly; **2 - Moderately;** **3 - Substantially**

Syllabus:

Fundamentals of Experimentation: Role of experimentation in rapid scientific progress, Historical perspective of experimental approaches, Steps in experimentation, Principles of experimentation; Simple Comparative Experiments: Basic concepts of statistics, Comparison of two means and two variances, Comparison of multiple (more than two) means & ANOVA, ANALYSIS OF CO-VARIANCE ANOCOVA

Experimental Designs: Factorial designs, fractional factorial designs, orthogonal arrays, standard orthogonal arrays & interaction tables, modifying the orthogonal arrays, selection of suitable orthogonal array design, analysis of experimental data

Taguchi's Parameter Design: Concept of robustness, noise factors, objective function & S/N ratios, inner-array and outer-array design, data analysis

Response Surface Methodology: Concept, linear model, steepest ascent, second order model, Linear regression, Multiple linear and non-linear regression analysis

Learning Resources:

Text Books:

1. Montgomery DC, Design and Analysis of Experiments, 10th Edition, John Wiley & Sons, NY, 2019
2. Ross PJ, Taguchi Techniques for Quality Engineering,McGraw-Hill Book Company, NY, 2008

ME 1427 **3-0-0 (3)**

Computer Control of Manufacturing Systems

Pre-Requisites: **None**

Course Outcomes:

CO-1	Understand basic concepts and classifications of Numerical Control (NC) systems.
CO-2	Explain features and design considerations of NC machine tools to improve accuracy and productivity.
CO-3	Describe system devices used in NC systems.
CO-4	Comprehend the operation of interpolators for manufacturing systems and Discuss adaptive control systems and their applications
CO-5	Analyse control loops of NC systems and the concepts of CNC and the role of digital computers and microcomputers in CNC systems

Course Articulation Matrix:

	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6	PO-7	PO-8	PO-9	PO-10	PO-11	PO-12	PSO-1	PSO-2
CO-1	2	2	2	2		2		2	2		2	2	3	3
CO-2	2	2											2	2
CO-3	2	3	2	3				2	2			2	3	3
CO-4	2	3	2	3				2	2				3	3
CO-5	2		2				2	2	2	2	3		2	3

1 - Slightly; **2 - Moderately;** **3 - Substantially**

Syllabus:

Introduction: Basic concepts in manufacturing systems, Fundamentals of Numerical Control, Advantages of NC systems, Classification of NC Systems

Features of NC Machine tools: Fundamentals of Machining, Design considerations of NC Machine tools, Methods of improving Machine Accuracy, Increasing Productivity with NC Machines, Machining Centers, MCU Functions

System Devices: Drives, Feedback devices, Counting Devices, Digital-to-Analog converters

Interpolators for Manufacturing Systems: DDA Integrator, DDA Hardware Interpolator, CNC Software Interpolator, Software DDA Interpolator, Reference-Word CNC Interpolators

Control Loops of NC Systems: Introduction, Control of point-to-point Systems, Control Loops in Contouring Systems

Computerized Numerical Control: CNC Concepts, Advantages of CNC, The Digital Computer, The Reference-Pulse Technique, Sampled-Data Technique, Microcomputers in CNC

Adaptive Control Systems: Introduction, Adaptive Control with Optimization, Adaptive Control with Constraints, Variable-Gain AC Systems, Adaptive Control of Grinding, Cost Analysis in Machining

Learning Resources:

Text Books:

1. Michael J. Peterson, Computer Numerical Control: Machining and Turning Centers,Pearson, 2003.
2. Peter Smid, CNC Programming Handbook, Industrial Press, 2003.
3. T.K. Kundra, P.N. Rao, and N.K. Tewari, Numerical Control and Computer-Aided Manufacturing, Tata McGraw-Hill Education, 1993.
4. Warren S. Seames, Computer Numerical Control: Operation and Programming, Prentice Hall, 2002.
5. Mikell P. Groover, Automation, Production Systems, and Computer-Integrated Manufacturing, Pearson, 2014.
6. B.S. Pabla and M. Adithan, CNC Machines, New Age International, 2014.
7. S. Kant Vajpayee, Principles of Computer-Integrated Manufacturing, Prentice Hall, 1995.
8. Godfrey C. Onwubolu, Mechatronics: Principles and Applications, Butterworth-Heinemann, 2005.
9. Yoram Koren, Computer Control of Manufacturing Systems, McGraw-Hill, 1983.

ME 1429 **3-0-0 (3)**

ROBOTICS

Pre-Requisites: None

Course Outcomes:

CO-1	Understand the basic components of robots and their grippers.
CO-2	Model forward and inverse kinematics of robot manipulators.
CO-3	Analyze forces in links and joints of a robot.
CO-4	Develop a program for the robot to perform tasks in industrial applications.
CO-5	Design intelligent robots using sensors.

Course Articulation Matrix:

	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6	PO-7	PO-8	PO-9	PO-10	PO-11	PO-12	PSO-1	PSO-2
CO-1	2	1				1						2	1	1
CO-2	3	2	2	2	2	2						2	2	2
CO-3	3	2	2	2	2	2						2	2	2
CO-4	3	3	3	3	3	3						2	3	3
CO-5	3	2	3	3	3	3						2	3	3

1 - Slightly; **2 - Moderately;** **3 - Substantially**

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

Reference Books:

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

Online Resources:

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

ME 1431 **3-0-0 (3)**

CONDITION MONITORING

Pre-Requisites: **None**

Course Outcomes:

CO-1	Understand effective maintenance schemes in industries.
CO-2	Diagnose the mechanical systems by applying vibration monitoring techniques.
CO-3	Apply oil analysis technique to diagnose the wear debris.
CO-4	Identify nonconventional methods for machine diagnoses.
CO-5	Develop technologies for effective plant maintenance.

Course Articulation Matrix:

	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6	PO-7	PO-8	PO-9	PO-10	PO-11	PO-12	PSO-1	PSO-2
CO-1		3						2	2			2	3	
CO-2	3	2	2		3			2	2			2	3	3
CO-3	3	2	2		3			2	2			2	3	
CO-4		3			3			2	2			2		
CO-5	3		3	3				2	2			2	3	3

1 - Slightly; **2 - Moderately;** **3 - Substantially**

Syllabus:

Introduction: Failures - System, component and services failures - classification and its causes, Maintenance Schemes - objectives - types and economic benefits, break down, preventive and predictive monitoring.

Vibration Monitoring - causes and effects of vibration, review of mechanical vibration concepts - free and forced vibrations, vibration signature of active systems - measurement of amplitude, frequency and phase.

Vibration monitoring equipment- vibration sensors (contact and non-contact type) -factors affecting the choice of sensors, signal conditioners, recording and display elements, vibration meter and analyzers, measurement of overall vibration levels.

Contaminant analysis: Contaminants in used lubricating oils - monitoring techniques (wear debris) - SOAP technique, Ferrography, X-ray spectrometry, Particle classification.

Temperature Monitoring - Various techniques - thermograph, pyrometers, indicating paint and NDT methods.

Special Techniques: Ultrasonic measurement method, shock pulse measurement, Kurtosis, Acoustic Emission mentoring, critical speed analysis, shaft orbit analysis, Cepstrum analysis. Non-destructive techniques, Structural health monitoring weldments for surface and subsurface cracks

Learning Resources:

Text Books:

1. Rao J. S., Vibration Condition Monitoring, Narosa Publishing House, 2/e 2000.
2. Isermann R., Fault Diagnosis Application, Springer-Verlag Berlin, 2011.
3. Collacott, R. A., Mechanical Faults Diagnosis, Chapman and Hall, London, 1990

Reference Books:

1. Choudary K K., Instrumentation, Measurement and Analysis, Tata McGraw Hill, 2012
2. Allan Davis, Handbook of Condition Monitoring, Chapman and Hall, 2000

ME 1433 **3-0-0 (3)**

TWO-PHASE HEAT TRANSFER

Pre-Requisites: **None**

Course Outcomes:

CO-1	Understand the fundamentals of two-phase flow
CO-2	Analyze flow regimes with appropriate models
CO-3	Understand pool boiling and flow boiling
CO-4	Measure parameters in multi-phase flow

Course Articulation Matrix:

	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6	PO-7	PO-8	PO-9	PO-10	PO-11	PO-12	PSO-1	PSO-2
CO-1	2	3	3	2	2	–	2	–	–	–	–	2	2	2
CO-2	3	3	3	2	2	–	1	–	–	–	–	2	2	2
CO-3	3	3	3	2	2	–	2	–	–	–	–	2	2	2
CO-4	3	3	3	3	1	–	1	–	–	–	–	2	2	2

1 - Slightly; **2 - Moderately;** **3 - Substantially**

Syllabus:

Hydrodynamics of two-phase flow: Introduction to multiphase flow, types and applications, Common terminologies, flow patterns and flow pattern maps. One dimensional steady homogenous flow, Concept of choking and critical flow phenomena, The separated flow model for stratified and annular flow, General theory of drift flux model, Application of drift flux model to bubbly and slug flow, Pressure Drop in Two-Phase Flow. Measurement techniques for multiphase flow, void fraction and flow rate measurement.

Pool and flow boiling: Description and Classification of Boiling, Pool Boiling Curve, Nucleation and Dynamics of Single Bubbles, Heat Transfer Mechanisms in Nucleate Boiling, Nucleate Boiling Correlations, Hydrodynamic of Pool Boiling Process, Pool Boiling Crisis, Film Boiling Fundamentals, Flow Boiling, Forced-Flow Boiling Regimes, Nucleate Boiling in Flow, Sub-cooled Nucleate Flow Boiling, Saturated Nucleate Flow Boiling, Flow Boiling Correlations, Flow Boiling Crisis.

Condensation: Film and dropwise condensation.

Learning Resources:

Text Books:

1. L. S. Tong and Y. S. Tang, Boiling Heat Transfer and Two-Phase Flow,Taylor and Francis, 1997
2. J. B. Collier, and J. R. Thome, Convective boiling and condensation, Oxford Science Publications, 1994

Reference Books:

1. C.E. Brennen, Fundamentals of Multiphase Flow, Cambridge University Press, New York, 2005

ME 1435 **3-0-0 (3)**

Power Plant Engineering

Pre-Requisites: **None**

Course Outcomes:

CO-1	Understand functions of the components of power plant
CO-2	Understand the working of nuclear, thermal and gas based power plants.
CO-3	Evaluate the design layout and working of hydroelectric power plants
CO-4	Evaluate economic and environmental implications on power plants.

Course Articulation Matrix:

	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6	PO-7	PO-8	PO-9	PO-10	PO-11	PO-12	PSO-1	PSO-2
CO-1	3	3	3	2	–	2	1	–	–	–	–	2	2	2
CO-2	3	3	3	2	–	2	1	–	–	–	–	2	2	2
CO-3	3	3	3	2	–	2	1	–	–	–	–	2	2	2
CO-4	3	3	3	3	–	1	1	–	–	–	2	2	2	2
CO-5	3	3	3	2	–	2	1	–	–	–	–	2	2	2

1 - Slightly; **2 - Moderately;** **3 - Substantially**

Syllabus:

Introduction: Energy resources and their availability, types of power plants, review of basic thermodynamic cycles used in power plants.

Steam Power Plants: Flow sheet and working of modern-thermal power plants, site selection, plant efficiency

Steam generators and their accessories: High pressure Boilers and its accessories, Draught system.

Fuel and combustion: coal storage, preparation, coal handling systems, mass and energy balance of steam generator, feeding and burning of pulverized fuel, Fluidized bed combustion system, ash handling systems, dust collection-mechanical dust collector and electrostatic precipitator.

Condensers: Direct Contact Condenser, Surface Condensers, Cooling towers and cooling ponds

Combined Cycles: Gas turbine power plants, integrated gasification combined cycle, PFBC based combined cycle, re-powering of thermal power plant.

Nuclear Power Plants: Principles of nuclear energy, basic nuclear reactions, nuclear cross- section, and different components of nuclear power station, PWR, BWR, fast breeder, nuclear waste disposal.

Non-conventional energy generation: Geothermal power plant, Tidal and wave power plant, solar power plant, wind power generation, direct to electricity method - Magneto-hydrodynamic (MHO) power generation

Hydro Electric Power Plants: Rainfall and run-off measurements and plotting of various curves for estimating stream flow and size of reservoir, power plant design, comparison with other types of power plants.

Power Plant Economics: load curve, different terms and definitions, base load and peak load plants, energy storage, cost of electrical energy, tariffs methods of electrical energy performance & operating characteristics of power plants- incremental rate theory, input- output curves, efficiency, heat rate, economic load sharing, Problems.

Learning Resources:

Text Books:

1. Power Plant Engineering, P. K. Nag, McGraw Hill Education, 4th Edition, 2017
2. Power plant engineering, Arrora, Domkundwar, DhanpatRai & Sons, New Delhi, 2008
3. Power plant engineering, P. C. Sharma, S.K. Kataria & Sons, New Delhi, 2010

Reference Books:

1. Power plant Technology, M.M.Ei-Wakil, McGraw Hill Com.,

Other Suggested Readings:

1. https://www.alternative-energy-tutorials.com/

ME 1437 **3-0-0 (3)**

Aerodynamics

Pre-Requisites: **None**

Course Outcomes:

CO-1	Understand the principles of flight and vehicle aerodynamics.
CO-2	Analyze inviscid, incompressible and irrotational flows for flow around an airfoil
CO-3	Analyze compressible flow over an airfoil
CO-4	Estimate the lift and drag over a vehicle body using the principles of aerodynamics

Course Articulation Matrix:

	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6	PO-7	PO-8	PO-9	PO-10	PO-11	PO-12	PSO-1	PSO-2
CO-1	3	2	2		–	–	–	–	–	–	–	–	2	2
CO-2	3	2	2		–	–	–	–	–	–	–	–	2	2
CO-3	2	3	2		–	–	–	–	–	–	–	–	1	2
CO-4	3	3	3		–	–	–	–	–	–	–	–	1	2

1 - Slightly; **2 - Moderately;** **3 - Substantially**

Syllabus:

Introduction: Importance of Aerodynamics in flights and automobiles, Aerofoils, wings and their nomenclature, Characteristics of Airfoil, Aerodynamic Forces and Moments (Lift, drag and pitching moment coefficients), A brief review on Continuity, Momentum and Energy Equations, Application of Momentum Equation for the Estimation of Drag of a Two- dimensional Body, Substantial Derivatives, Pathlines and Streamlines of a Flow, Angular Velocity, Vorticity and Strain; Circulation; Stream Function; Velocity Potential.

Inviscid Incompressible Flows: Elementary Flows and their Superposition (Uniform flow, Source Flow, Source- Sink Flows, Doublet Flow, Non- lifting Flow over a Circular Cylinder, Vortex Flow, Lifting Flow over a Cylinder), Kutta – Joukowski Theorem and the Generation of Lift, Non-lifting flows over arbitrary bodies: Numerical Source Panel method.

Incompressible flows over airfoils: Kutta Condition, Kelvin's Circulation Theorem, Starting Vortex, Classical Thin Airfoil Theory of Symmetric and Cambered Airfoils, Lift and Moment Coefficients, Center of Pressure, Predicting Zero Lift Angle of Attack, Flapped Airfoils, Effects of Thickness.

Finite Wing Theory: The Concept of Downwash and Induced Drag – Classical Theorems: Curved Vortex Filament, Biot-Savart Law, Helmholtz's Vortex Theorems – Method of Analysis: Prandtl's Classical Lifting Line Theory, Modern Numerical Lifting Line Method, Lifting Surface Theory, Modern Vortex Lattice Numerical Method.

Compressible Flow Theory: Compressibility, Isentropic flow through nozzles, shocks and expansion waves, Rayleigh and Fanno Flow, Potential equation for compressible flow

Compressible flow past airfoils: Linearized Velocity potential, Prandtl Glauert compressibility corrections, Critical Mach number, drag divergence Mach number, supercritical airfoils,

Linearized supersonic flow, Method of characteristics, Supersonic flow over airfoils and wings, subsonic/supersonic leading edge, Hypersonic flows, real gas effects, Newtonian theory, lift and drag in hypersonic flows.

Viscous Flows: Navier- Stokes Equations, Laminar and Turbulent Flows, Boundary Layers and Boundary Layer Thickness; Displacement Thickness; Momentum Thickness and Energy Thickness; Estimation of Skin Friction Drag from Momentum Thickness over a Flat Plate; Derivation of Prandtl's Boundary Layer Equation from Navier- Stokes Equation.

Automotive Aerodynamics: Automobiles as bluff bodies, flow field around the vehicle, drag force, types of drag force, analysis of aerodynamic drag, drag coefficient of vehicles, strategies for aerodynamic development, low drag profiles, fuel consumption and performance potential of vehicle aerodynamics, effects of platooning, Case studies on modern vehicles.

Learning Resources:

Text Books:

1. Anderson, J. D., Fundamentals of Aerodynamics, McGraw-Hill Education, 2016, 6th edition

Reference Books:

1. E. L. Houghton and P. W. Carpenter, Aerodynamics for Engineering Students, Butterworth -Heinemann, 2003, 5th edition
2. W. H. Hucho, Aerodynamic of Road Vehicles: From Fluid Mechanics to Vehicle Engineering, Butterworths Co., Ltd., 1997, 1st Edition.

Other Suggested Readings:

1. Introduction to Aerodynamics by Dr. K.P. Sinhamahapatra (IIT Kharagpur), NPTEL Course (Link: https://nptel.ac.in/courses/101/105/101105059/)
2. Experimental Gas/Aerodynamics, Prof. Job Kurian (IIT Madras), NPTEL Course (Link: https://nptel.ac.in/courses/101/106/101106040/)

ME 1439 **3-0-0(3)**

Artificial Intelligence For Cyber Physical Systems

Pre-Requisites: **None**

Course Outcomes:

CO-1	Understand the core concepts of Cyber Physical Systems and Industry 4.0
CO-2	Apply AI, ML and Deep Learning concepts to Manufacturing Systems
CO-3	Apply the IoT and IIoT concepts on Cyber Physical Systems
CO-4	Examine the Sensors, actuators and their performance using simulation and experimental analysis
CO-5	Evaluate the Digital twins for a given case study

Course Articulation Matrix:

	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6	PO-7	PO-8	PO-9	PO-10	PO-11	PO-12	PSO-1	PSO-2
CO-1	2	3	3			3	3	3	3		2	3	3	3
CO-2				3		3	3	3	3		3	3	3	3
CO-3						3	3	3	3			3	3	3
CO-4	2			3	3	3	3	3	3	3		3	3	3
CO-5		3				3	3	3	3	3	3	3	3	3

1 - Slightly; **2 - Moderately;** **3 - Substantially**

Syllabus:

Module 1: Industry 4.0, and its Key issues; Models for Cyber Physical Systems.

Module 2: Introduction of Artificial Intelligence, Machine Learning and Deep learning components; Overview of supervised and unsupervised learning.

Module 3: CPS HW platforms: Processors, Sensors, Actuators, CPS Network, CPS SW stack RTOS, Scheduling Real Time control tasks; Basic Data formats, databases and operations; Statistics and probability basics, regression and correlation; Server client programming; Communication using WIFI, Bluetooth, WANs. Introduction to cloud computing and Fog computing.

Module 4: Introduction to Raspberry Pi; Installation, controlling and integrating of Raspbian OS on Raspberry Pi with different sensors; Data acquisition using Raspberry Pi; Analysis of stateflow implementation using Matlab toolboxes, and Mapping software components to ECUs.

Module 5: Introduction of Digital twins; architectures, frameworks; Systematic approach for implementation of Digital twins in organisations; Case studies: AI and CPS approaches on various cases of Manufacturing Systems.

Learning Resources:

Text Books:

1. Rajkumar, Dionisio De Niz and Mark Klein, Cyber-Physical Systems, Wesley Professional.
2. Rajeev Alur, Principles of Cyber-Physical Systems, MIT Press, 2015.
3. Robert Levine, A Comprehensive guide to AI and Expert Systems, McGraw Hill Inc, 1986.
4. E. A. Lee and S. A. Seshia, Introduction to Embedded Systems: A Cyber-Physical Systems Approach, 2011.
5. C. Cassandras, S. Lafortune , Introduction to Discrete Event Systems, Springer 2007.
6. Constance Heitmeyer and Dino Mandrioli, Formal methods for real-time computing, Wiley publisher, 1996.

ME 1441 **3-0-0(3)**

TOOL DESIGN

Pre-Requisites: **NONE**

Course Outcomes:

CO-1	Design Locating and Clamping systems for the given component based on geometrical and dimensional features.
CO-2	Design progressive, compound or combination dies for producing a given component.
CO-3	Design single point and multipoint cutting tools for conventional and CNC Machining.
CO-4	Design jigs and fixtures for conventional and NC machining.
CO-5	Design Locating and Clamping systems for the given component based on geometrical and dimensional features.

Course Articulation Matrix:

	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6	PO-7	PO-8	PO-9	PO-10	PO-11	PO-12	PSO-1	PSO-2
CO-1	3	2	-	-	-	2	-	-	-	-	-	-	3	2
CO-2	3	2	-	-	-	2	-	-	-	-	-	-	3	2
CO-3	3	-	-	-	-	2	-	-	-	-	-	-	3	2
CO-4	3	2	-	-	2	2	-	-	-	-	-	-	3	2
CO-5	3	2	-	-	-	2	-	-	-	-	-	-	3	2

1 - Slightly; **2 - Moderately;** **3 - Substantially**

Syllabus:

Introduction: Tool design – An overview, Introduction to Jigs and fixtures.

Work holding devices: Basic principle of six-point location, Locating methods and devices, Principle of clamping and Types of clamps.

Design of jigs: Type of Drill bushes, Classification of drill jigs, Design of drill jigs.

Design of fixtures: Design of milling fixtures, Design of turning fixtures.

Introduction of press tool design: Introduction to Die cutting operations, Introduction to press and classifications, Die set assembly with components, Introduction to Centre of pressure, Examples of center of pressure, Design of piercing die, Design of blanking die, Progressive, Compound and Combination dies.

Design of cutting tools: Introduction to cutting tools, Design of single point tool, Design of drill bit, Design of milling cutter.

Brief introduction of NC machines work holding devices: Tool design for NC machines- An introduction, Fixture design for NC Machine, cutting tools for NC Machine, Tool holding methods for NC Machine, ATC and APC for NC Machine, Tool presetting for NC Machine.

Learning Resources:

Text Books:

1. F. W. Wilson, Fundamentals of Tool Design, ASME, PHI, 2010
2. Donaldson C, G. H. Lecain and V. C. Goold, Tool Design, TMH, 2010

Reference Books:

1. Prakash Joshi, Jigs and Fixtures Design Manual, McGraw-Hill, 2002, 2nd Edition
2. K. Venkataraman, Design of Jigs, Fixtures and Press Tools, Wiley Athena Academic, 2015, 1st Edition

ME 1443 **3-0-0 (3)**

Total Quality Management

Pre-Requisites: **None**

Course Outcomes:

CO-1	Understand quality management philosophies, techniques, and frameworks
CO-2	Adopt TQM methodologies for continuous quality improvement
CO-3	Identify the areas of improvement through measurement of cost of poor quality, effectiveness and efficiency of processes
CO-4	Apply TQM process and concepts to enhance the performance of systems
CO-5	Understand the implications of quality management standards and systems

Course Articulation Matrix:

	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6	PO-7	PO-8	PO-9	PO-10	PO-11	PO-12	PSO-1	PSO-2
CO-1	2							3	2	2	2	2	2	2
CO-2	2					2		3	2	2	2	2	2	2
CO-3	2				2	3		3	2	2	2	2	3	2
CO-4	2	2		3	3	2		3	3	3	3	2	2	3
CO-5	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

Learning Resources:

Text Books:

1. Total Quality Management, Dale H.Besterfiled, Pearson Education, Delhi, 2015, 4th Edition .

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

ME 1445 **3-0-0 (3)**

MICRO AND NANO MANUFACTURING

Pre-Requisites: **None**

Course Outcomes:

CO1	Understand different techniques for the synthesis and characterization of nano-materials
CO2	Design and analyze methods and tools for micro and nano-manufacturing.
CO3	Select micro and nano-manufacturing methods and identify key variables to improve the quality of MEMS.
CO4	Choose appropriate industrially viable process, equipment and tools for a specific product.

Course Articulation Matrix:

	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6	PO-7	PO-8	PO-9	PO-10	PO-11	PO-12	PSO-1	PSO-2
CO-1	3	3	2	2	3						2	2	2	2
CO-2	2	2	2	3	2						2	2	2	2
CO-3	3	2	2	2	3						2	2	2	2
CO-4	3	3	3	2	3						2	3	2	2

1 - Slightly; **2 - Moderately;** **3 - Substantially**

Syllabus:

Introduction: Importance of Nano-technology, Emergence of Nanotechnology, Bottom-up and Top-down approaches, challenges in Nanotechnology, Scaling Laws in Mechanics, fluids, thermodynamics, Electromagnetism, tribology and Examples.

Nano-materials Synthesis and Processing: Methods for creating Nanostructures; Processes for producing ultrafine powders- Mechanical grinding; Wet Chemical Synthesis of nano-materials- sol-gel process, Liquid solid reactions; Gas Phase synthesis of nano-materials.

Structural Characterization: X-ray diffraction, Optical Microscope and their description, Scanning Electron Microscopy (SEM), TEM and EDAX analysis, Scanning Tunneling Microscopy (STM), Atomic force Microscopy (AFM).

Micro fabrication Techniques: Lithography – LIGA, Thin Film Deposition and Doping, Etching and Substrate Removal, Substrate Bonding, MEMS Fabrication Techniques, Bulk Micromachining, Surface Micromachining, High- Aspect-Ratio Micromachining

Nanofabrication Techniques: Laser based nana manufacturing, E-Beam and Nano-Imprint Fabrication, Epitaxy and Strain Engineering, Scanned Probe Techniques, Self-Assembly and Template Manufacturing.

MEMS devices and applications: Pressure sensor, inertial sensor, Optical MEMS and RF-MEMS, Micro-actuators for dual-stage servo systems.

Learning Resources:

Text Books:

1. Tai-Ran Hsu, MEMS and Microsystems: Design and Manufacture, McGraw- Hill, 2008

2. Marc Madou, Fundamentals of Microfabrication: The Science of Miniaturization, CRC Press, 2002, Second Edition.
3. Mark James Jackson, Microfabrication and Nanomanufacturing, CRC Press, 2005.

Reference Books:

1. Gabor L. Hornyak, H.F Tibbals, Joydeep Dutta & John J Moore, Introduction to Nanoscience and Nanotechnology, CRC Press, 2009.
2. Ray F. Egerton, Physical Principles of Electron Microscopy: An Introduction to TEM, SEM, and AEM, Springer, 2005.
3. Robert F Speyer, Thermal Analysis of Materials, Marcel Dekker Inc. New York, 1994.
4. B.D. Cullity, Elements of X-Ray Diffraction, Prentice Hall, 2002, 3rd edition.

ME 1447 **3-0-0 (3)**

TRIBOLOGY

Pre-Requisites: **None**

Course Outcomes:

CO-1	Understand the fundamentals of tribology and associated parameters.
CO-2	Apply concepts of tribology for the performance analysis and design of components experiencing relative motion.
CO-3	Analyze the surface properties for predicting their tribological properties.
CO-4	Identify the lubrication regime for the given mechanical application.

Course Articulation Matrix:

	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6	PO-7	PO-8	PO-9	PO-10	PO-11	PO-12	PSO-1	PSO-2
CO-1	3	2	2	2	2	2	1				2	2	3	2
CO-2	3	2	2	2	3	2	1				2	2	3	3
CO-3	3	2	3	3	3	2	1				2	2	3	3
CO-4	3	2	3	3	3	2	1				2	2	3	3

1 - Slightly; **2 - Moderately;** **3 - Substantially**

Syllabus:

Introduction to tribology: Historical background, practical importance, and subsequent use in the field. Lubricants: Types and specific field of applications. Properties of lubricants,viscosity, its measurement, effect of temperature and pressure on viscosity, lubrication types, standard grades of lubricants, and selection of lubricants.
Friction and wear: Origin of sliding friction, Causes of Friction, friction theories, measurement methods, friction of metals and non-metals. the interfaces between two or more bodies in relative motion. Classification and mechanisms of wear, delamination theory, debris analysis, testing methods and standards. friction and wear mechanisms for metals, polymers, and ceramics, including abrasive wear, delamination theory, tool wear, erosive wear, wear of polymers and composites; Related case studies.
Surface engineering: Concept and scope of surface engineering. Surface modification – transformation hardening, surface melting, thermo chemical processes. Surface Coating – plating,fusion processes, vapor phase processes. Selection of coating for wear and corrosion resistance.
Lubrication: Types of lubricants, Objectives and selection of lubricant, Physical properties of lubricants, Regimes of lubrication - hydrodynamic, Elasto-hydrodynamic, mixed and boundary lubrication, Reynolds' equation, Hydrodynamic lubrication of roughened surfaces

Learning Resources:

Text Books:

1. Stachowaik, G.W., Batchelor, A.W., Engineering Tribology, Elsevier, 2010, 3rd Ed.
2. Stolarski TA, Tribology in Machine Design, Butterworth Heinemann, 2000

Reference Books:

1. B. Bhushan, Introduction to Tribology, John Wiley & Sons, Inc., New York, 2002
2. Andras Z. Szeri, Fluid film lubrication theory and design, Cambridge University press, 1998

ME 1449 **3-0-0 (3)**

FRACTURE MECHANICS

Pre-Requisites: None

Course Outcomes:

CO-1	Understand the concept of crack propagation leading to fracture failure.
CO-2	Analyze the fracture strength of mechanical components under different fracture modes.
CO-3	Apply fracture mechanics principles for determining Fracture Parameters using Experimental Methods.
CO-4	Design mechanical components against fracture
CO-5	Analyze the mechanical components against fracture through Non-Destructive Testing.

Course Articulation Matrix:

	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6	PO-7	PO-8	PO-9	PO-10	PO-11	PO-12	PSO-1	PSO-2
CO-1	3	3	3	1	1							2	2	2
CO-2	3	3	2	2	2							2	2	2
CO-3	3	3	2	3	2							2	2	2
CO-4	3	3	2	2	3							3	2	3
CO-5	3	3	2	3	3							2	2	2

1 - Slightly; 2 - Moderately; 3 - Substantially

Syllabus:

Introduction: Brittle and Ductile Fracture, Modes of Fracture Failure, Surface Energy, Griffith's Dilemma, Realization and Analysis. Energy Release Rate, Energy Release Rate of DCB Specimen, Anelastic Deformation at Crack-tip, Crack Resistance, Stable and Unstable Crack Growth, Critical Energy Release Rate.

Stress Intensity Factor: Linear Elastic Fracture Mechanics (LEFM), Stress and Displacement Fields in Isotropic Elastic Materials, Westergaard's Approach.

SIF of More Complex Cases: Applications of Westergaard Approach, Crack in a Plate of Finite Dimensions, Edge Cracks, Embedded Cracks, The Relation between GIand KI, Critical Stress Intensity Factor.

J-Integral: Definition of the J-Integral, Path Independence, Stress-Strain Relation, Experiments to Determine the Critical J-Integral,Comments on the Numerical Evaluation ofJ- Integral, A Simplified Relation for the J-Integral, Applications to Engineering Problems.

Test Methods: KIC-Test Technique, Test Methods to Determine JIC ,Test Methods to Determine GIC and GIIC ,Determination of Critical CTOD.

Fracture Parameters: Direct Methods to Determine Fracture Parameters. Indirect Methods to Determine Fracture Parameters. Mixed Mode Crack Initiation and Growth.

Crack Detection through Non-Destructive Testing: Examination through Human Senses, Liquid

Penetration Inspection, Ultrasonic Testing, Radiographic Imaging, Magnetic Particle Inspection.

Learning Resources:

Text Books:

1. Prashant Kumar, Elements of fracture mechanics, Tata McGraw-Hill Education, 2009

Reference Books:

1. Anderson, Ted L., Fracture mechanics: fundamentals and applications, CRC press, 2017
2. Broek, David, Elementary engineering fracture mechanics, Springer Science & Business Media, 2012
3. S.T. Rolfe and J.M. Barson, Fracture and Fatigue control in Structures, Prentice Hall Inc. New Jersy, 1977
4. M.F. Kanninen and C.H. Popelar, Advanced Fracture Mechanics, Oxford University Press, 1985
5. J.W. Hutchinson, Nonlinear Fracture Mechanics, Department of Solid Mechanics, The Technical University of Denmark Publications, 1979
6. Maiti, Surjya Kumar, Fracture mechanics: Fundamentals and applications. Cambridge University Press, 2015

Professional Electives - VI, VII and VIII

ME 1422 **3-0-0 (3)**

Introduction to Turbulence

Pre-Requisites: **None**

Course Outcomes:

CO-1	Understand the origin, statistical nature and applications of Turbulent flows.
CO-2	Derive the Reynolds averaged Navier-Stokes equations to predict turbulence transport
CO-3	Understand the physics of turbulent transport for free-shear and wall bounded flows
CO-4	Derive the turbulence models and analyze various complex turbulent flows.

Course Articulation Matrix:

	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6	PO-7	PO-8	PO-9	PO-10	PO-11	PO-12	PSO-1	PSO-2
CO-1	2	2	3	1	1	2	2	1	1	1	1	2	2	2
CO-2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
CO-3	2	2	2	3	2	2	2	3	3	3	3	2	2	2
CO-4	2	2	2	2	3	2	2	2	2	2	2	3	2	3

1 - Slightly; **2 - Moderately;** **3 - Substantially**

Syllabus:

Introduction: The nature of turbulence, Consequences of Turbulence, Origin of turbulence, Examples of Laminar-Turbulent Transition, Laminar and Turbulent Boundary layers, Length scales of turbulent flows, Turbulent flows in industrial applications.

Statistical description of turbulence: Random nature of turbulence, Characterization of random variables, Two-point correlation functions and spectra, Probability density functions and averaging.

Governing equations of Turbulent Transport: Eulerian and Lagrangian fields, Continuity, Momentum and Scalar transport equations, The Reynolds decomposition, Equations of Mean Flow (Momentum and Scalar transport), Reynolds Stresses, Gradient diffusion and Turbulent viscosity hypothesis, Estimation of Reynolds Stresses

The scales of turbulent motion: Energy Cascade and Kolmogorov Hypothesis, Spectral view of energy cascade, Limitations, Shortcomings and refinements

Free-shear flows: Plane shear flows in Turbulent wakes, jets and mixing layers, Streamwise and cross-stream momentum equations, Momentum integral and momentum thickness

Wall-bounded flows: Turbulent boundary layers on smooth wall, Inertial sublayer, Core region, Logarithmic frictional law, Viscous sublayer, Turbulent flow in pipe, Turbulent scalar transport in wall bounded flows.

Modelling and Simulation of turbulent flows: History of turbulence modelling, Reynolds-Averaged Navier Stokes Equations, The Closure Problem, Boussinesq Eddy-viscosity approximation, Mixing length hypothesis, Algebraic Models, One-equation and two-equation models, Application of various turbulence models to free shear flows and wall bounded flows, Near wall treatment, Direct Numerical Simulation, Large Eddy Simulation and related techniques.

Learning Resources:

Text Books:

1. Stephen B. Pope, Turbulent Flows - Cambridge University Press 2000
2. Biswas, G., and V. Eswaran, eds. Turbulent flows: Fundamentals, experiments and modeling, CRC Press, 2002.

Reference Books:

1. Hendrik Tennekes and John L. Lumley, A First Course in Turbulence, MIT Press 1972
2. Peter Davidson, Turbulence: An Introduction for Scientists and Engineers, Second Edition, Cambridge University Press, Oxford University Press; 2015.

Online Resources:

1. Introduction to Turbulence by Prof. Gautam Biswas (IIT Kanpur), NPTEL Course (Link: https://nptel.ac.in/courses/112/104/112104120/)
2. Introduction to Turbulent Flows and their prediction by Prof. E.G. Tulapurkara (IIT Madras), NPTEL Course (Link: https://nptel.ac.in/courses/101/106/101106060/)

ME 1424 **3-0-0 (3)**

HYBRID ELECTRIC VEHICLES

Pre-Requisites: **None**

Course Outcomes:

CO-1	Understand the need for hybrid electric vehicles and classify based on configuration
CO-2	Identify power sources for hybrid electric vehicles
CO-3	Analyse plug-in hybrid systems with different energy storage devices
CO-4	Evaluate the HEV configurations with battery, hybrid and fuel cell electric vehicles

Course Articulation Matrix:

	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6	PO-7	PO-8	PO-9	PO-10	PO-11	PO-12	PSO-1	PSO-2
CO-1	2	1	3	3	3	2	–	–	–	–	–	–	–	–
CO-2	1	2	3	3	3	2	–	–	–	–	–	–	–	–
CO-3	1	2	3	3	3	1	–	–	–	–	–	–	–	–
CO-4	2	1	2	2	2	1	–	–	–	–	–	–	–	–

1 - Slightly; **2 - Moderately;** **3 - Substantially**

Syllabus:

Introduction: Sustainable Transportation - Population, Energy, and Transportation - Environment - Economic Growth – Emissions regulations and norms- impact of modern drivetrains on energy supplies-New Fuel Economy Requirement Emergence of Electric Vehicles- Basics of the EV - Constituents of an EV -Vehicle and Propulsion Loads.

HEV Fundamentals: Classification- Hybridization of the Automobile-Mild Hybrids, Full Hybrids, Plug-In Hybrids and Electric Vehicles with Range Extender Hybrids- Architectures of HEVs - Series HEVs Parallel HEVs - Series–Parallel HEVs - Complex HEVs - Diesel and other Hybrids - Other Approaches to Vehicle Hybridization Basics of the HEV-Importance of HEV- Constituents of an HEV –Vehicle Model - Vehicle Performance - HEV Powertrain Component Sizing - Series Hybrid Vehicle - Parallel Hybrid Vehicle - Electrically Peaking Hybrid Concept - Gradeability Requirement -Selection of Gear Ratio from ICE to Wheel - Wheel Slip Dynamics.

Plug-In Hybrid Electric Vehicles: Basics of Plug-In Hybrid Electric Vehicle (PHEV) - Constituents of a PHEV - Comparison of HEV and PHEV - Basics of Fuel Cell Vehicles (FCVs) - Constituents of a FCV-Some Issues Related to Fuel Cells-Introduction to PHEVs - PHEVs and EREVs - Blended PHEVs - Electricity for PHEV Use -PHEV Architectures - Equivalent Electric Range of Blended PHEVs - Fuel Economy of PHEVs - Well-to-Wheel Efficiency - PHEV Fuel Economy - Utility Factor - Power Management of PHEVs - Vehicle-to-Grid Technology(V2G) - PHEV Battery Charging - Impact of G2V - The Concept of V2G-Advantages of V2G - Case Studies of V2G.

Electric Machines and Drives in HEVs: Introduction - Induction Motor Drives – Principle of Induction Motors - Equivalent Circuit of Induction Motor - Speed Control of Induction Machine - Variable Frequency, Variable Voltage Control of Induction Motors – Efficiency and Losses of Induction Machine - Permanent Magnet Motor Drives - Basic Configuration of PM Motors - Basic Principle and Operation of PM Motors - Unsaturated Motor -Saturated Motor.

Electric Energy Sources and Storage Devices: Introduction – Characterization of Batteries - Battery Capacity - Energy Stored in a Battery - State of Charge in Battery (SOC) and Measurement of SOC - SOC

Determination - Direct Measurement - Amp-hr Based Measurement - Some Better Methods - Initialization Process - Depth of Discharge (DOD) of a Battery - Specific Power and Energy Density - Ampere-Hour (Charge and Discharge) Efficiency - Number of Deep Cycles and Battery Life - Some Practical Issues About Batteries and Battery Life- Battery Management Implementation - Comparison of Energy Storage Technologies.

Fundamentals of Regenerative Braking: Braking Energy Consumed in Urban Driving - Braking Energy versus Vehicle Speed - Braking Energy versus Braking Power Braking Power versus Vehicle Speed - Braking Energy versus Vehicle Deceleration Rate - Braking Energy on Front and Rear Axles - Brake System of EV, HEV, and FCV.

Special Hybrid Vehicles: Brief Introduction of Hydraulic Hybrid Vehicles – Regenerative Braking in HHVs-Off-Road HEVs - Hybrid Excavators - Hybrid Excavator Design Considerations - Diesel HEVs Electric or Hybrid Ships- Locomotives.

Learning Resources:

Text Books:

1. Modern Electric, Hybrid Electric, and Fuel Cell Vehicles, Mehrdad Ehsani, Yimin Gao, Stefano Longo and Kambiz Ebrahimi, CRC Press, 2018, II Edition.
2. Hybrid Electric Vehicles Principles and Applications with Practical Perspectives, Chris Mi, M. Abul Masrur John Wiley & Sons, Inc.,2018, II Edition.

Reference Books:

1. Electric vehicle technology explained, John Lowry and James Larmine, John Wiley and Sons, 2012.
2. Electric and Hybrid Vehicles: Design Fundamentals, Iqbal Hussein, CRC Press, 2003.

Other Suggested Readings:

1. Introduction to Hybrid and Electric vehicles by Dr. Praveen Kumar and Prof. S. Majhi (IIT Guwahati), NPTEL Course (Link: https://nptel.ac.in/courses/108/103/108103009/)

ME 1426 **3-0-0 (3)**

FLEXIBLE MANUFACTURING SYSTEMS

Pre-Requisites: **None**

Course Outcomes:

CO-1	Classify and distinguish FMS and other manufacturing systems including job-shop and mass production systems.
CO-2	Explain processing stations and material handling systems used in FMS environments.
CO-3	Design and analyze FMS using simulation and analytical techniques.
CO-4	Describe tool management in FMS.
CO-5	Analyze the production management problems in planning, loading, scheduling, routing and breakdown in a typical FMS.

Course Articulation Matrix:

	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6	PO-7	PO-8	PO-9	PO-10	PO-11	PO-12	PSO-1	PSO-2
CO-1	3	2	2	1	2	1	1	1	1	1	1	1	3	2
CO-2	3	3	2	2	2	1	1	1	1	1	1	1	3	2
CO-3	3	3	3	3	3	1	1	1	2	2	2	2	3	3
CO-4	3	2	2	2	3	1	1	1	2	2	2	2	3	2
CO-5	3	3	3	3	3	2	2	2	2	3	3	3	3	3

1 - Slightly; **2 - Moderately;** **3 - Substantially**

Syllabus:

Understanding of FMS: Evolution of Manufacturing Systems, FMS: Definition, objective and Need, FMS: components, Merits, Demerits and Applications, Flexibility in Pull and Push type.

Classification of FMS Layout: FMS: Layouts and their Salient features, Single line, dual line, loop, ladder, robot centre type etc.

Salient features of processing stations: Processing stations- Machining Centers, Turning centre, Coordinate measuring machine (CMM), Washing/ Deburring station.

MHS; An introduction: Material Handling System Conveyor, Robots, Automated Guided Vehicle (AGV), Automated Storage Retrieval System (ASRS).

Management Technology: Tool Management, tool magazine, Tool preset, identification, Tool monitoring and fault detection, FMS: Configuration planning and routing, FMS: Production Planning and Control, FMS: Scheduling and loading.

Design of FMS: FMS: Performance Evaluation introduction, Analytical model of FMS, Simulation model of FMS.

Case studies: Typical examples /case studies of FMS.

Learning Resources:

Text Books:

1. William W Luggen, “Flexible Manufacturing Cells and System” Prentice Hall of Inc New Jersey, 1991
2. Reza A Maleki “Flexible Manufacturing system” Prentice Hall of Inc New Jersey, 1991
3. John E Lenz “Flexible Manufacturing” marcel Dekker Inc New York, 1989.
4. Groover,M.P “Automation, Production Systems and Computer Integrated Manufacturing”, Prentice Hall of India Pvt.Ltd. New Delhi 2009

ME 1428 **3-0-0 (3)**

Supply Chain Management

Pre-Requisites: **None**

Course Outcomes:

CO-1	Understand the decision phases and apply competitive and supply chain strategies.
CO-2	Understand drivers of supply chain performance.
CO-3	Analyze factors influencing network design.
CO-4	Analyze the role of forecasting in a supply chain
CO-5	Understand the role of aggregate planning, inventory, IT and coordination in a supp chain.

Course Articulation Matrix:

	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6	PO-7	PO-8	PO-9	PO-10	PO-11	PO-12	PSO-1	PSO-2
CO-1	2		2		2	1		2	2	2	2	2	2	2
CO-2	2	1	2		2	1		3	3	3	3	3	3	3
CO-3	3	1	2	2	2	1		2	2	2	2	2	2	2
CO-4	2		2	2	2	1		2	2	2	2	2	2	2
CO-5	2	1	2	3	2	1		2	2	2	2	2	2	2

1 - Slightly; **2 - Moderately;** **3 - Substantially**

Syllabus:

Strategic Framework: Introduction to Supply Chain Management, Decision phases in a supply chain, Process views of a supply chain: push/pull and cycle views, Achieving Strategic fit, Expanding strategic scope.

Supply Chain Drivers and Metrics: Drivers of supply chain performance, Framework for structuring Drivers, Obstacles to achieving strategic fit.

Designing Supply Chain Network: Factors influencing Distribution Network Design, Design options for a Distribution network, E-Business and Distribution network, Framework for Network Design Decisions, Models for Facility Location and Capacity Allocation.

Forecasting in SC: Role of forecasting in a supply chain, Components of a forecast and forecasting methods, Risk management in forecasting.

Aggregate Planning and Inventories in SC: Aggregate planning problem in SC, Aggregate Planning Strategies, Planning Supply and Demand in a SC, Managing uncertainty in a SC: Safety Inventory.

Coordination in SC: Modes of Transportation and their performance characteristics, Supply Chain IT framework, Coordination in a SC and Bullwhip Effect.

Emerging Trends and Innovations in Supply Chain Management: Digital transformation and technology in supply chains, Role of IoT, Big Data, and AI in supply chain management sustainability and resilience in supply chains, Global strategies and risk management

Learning Resources:

Text Books:

1. Sunil Chopra and Peter Meindl, Supply Chain Management - Strategy, Planning and Operation, Pearson Education Asia, 2021, 7th Edition.
2. David Simchi-Levi, PhilpKamintry and Edith Simchy Levy, Designing and Managing the Supply Chain - Concepts Strategies and Case Studies, Tata-McGraw Hill, 2007, 3rd Edition.
3. John J Coyle, Managing Supply Chains A Logistics Approach', Cengage Learning, 2019, 10th Edition.
4. Jeremy F Shapiro, Modelling the Supply Chain',Cengage Learning, 2019, 3rd Edition.

Other Suggested Readings:

1. https://scm.mit.edu/

ME 1430 **3-0-0 (3)**

Additive Manufacturing Processes and Applications

Pre-Requisites: **None**

Course Outcomes:

CO-1	Develop preprocess data for the additive manufacturing process
CO-2	Describe the working principles of each AM process
CO-3	Identify suitable AM process for any given industrial application
CO-4	Apply design for AM guidelines to fabricate optimized components
CO-5	Select the postprocessing and testing method for the given application

Course Articulation Matrix:

	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6	PO-7	PO-8	PO-9	PO-10	PO-11	PO-12	PSO-1	PSO-2
CO-1	2	2			2								3	2
CO-2	2	3			2								3	2
CO-3	2	2			2	3							3	2
CO-4	2	3			2	3			3			3	3	2
CO-5	2	2			2								3	2

1 - Slightly; **2 - Moderately;** **3 - Substantially**

Syllabus:

Computer Aided Design (CAD) and Additive Manufacturing (AM) Preprocessing: Introduction to Geometric Modelling. Modelling of Synthetic Curves like Hermite, Bezier and B-spline; Parametric Representation of Freeform Surfaces and Solids. CAD Data Exchange Formats, Input File Sources and Characteristics, AM Data File Formats and Software, STL File Errors and Manipulation, AM Process Chain, Part Orientation and Support Generation, Model Slicing and Contour Data Organisation, Hatching Strategies, AM Toolpaths Generation and Process Plan, Build Preparation and AM Process Simulation.

Additive Manufacturing Processes: Classification of AM Processes. Description, Process Parameters, Material Selection and Characterisation, Application, Strengths and Weaknesses of Vat Photopolymerization, Material Jetting, Binder Jetting, Material Extrusion, Sheet Lamination, Powder Bed Fusion and Directed Energy Deposition Processes; *Other Processes:* Aerosol Printing and Bio-plotter. *Construction of DIY Printers:* Motion System, Frame/Chassis, Print Bed, Extruder, Electronics.

Additive Manufacturing Applications: An Overview of AM Applications, *Aerospace:* Aerospace Materials and their Requirements, Qualification and Certification of AM Parts, Aerospace Case Studies. *Medical:* Medical Scanning Technologies, Biomaterials, Planning and Simulation of Complex Surgeries, Design and Fabrication of Customized Implants, Medical Case Studies. *Automobile:* Prototyping, Jigs and Fixtures, Components of Electric Vehicles, Formula 1, Cooling Ducts, Intake Manifolds, Automobile Case Studies. *Other Applications of AM:* Marine, Railway, Oil and Gas, Construction, Retail Industry, Arts and Architecture, Fashion and Textile, Jewellery, Cion and Tableware, Weapons, Food, Packaging, and Toy Industry.

Design for AM (DfAM): Need for DfAM, AM Production Economics, General Guidelines for DfAM, Design to Minimise Print Time, Design to Minimise Post-processing, Design Guidelines for Part Consolidation,

DfAM Guidelines for AM Tooling Design, Design for Improved Functionality, Design for Minimal Material Usage, Lattice Structures in AM, Generative Design and AM, Topology Optimization for AM, Polymer AM Design Guidelines, Metal AM Design Guidelines, Modelling and Optimization of AM Processes, Guidelines for AM Process Selection.

Postprocessing and Testing of AM Parts: Need for Postprocessing in AM, *Surface Treatment Methods:* Subtractive Machining Methods, Thermal-based Methods, Abrasive-based Methods, Chemical Methods. *Surface Protection, Functionalization, and Decorative Methods.* Heat Treatment and Aging. Establish a Relationship between Processing Parameters, Resulting Microstructure, Mechanical Properties, Fatigue, Creep and Corrosion Resistance of AM Parts. *Testing of AM Parts:* Metrology Measurement Methods, Porosity and Density, Dimensions, Mechanical Measurement Methods, NDT Methods of AM Parts, AM Safety, AM Standards.

Learning Resources:

Text Books:

1. Mathematical Elements for Computer Graphics, David F. Rogers, J. A. Adams, Tata McGrawHill, 2008.
2. Additive Manufacturing Technologies, Ian Gibson, David Rosen, Brent Stucker, and Mahyar Khorasani, 3rd Edition, Springer, 2021.
3. Medical Modelling: The Application of Advanced Design and Rapid Prototyping Techniques in Medicine, Richard Bibb, Dominic Eggbeer and Abby Paterson, Woodhead, 2017.
4. A Practical Guide to Design for Additive Manufacturing, Diegel, Olaf, Axel Nordin, and Damien Motte, Springer, 2020.
5. Post-processing Techniques for Additive Manufacturing, Zafar Alam Faiz Iqbal, Dilshad Ahmad Khan, CRC Press, 2024.

Reference Books:

1. Geometric Modeling, Michael E. Mortenson, McGrawHill, 2013.
2. Rapid Prototyping: Laser-based and Other Technologies, Patri K. Venuvinod and Weiyin Ma, Springer, 2004.
3. Laser Additive Manufacturing: Materials, Design, Technologies, and Applications, Milan Brandt, Elsevier, 2017.
4. Additive Manufacturing for the Aerospace Industry, Francis Froes, Rodney Boyer, Elsevier, 2019.
5. Rapid Prototyping: 3D Printing and Additive Manufacturing Principles & Applications, Chua Chee Kai, Leong Kah Fai, 5th Edition. World Scientific, 2019.
6. Handbook of Post-Processing in Additive Manufacturing: Requirements, Theories, and Methods, Gurminder Singh, Ranvijay Kumar, Kamalpreet Sandhu, Eujin Pei, and Sunpreet Singh, CRC Press, 2024.

ME 1432 **3-0-0 (3)**

Project Management

Pre-Requisites: **NONE**

Course Outcomes:

CO-1	Understand the importance of projects and its phases.
CO-2	Analyze projects from marketing, operational and financial perspectives.
CO-3	Evaluate projects based on discount and non-discount methods.
CO-4	Develop network diagrams for planning and execution of a given project.
CO-5	Apply crashing procedures for time and cost optimization

Course Articulation Matrix:

	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6	PO-7	PO-8	PO-9	PO-10	PO-11	PO-12	PSO-1	PSO-2
CO-1						2		2			3	2	3	
CO-2	3	2						2			3	2	3	
CO-3	3	2	3	3							3	2	3	
CO-4		3	3	3	2						3	2	3	
CO-5	3	3	3	3	2						3	2	3	

1 - Slightly; **2 - Moderately;** **3 - Substantially**

Syllabus:

Introduction: Introduction to Project Management, History of Project Management, Project Life Cycle.

Project Analysis: Facets of Project Analysis, Strategy and Resource Allocation, Market and Demand Analysis, Technical Analysis, Economic and Ecological Analysis.

Financial Analysis: Financial Estimates and Projections, Investment Criteria, Financing of Projects.

Network Methods in PM: Origin of Network Techniques, AON and AOA differentiation, CPM network, PERT network, other network models.

Optimization in PM: Time and Cost trade-off in CPM, Crashing procedure, Scheduling when resources are limited.

Project Risk Management: Scope Management, Work Breakdown Structure, Earned Value Management, Project Risk Management.

Learning Resources:

Text Books:

1. Prasanna Chandra, Projects: Planning, Analysis, Selection, Financing, Implementation, and Review, McGraw Hill Education, 9th Edition, 2019.
2. David I. Cleland and Lewis R. Ireland, Project Management: Strategic Design and Implementation, McGraw-Hill, 5th Edition, 2006.
3. Jack R. Meredith and Samuel J. Mantel, Jr., Project Management: A Managerial Approach, John

Wiley & Sons, 10th Edition, 2017.

Reference Books:

1. Eliyahu M. Goldratt, The Critical Chain, North River Press, 2017.
2. Project Management Institute, A Guide to the Project Management Body of Knowledge, Seventh Edition, 2021

ME 1434 **3-0-0 (3)**

Reliability Engineering

Pre-Requisites: **NONE**

Course Outcomes:

CO-1	Understand the concepts of Reliability, Availability and Maintainability
CO-2	Develop hazard-rate models to know the behavior of components.
CO-3	Build system reliability models for different configurations.
CO-4	Assess reliability of components & systems using field & test data.
CO-5	Implement strategies for improving reliability of repairable and non-repairable systems.

Course Articulation Matrix:

	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6	PO-7	PO-8	PO-9	PO-10	PO-11	PO-12	PSO-1	PSO-2
CO-1			2	2			2	3	2	3	–	–	2	2
CO-2	2		2	2			3	3	3	3	–	–	3	3
CO-3	2		2	2	2		2	2	2	1	1	–	2	2
CO-4	2	2	2	2			2	2	3	2	–	–	2	2
CO-5	2	2	2	2	2		2	3	2	3	–	–	2	2

1 - Slightly; **2 - Moderately;** **3 - Substantially**

Syllabus:

Introduction: Probabilistic reliability, failures and failure modes, repairable and non-repairable items, pattern of failures with time, reliability economics.

Component Reliability Models: Basics of probability and statistics, hazard rate and failure rate, constant hazard rate model, increasing hazard rate models, decreasing hazard rate model, time-dependent and stress-dependent hazard models, bath-tub curve.

System Reliability Models: Systems with components in series, systems with parallel components, combined series-parallel systems, k-out-of-m systems, standby models, load sharing models, stress-strength models, reliability block diagram.

Life Testing and Reliability Assessment: Censored and uncensored field data, burn-in testing, acceptance testing, accelerated testing, identifying failure distributions and estimation of parameters, reliability assessment of components and systems.

Reliability Analysis and Allocation: Reliability specification and allocation, failure modes and effects and criticality analysis (FMECA), fault tree analysis, cut sets and tie sets approaches

Maintainability Analysis: Repair time distribution, MTBF, MTTR, availability, maintainability, preventive maintenance, introduction to reliability software

Learning Resources:

Text Books:

1. Charles E. Ebeling (2019) “An Introduction to Reliability and Maintainability Engineering”, 3rd

edition, Publisher: McGraw Hill Education.

2. Patrick D. T. O'Connor, Andre Kleyner (2012) "Practical Reliability Engineering", 5th edition, Publisher: Wiley.
3. Roy Billinton, Ronald N. Allan (1992) "Reliability Evaluation of Engineering Systems: Concepts and Techniques", 2nd edition, Publisher: Springer.
4. Mohammad Modarres, Mark P. Kaminskiy, VasiliyKrivtsov (2016) "Reliability Engineering and Risk Analysis: A practical guide", 3rd edition, Publisher: CRC Press.
5. Krishan B. Misra, "reliability analysis and prediction: a methodology oriented treatment", Publisher: Elsevier.

ME 1436 **3-0-0 (3)**

Material Characterization

Pre-Requisites: **None**

Course Outcomes:

CO-1	Identify advanced techniques available for characterization of materials
CO-2	Select constituent materials for producing a given composite
CO-3	Analyze defects and failure surfaces of materials
CO-4	Select a characterization technique for evaluating the behavior of materials

Course Articulation Matrix:

	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6	PO-7	PO-8	PO-9	PO-10	PO-11	PO-12	PSO-1	PSO-2
CO-1	2	2	3	2	3	1	2			2	3	3	2	3
CO-2	2	2	3	2	3	1	2			2	3	3	2	3
CO-3	3	2	3	2	3	1	2			2	3	2	2	3
CO-4	3	2	3	2	3	1	2			2	3	2	2	3

1 - Slightly; **2 - Moderately;** **3 - Substantially**

Syllabus:

Introduction: Overview of the course, material classification- metals and alloys, ceramics, polymers and composites, Importance of materials selection, property classification, Criteria for selection of materials, Ashby charts for materials selection

Introduction to Materials Characterization Techniques: Different techniques and their purposes; Introduction, Principle, construction and operation. Sample preparation for all the characterization.

Physical characterization of materials: Optical Microscopy, SEM,TEM, Density, Void content in materials,Electron Probe Micro Analyzer (EPMA), Atomic Force Microscopy (AFM), Thermogravimetric analysis (TGA), nano indentation, NMR spectroscopy, EDAX, FTIR, XRD

Mechanical characterization: Tensile test, flexural test, compression test, ILSS, creep, fatigue, Hardness, Impact test, Fracture toughness test, Principle, construction and operation working parameters, equipment operation.

Tribological characterization: Abrasive wear, Pin-on Disc, Erosion test, Corrosion test, sand abrasion, slurry erosion, scratch test, nano indent scratch test.

Learning Resources:

Text Books:

1. M.F. Ashby, Materials Selection in Mechanical Design, Butterworth Heinemann, 2005
2. Yang Leng, Materials Characterization-Introduction to Microscopic and Spectroscopic Methods, John Wiley & Sons (Asia) Pte Ltd, 2008.
3. ASM Handbook: Materials Characterization, ASM International, 2008

Reference Books:

1. V. T. Cherapin and A. K. Mallik: Experimental Techniques in Physical Metallurgy, Asia Publishing House, 1967.
2. George E. Dieter, Mechanical Metallurgy, McGraw Hill, 2nd Edition, 2005

ME 1438 **3-0-0 (3)**

HEATING, VENTILATION & AIR-CONDITIONING

Pre-Requisites: **None**

Course Outcomes:

CO-1	Understand the fundamentals of Psychrometry
CO-2	Apply human comfort indices and comfort chart to design indoor conditions of HVAC systems.
CO-3	Estimate heating and cooling loads for buildings according to ASHRAE procedures/ standards.
CO-4	Design and evaluate complete air distribution system including fan, duct, and installation requirements for a typical HVAC system.

Course Articulation Matrix:

	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6	PO-7	PO-8	PO-9	PO-10	PO-11	PO-12	PSO-1	PSO-2
CO-1	3	3	-	-	-	-	-	-	-	-	-	2	1	1
CO-2	3	3	3	-	-	2	2	-	2	-	2	2	2	2
CO-3	3	3	3	-	-	-	3	-	3	-	-	3	2	2
CO-4	3	3	3	-	-	-	3	-	3	-	-	3	3	3

1 - Slightly; **2 - Moderately;** **3 - Substantially**

Syllabus:

Introduction: Brief history of air conditioning and impact of air conditioning. HVAC systems and classifications, Heat Pumps

Psychrometry of Air Conditioning Processes: Thermodynamic properties of moist air, Important Psychrometry properties, Psychometric chart; Psychrometric process in air conditioning equipment, applied Psychrometry, air conditioning processes, air washers.

Comfort Air Conditioning: Thermodynamics of human body, metabolic rate, energy balance and models, thermoregulatory mechanism. Comfort & Comfort chart, Effective temperature, Factors governing optimum effective temperature, Design consideration. Selection of outside and inside design conditions.

Heat Transfer Through Building Structures: Solar radiation; basic concepts, sun-earth relationship, different angles, measurement of solar load, Periodic heat transfer through walls and roofs. Empirical methods to calculate heat transfer through walls and roofs using decrement factor and time lag method. Infiltration, stack effect, wind effect. CLTD/ETD method - Use of tables, Numerical and other methods, Heat transfer through penetration - Governing equations, SHGF/SC/CLF Tables

Load Calculation: Types of air-conditioning systems, General consideration, internal heat gains, system heat gain, cooling and heating load estimate.

Ventilation System: Introduction- Fundamentals of good indoor air quality, need for building ventilation, Types of ventilation system, Air Inlet system. Filters heating & cooling equipment, Fans, Duct design, Grills, Diffusers for distribution of air in the work place.

Learning Resources:

Text Books:

1. F.C. McQuiston& J.D. Parker, “Heating Ventilating and Air Conditioning- Analysis and Design”, 5th Ed., John Wiley & Sons, 2001.
2. J.L. Threlkeld, “Thermal Environmental Engineering”, 2nd Ed., Prentice-Hall, Inc., 1970.

Reference Books:

1. American Society of Heating, Refrigerating and Air-Conditioning Engineers, Handbooks: HVAC Applications, HVAC Systems & Equipment, ASHRAE, 2015.
2. R.C. Arora, “Refrigeration & Air conditioning”, PHI, 2010.

ME 1440 **3-0-0 (3)**

FUEL CELL TECHNOLOGY

Pre-Requisites: **None**

Course Outcomes:

CO-1	Understand fuel cell fundamentals
CO-2	Analyse the performance of PEM fuel cell system
CO-3	Demonstrate the operation of fuel cells
CO-4	Apply the modelling techniques for fuel cell systems

Course Articulation Matrix:

	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6	PO-7	PO-8	PO-9	PO-10	PO-11	PO-12	PSO-1	PSO-2
CO-1	2	3	2	3	–	–	–	–	–	–	–	2	2	1
CO-2	3	3	3	3	–	–	–	–	–	–	–	2	2	1
CO-3	2	2	2	1	1	–	–	–	–	–	–	2	2	1
CO-4	2	2	3	2	–	–	–	1	–	–	–	1	2	1

1 - Slightly; **2 - Moderately;** **3 - Substantially**

Syllabus:

Overview of Fuel Cells: Description of fuel cell, brief history, classification, working principle, Fuel cell basic chemistry and thermodynamics of fuel cell and performance.

Fuel Cell Thermodynamics: Thermodynamic Potentials, Heat Potential of a Fuel: Enthalpy of reaction, Reaction Enthalpies, Work Potential of a Fuel: Gibbs Free Energy, Relationship between Gibbs Free Energy and Electrical Work, Computing Reversible Voltages, Reversible Voltage Variation with Temperature, Reversible Voltage Variation with pressure, Reversible Voltage Variation with concentration: Nernst Equation, Fuel Cell Efficiency-Ideal and real fuel cell efficiency.

Fuel cell electrochemistry: electrode kinetics, types of voltage losses, polarization curve, fuel cell efficiency, Tafel equation, exchange currents.

Fuel Cell Modeling: A Basic Fuel Cell Model, 1-D PEM Fuel Cell Model,

Fuels for Fuel Cells: Hydrogen, Hydrocarbon fuels, effect of impurities such as CO, S and others, hydrogen generation and storage; limitations, recent advances.

Overview of fuel cell types: Phosphoric acid fuel cell (PAFC), Polymer electrolyte membrane fuel cell (PEMFC), Alkaline fuel cell (AFC), Molten carbonate fuel cell (MCFC), Solid-oxide fuel cell (SOFC) and other fuel cells.

PEM Fuel cell components: Main PEM fuel cell components, materials, properties and processes: membrane, electrode, gas diffusion layer, bi-polar plates, flow field plate design, Fuel cell operating conditions: pressure, temperature, flow rates, humidity. Direct methanol fuel cell, active and passive DMFC, methanol cross over and techniques to reduce, current collectors.

Main components of solid-oxide fuel cells: Cell stack and designs, Electrode polarization, testing of electrodes, cells and short stacks, Cell, stack and system modelling.

Fuel processing: Direct and in-direct internal reforming, Reformation of hydrocarbons by steam, CO2 and partial oxidation, Direct electro-catalytic oxidation of hydrocarbons, carbon decomposition, Sulphur tolerance and removal , Using renewable fuels for SOFCs.

Learning Resources:

Text Books:

1. Fuel Cell Fundamentals, Ryan O'Hayre, Suk-Won Cha Whitney Colella second edition, John Wiley & Sons, 2018.
2. PEM Fuel Cells: Theory and Practice, Franno. Barbir, (2nd Ed.) Elsevier/Academic Press, 2013.

Reference Books:

1. Fuel Cells and Their Applications, Karl Kordesch& Gunter Simader, VCH Publishers, 2001
2. Fuel Cell Technology Hand Book, Hoogers G., CRC Press, 2010

Other Suggested Readings:

1. NPTEL Courses
2. MIT Open Course Ware, etc.

ME 1442 **3-0-0 (3)**

Design for Manufacturing and Assembly

Pre-Requisites: None

Course Outcomes:

CO-1	Utilize Design-for-Manufacturing concepts for effective product development
CO-2	Estimate the cost of dies, molds and machined components based on die life.
CO-3	Formulate appropriate design rules for forging, sheet metal forming, machining and powder metallurgy processes
CO-4	Propose manual and automated assembly sequences using appropriate design rules

Course Articulation Matrix:

	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6	PO-7	PO-8	PO-9	PO-10	PO-11	PO-12	PSO-1	PSO-2
CO-1	3	2	2	2									2	2
CO-2	3	2	2	2									2	2
CO-3	3	2	2	2									2	2
CO-4	3	2	2	2									2	2

1 - Slightly; **2 - Moderately;** **3 - Substantially**

Syllabus:

Introduction: Overview of the course, Design for manufacturing, Typical Case studies, Innovative product and service designs.

Material Selection: Requirements for material selection, systematic selection of processes and materials, ASHBY charts

Design for Casting: Basic characteristics and Mold preparation, Sand casting alloys, Design rules for sand castings, Example calculations, Investment casting overview, Cost estimation, Number of parts per cluster, Ready to pour liquid metal cost, Design guide lines for Investment casting, Die casting cycle, Determination of optimum number of cavities, appropriate machine size, Die cost estimation, Design principles.

Design for Injection molding: Injection molding systems, Molds, molding cycle time, mold cost estimation, estimation of optimum number of cavities, Assembly techniques, Design Guidelines.

Design for Hot Forging: Characteristics of the forging process, forging allowances, flash removal, die cost estimation, die life and tool replacement costs.

Design for Sheet metalworking: Press selection, press brake operations, Design rules.

Design for Powder Metal processing: Powder metallurgy, tooling and presses for Compaction, Sintering, materials, heat treatments, Design guidelines.

Design for machining: Machining using single point cutting tools, multipoint cutting tools, abrasive wheels, Assembly, cost estimation for machined components, Design guidelines.

Design for Assembly: Historical Development, Choice of Assembly method, Social effects of automation, Design guidelines for Manual assembly, Analysis of an assembly, Development of a systematic DFA analysis method, DFA index, classification system for manual handling, Manual insertion and Fastening.

Learning Resources:

Text Books:

1. Geoffrey Boothroyd, Dewhurst P., Knight W., “Product design for manufacture and assembly”, CRC press, 2002
2. George E Dieter, “Engineering Design – A material processing approach”, 5th Edition, McGraw Hill International, 2003.

Reference Books:

1. ASM Handbook, “Design for manufacture”, 2000.

Other Suggested Readings:

1. https://nptel.ac.in/courses/112/101/112101005/

ME 1444 **3-0-0 (3)**

Advanced Materials Processing

Pre-Requisites: **NONE**

Course Outcomes:

CO-1	Select appropriate advanced manufacturing Processes materials and Surface finish.
CO-2	Select suitable welding processes for joining different materials
CO-3	Analyze metal removal mechanism in subtractive processes
CO-4	Identify appropriate advanced material processing techniques for different requirements and applications.
CO-5	Compare different advance material processing techniques for industry applications.

Course Articulation Matrix:

	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6	PO-7	PO-8	PO-9	PO-10	PO-11	PO-12	PSO-1	PSO-2
CO-1	2	3	2	3	–	–	–	–	–	–	–	2	2	1
CO-2	3	3	3	3	–	–	–	–	–	–	–	2	2	1
CO-3	2	2	2	1	1	–	–	–	–	–	–	2	2	1
CO-4	2	2	3	2	–	–	–	1	–	–	–	1	2	1
CO-5	2	3	2	3	–	–	–	–	–	–	–	2	2	1

1 - Slightly; **2 - Moderately;** **3 - Substantially**

Syllabus:

Overview and Prospective Challenges: Introduction to Advanced Materials Processing and Manufacturing. Laser Lubrication Techniques: Laser Processing Techniques. Ingot Metallurgy Routes: Conventional and Non-Conventional Casting Routes. Powder-Based Manufacturing Techniques: Powder Metallurgy Routes. Advanced machining processes - introduction of USM, AJM, ECM,EDM, LBM, and EBM; Advanced forming processes - electro-magnetic forming, explosive forming, electro-hydraulic forming, stretch forming, contour roll forming; Advanced welding processes - EBW, LBW, USW; Advanced foundry processes - metal mould, continuous, squeeze, vacuum mould, evaporative pattern, and ceramic shell casting. Characterization Techniques: Material Testing and Characterization.

Hybrid Processes: Process variables and applications and advantages Hybrid welding processes, hybrid welding process (TIG and Plasma welding, etc.).

Surface Coating: Coating Materials, Coating on different materials, Coating methods and its applications, Limitations.

Composite Materials Introduction, Classification of composites, Manufacturing methods: Spray Lay-Up, Wet/Hand Lay-up, Vacuum Bagging, Filament Winding, Pultrusion, Resin Transfer Moulding (RTM), Resin Film Infusion (RFI), Mechanical Properties -Stiffness and Strength

Learning Resources:

Text Books:

1. Bolokang, A. S., & Mathabathe, M. N. (2023). Advanced Materials Processing and Manufacturing: Research, Technology, and Applications. CRC Press.
2. Jaluria, Y. (2018). Advanced materials processing and manufacturing. Cham, Switzerland: Springer.
3. P. C. Pandey, H. S. Shan, Modern Machining Processes, Tata McGraw-Hill
4. Nadkarni S.V., Modern Arc Welding Technology, Oxford IBH Publishers, 1996.
5. Surender Kumar, Technology of Metal Forming Processes, Prentice- Hall, Inc., 2008.

Reference Books:

1. El-Hofy, H.. Advanced machining processes: nontraditional and hybrid machining processes, McGraw-Hill Professional, 2005.
2. Groover, M. P. Fundamentals of modern manufacturing: materials, processes, and systems. John Wiley & Sons, 2010.
3. Mamalis, A. G. Advanced manufacturing engineering. Journal of Materials Processing Technology, 161(1-2), 1-9, 2005.

Online Resources:

1. https://archive.nptel.ac.in/courses/113/105/113105081/
2. https://www.coursera.org/learn/material-science-engineering
3. https://handbook.monash.edu/2022/units/MTE4102

ME 1446 **3-0-0 (3)**

Lean Manufacturing & Six Sigma

Pre-Requisites: **None**

Course Outcomes:

CO-1	Discuss the basics of 6 SIGMA
CO-2	Elaborate the lean manufacturing tools.
CO-3	Illustrate about the deeper understanding of methodologies of Lean manufacturing.
CO-4	Describe the implementation and challenges of lean manufacturing.

Course Articulation Matrix:

	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6	PO-7	PO-8	PO-9	PO-10	PO-11	PO-12	PSO-1	PSO-2
CO-1	3		3		2				2			2	3	
CO-2	3		2		2				2		2		3	
CO-3	3		2		3		2	2	2				3	
CO-4	3		2		3		2	2	2			2	3	

1 - Slightly; **2 - Moderately;** **3 - Substantially**

Syllabus:

BASICS OF SIX SIGMA: Introduction to 6 Sigma, basic tools of six sigma like problem solving approach, standard deviation, normal distribution, various sigma levels with some examples, value for the enterprise, Variation, and sources of variation, Mean and moving the mean, Various quality costs, cost of poor quality.

INTRODUCTION TO LEAN MANUFACTURING TOOLS: Process Capability Indices, Cause and Effect diagram, Control Charts, Introduction to FMEA, APQP, PPAP. 3 foundational 6 Sigma methodologies: DMAIC, DMEDI, and Process Management DMEDI for process creation, DMAIC for process improvement and PDCA for sustaining improvements.

DEEPER UNDERSTANDING METHODOLOGIES: What is a process, Why Process management, Keys to process management, Difference between process management and 6 Sigma, Introduction to Deming cycle, PDCA, DMAIC and continuous improvement, DMEDI for creation process, DMAIC Vs DMEDI with examples, Introduction to Toyota Production System, Six Sigma and Production System integration.

LEAN ELEMENTS: Introduction to Lean Concepts like In-Built Quality, Concept of Right Part at the Right Time, Lead Time reduction, Optimum utilization of Capital, Optimum utilization of People. Understanding the Zero-defect concept and Metrics, Focus on Human Resources, Quality, Delivery, Cost. Building Zero defect capabilities, Cultural and Organizational aspects

IMPLEMENTATION AND CHALLENGES: Implementing Checks and Balances in the process, Robust Information Systems, Dashboard, follow up and robust corrective and preventive mechanism. Concept of Audits, and continuous improvement from gap analysis, risk assessments etc.

Learning Resources:

Text Books:

1. JM Juran& FM Gryna , Quality Planning and Analysis-. Tata Mc Graw Hill, 2017
2. Akhilesh N. Singh, Lean Manufacturing: Principles to Practice, L.B. Associates Pvt. Ltd. 2019

Reference Books:

1. The Toyota Way: 14 Management Principles , Tata Mc Graw Hill, 2020
2. Quality Council of India https://qcin.org/ & its library. https://qcin.org/nbqp/knowledge_bank/

Online Resources:

1. International Society of Six Sigma Professionals: https://isssp.org/about-us/
2. NPTEL / SWAYAM: https://nptel.ac.in/courses/110105123 : Six Sigma, Prof. Jitesh J Thakkar, IIT Kharagpur, Certification course.

ME 1448 **3-0-0 (3)**

Surface Coating Technology

Pre-Requisites: **NONE**

Course Outcomes:

CO-1	Decide the surface preparation methods suitable for different substrate materials
CO-2	Apply knowledge on properties offered by different Coatings based on the application requirement
CO-3	Understand & interpret testing &evaluation of metallic coatings
CO-4	Explain importance of specific coatings & its applications on specific Engineering components
CO-5	Understand the importance & role of surface modifications to achieve several technological properties

Course Articulation Matrix:

	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6	PO-7	PO-8	PO-9	PO-10	PO-11	PO-12	PSO-1	PSO-2
CO-1	3	2	3		2				2			2	3	2
CO-2	3	2	2		2				2		2		3	2
CO-3	3	3	2		3		2	2	2				3	3
CO-4	3	3	2		3		2	2	2			2	3	3
CO-5	3	2	3		2				2			2	3	2

1 - Slightly; **2 - Moderately;** **3 - Substantially**

Syllabus:

Surface engineering: Introduction to surface engineering, Scope of surface engineering for different engineering materials, Surface Preparation methods such as Chemical, Electrochemical, Mechanical: Sand Blasting, Shot peening, Shot blasting, Hydro-blasting, Vapor Phase Degreasing etc., Coatings: Classification, Properties and applications of Various Coatings.

Metallic coating: Hot Dipping, Galvanizing, Electrolytic and Electro less plating: Methodology used, mechanisms, important reactions involved, Process parameters and applications. Testing/ evaluation of metallic coatings.

Coating from Vapour Phase: PVD, and CVD: Various Methods used, mechanisms, important reactions involved, Process parameters and applications.

Different methods for surface modification: Surface modification by use of directed energy beams, Plasma, Sputtering & Ion Implantation. Surface modification by Friction stir processing. Surface composites.

Thermal spray coatings: Processes, Types of spray guns, Comparison of typical thermal spray processes, Surface Preparation, Finishing Treatment, Coating Structures and Properties, Applications.

Diffusion Coating: Carburizing, Carbonitriding, Siliconizing, Chromizing, Aluminizing, Boronizing, Boronitriding: Various Methods used, mechanisms, important reactions involved, Process parameters and applications.

Case studies based on coatings and surface modification of important engineering components.

Learning Resources:

Text Books:

1. James A. Murphy, Surface Preparation and Finishes for Metal, McGraw-Hill, New York 1971
2. Keith Austin, Surface Engineering Hand Book, London : Kogan Page, 1998
3. Swaraj Paul, Surface Coatings: Science and Technology, Wiley Publisher, 2nd Edition, 1996

Reference Books:

1. Quintino, Luisa. "Overview of coating technologies." Surface Modification by Solid State Processing. Woodhead Publishing, 2014. 1-24.
2. Mellor, Brian G., ed. Surface coatings for protection against wear. Woodhead Publishing, 2006.

Online Resources:

1. https://archive.nptel.ac.in/courses/112/105/112105053/
2. https://nptel.ac.in/courses/112107248

3-0-0 (3)

ME 1450

LUBRICATION AND ROTOR DYNAMICS

Pre-Requisites: **None**

Course Outcomes:

CO-1	Identify the proper lubricant for a given application.
CO-2	Determine the lubrication regime for the rotor-bearing system
CO-3	Model the Rotor bearing systems and formulate the governing equations.
CO-4	Compute the critical speeds and stability limits for rotors under axial, transverse and torsional modes.
CO-5	Analyse the rotor bearing systems using transfer matrix method and Finite Element Method.

Course Articulation Matrix:

	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6	PO-7	PO-8	PO-9	PO-10	PO-11	PO-12	PSO-1	PSO-2
CO-1	3	3	3	1	1							2	2	2
CO-2	3	3	2	2	2							2	2	2
CO-3	3	3	2	3	2							2	2	2
CO-4	3	3	2	2	3							3	2	2
CO-5	3	3	2	2	3							3	2	3

1 - Slightly; **2 - Moderately;** **3 - Substantially**

Syllabus:

Introduction: Rotating machinery, Technology of friction control and wear prevention in rotating machinery, Properties and testing of lubricants. Bearing Systems: Rolling element bearings, Hydrodynamic oil-journal bearings, Gas lubricated bearings, Hydrostatic bearings and Squeeze film bearings.

Lubricants and Lubrication: Physical properties of lubricants, Viscosity index, Viscosity measurement, Temperature characteristics of lubricants, Different lubrication regimes and Stribeck Curve, Derivation of 2D Reynold's equation, Mechanism of pressure development in lubrication, Theories of Hydrostatic lubrication, Squeeze film lubrication and Gas lubrication.

Linear Rotor Dynamics : Equation of motion, Rotating systems, Complex coordinate representation, Jeffcott Rotor – Free whirling, Unbalance response, Shaft Bow With structural damping.

Discrete multi-degree of freedom: Introduction, Transfer matrix approach for undamped systems, Damped systems, The finite element method for rotors, Beam elements, spring elements, Mass elements, Assembly and constraints, Damping matrices, Computation of critical speeds, Computation of unbalance response. Campbell and root locus diagrams, Reduction of DOF: Nodal reduction, model reduction and component mode synthesis.

Torsional and Axial Dynamics: Free and forced Torsional vibrations and critical speeds, Axial Vibration of rotors.

Learning Resources:

Text Books:

1. Andras Z. Szeri, Fluid film lubrication theory and design, Cambridge University press, 1998.

2. Majumdar B.C, Mihir Sarangi, M K Ghosh, Theory of Lubrication, Tata McGraw Hill Education Private Limited, 2013.

3. Giancarlo Genta, Dynamics of Rotating Systems, Springer, 2009.

Reference Books:

1. Cameron A, Basic lubrication theory, Ellis Horwood Ltd., 2002.

2. Rao, J.S., Rotor Dynamics, New Age International, 2003, 3rd Edition

ME 1452 **3-0-0 (3)**

JET PROPULSION AND ROCKETRY

Pre-Requisites: **None**

Course Outcomes:

CO-1	Understand the principles of Rocket propulsion
CO-2	Analyze the performance of Rocket components
CO-3	Select suitable solid, liquid and hybrid propellants for specific application
CO-4	Evaluate the performance of Rocket engines

Course Articulation Matrix:

	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6	PO-7	PO-8	PO-9	PO-10	PO-11	PO-12	PSO-1	PSO-2
CO-1	2	2	3	3		1	–	–	–	–	–	–	–	–
CO-2	2	2	3	3	2	1	–	–	–	–	–	–	–	–
CO-3	2	2	3	3	2	1	–	–	–	–	–	–	–	–
CO-4	2	2	3	3		1	–	–	–	–	–	–	–	–

1 - Slightly; **2 - Moderately;** **3 - Substantially**

Syllabus:

Jet Propulsion Cycles and their Analysis: Criteria of Performance, Simple Turbojet Engine, Simple Turbofan Engine, Simple Turboprop Engine, Turbo-shaft Engine, Thrust Augmentation Techniques

Fundamentals of Rotating Machines: General Fluid Dynamic Analysis, Euler's Energy Equation, Components of Energy Transfer, Impulse and Reaction Machines

MOTION IN SPACE: REQUIREMENT FOR ORBIT: Motion of Bodies in space, Parameters describing motion of bodies, Newton's Laws of motion, Universal law of gravitational force, Gravitational field, Requirements of motion in space, Geosynchronous and geostationary orbits, Eccentricity and inclination of orbits, Energy and velocity requirements to reach a particular orbit, Escape velocity, Freely falling bodies, Means of providing the required velocities

THEORY OF ROCKET PROPULSION: Illustration by example of motion of sled initially at rest, Motion of giant squid in deep seas, Rocket principle and rocket equation, Mass ratio of rocket, Desirable parameters of rocket, Rocket having small propellant mass fraction, Propulsive efficiency of rocket, Performance parameters of rocket, Staging and clustering of rockets, Classification of rockets.

ROCKET NOZZLE AND PERFORMANCE: Expansion of gas from a high pressure chamber, Shape of the nozzle, Nozzle area ratio, Performance loss in conical nozzle, Flow separation in nozzles, Contour or bell nozzles, Unconventional nozzles, Mass flow rates and characteristics velocity, Thrust developed by a rocket; Thrust coefficient, Efficiencies, Specific impulse and correlation with C* and CF, General Trends.

SOLID PROPELLANTS, LIQUID PROPELLANTS, AND HYBRID ROCKETS: Working principle, Choice of fuels and oxidizer, Mechanism of burning and burn rate

Learning Resources:

Text Books:

1. Barrere, M., Rocket Propulsion, Elsevier Pub. Co., 1990.

2. Sutton, G. P., Rocket Propulsion Elements, John Wiley, New York, 1993.
3. Ramamurthi K., Rocket Propulsion, Macmillan Publishers India Ltd., 2010
4. Feedesiev, V. I. and Siniarev, G. B., Introduction to Rocket Technology, Academic Press, New York, 2000.
5. Saravanamuttoo, H.I.H., Rogers, G. F. C. and Cohen, H., Gas Turbine Theory, Pearson PrenticeHall, 6th Edition, 2008.

ME 1454 **3-0-0 (3)**

Applied Heat Transfer

Pre-Requisites: **None**

Course Outcomes:

CO-1	Understand the heat transfer alteration requirement in industry
CO-2	Understand the basics for air, liquid and two phase cooling
CO-3	Understand the basics of insulation
CO-4	Select appropriate heat transfer techniques and devices for a given application

Course Articulation Matrix:

	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6	PO-7	PO-8	PO-9	PO-10	PO-11	PO-12	PSO-1	PSO-2
CO-1	2	2	2	2	2	–	2	2	–	–	1	2	2	2
CO-2	3	2	2	2	2	–	2	1	–	–		2	2	3
CO-3	3	2	2	2	2	–	1	1	–	–		2	2	2
CO-4	3	2	2	3	3	–	2	2	–	–	2	2	3	3

1 - Slightly; **2 - Moderately;** **3 - Substantially**

Syllabus:

Introduction: Introduction to requirement of heat transfer alteration. Overview of heat generation components and processes in electric vehicle, gas turbine, electronic and electrical systems.

Air cooling: Active and passive methods, flow through channels, jet impingement, film cooling, wall jet etc. Application in industry.

Liquid cooling: Basics of microfluidics, mini channel flow, nano-fluids, types of fluids. Application in industry

Two phase cooling: Two phase flow basics. Heat pipe – working, mathematical modelling, types of heat pipe. Phase change material – introduction, modelling, types. Application in industry

Insulation: Basic derivations, types, application in industry

Learning Resources:

Text Books:

1. Je-Chin Han, Sandip Dutta, and Srinath Ekkad, Gas Turbine Heat Transfer and Cooling Technology, CRC Press, 2000
2. Lian-Tuu Yeh, Thermal Design of Liquid Cooled Microelectronic Equipment, ASME Press 2019
3. Bahman Zohuri, Heat Pipe Design and Technology- A Practical Approach, CRC Press 2011

Other Suggested Readings:

1. https://nptel.ac.in/courses/112/107/112107207/
2. https://nptel.ac.in/courses/112/106/112106169/

ME 1456 **3-0-0 (3)**

ENGINEERING ACOUSTICS

Pre-Requisites: **None**

Course Outcomes:

CO-1	Understand wave propagation, absorption, transmission, reflection and radiation.
CO-2	Formulate acoustic problems for reduction of sound levels.
CO-3	Design resonant systems including pipes, mufflers, Helmholtz resonators.
CO-4	Evaluate architectural acoustics reverberation time, direct echoes and acoustical amplification.
CO-5	Analyse the acoustic levels and analytical predictions.

Course Articulation Matrix:

	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6	PO-7	PO-8	PO-9	PO-10	PO-11	PO-12	PSO-1	PSO-2
CO-1	3	2		1								2	2	1
CO-2	3	3	3	1	1							1	3	2
CO-3	2	2	2	2	2							2	3	2
CO-4	2	1	1	2									3	3
CO-5	2	2	2	2	1							1	3	2

1 - Slightly; **2 - Moderately;** **3 - Substantially**

Syllabus:

Introduction: Review of vibrations, resonance and frequency, Sound pressure, power and intensity and its measurement, Concept of Monopoles, Dipoles and Quadrupoles, Sound Power measurement, Transmission loss, Longitudinal and Transverse wave equations, Spherical and cylindrical wave equation, Acoustic intensity, decibel scales, Sound wave generators.

Acoustic wave propagation: Transmission/reflection of waves in different media, radiation and reception of acoustic waves, absorption and attenuation of sound, Cavities and waveguides. Wave types in fluids and solids. Modes of vibrations in solids.

Pipes, Resonators, and Filters: Resonance in pipes, standing waves, Absorption of sound, Helmholtz resonator, acoustic impedance, acoustic filters.

Damping Attenuation and Absorption: Viscous attenuation of sound, absorption by atmosphere, attenuation in water, absorption in fluid filled pipes, damping in solids.

Architectural Acoustics: Sound in enclosures, direct and reverberant sounds, sound absorption materials, acoustic factors in architectural design, standing waves and normal modes in enclosures.

Noise Control: The auditory system, Effects of noise on humans, noise measurement and criterion, treatment at source and treatment of transmission path, Analysis and design of mufflers for automotive applications, Noise measurement and instrumentation standards. Noise Control approaches.

Learning Resources:

Text Books:

1. Robert D Finch., Introduction to acoustics, PHI, 2008
2. Michael Moser, Michael Maser, S. Zimmermann Engineering Acoustics: An introduction to Noise Control, Springer, Springer, 2009, 2nd edition.

Reference Books:

1. Frank J Fahy, Foundations of Engineering Acoustics, Academic Press, 2000.
2. L. E. Kinsler, A R. Frey, A B. Coppens and J V. Sanders, Fundamentals of Acoustics, Wiley Publishers, 2005

Other Suggested Readings:

1. https://nptel.ac.in/courses/112/104/112104212/

ME 1458 **3-0-0 (3)**

ANALYSIS OF MECHANISMS

Pre-Requisites: **None**

Course Outcomes:

CO-1	Analyze coupler curves and design both exact and approximate straight-line mechanisms.
CO-2	Perform position, velocity, and acceleration analysis using loop closure equations
CO-3	Explore the concepts of dimensional synthesis, focusing on two/ three-position synthesis for rocker output and precision points.
CO-4	Synthesize double dwell cams based on critical extreme position motion constraints

Course Articulation Matrix:

	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6	PO-7	PO-8	PO-9	PO-10	PO-11	PO-12	PSO-1	PSO-2
CO-1	3	2		1								2	2	1
CO-2	3	3	3	1	1							1	3	2
CO-3	2	2	2	2	2							2	3	2
CO-4	2	1	1	2									3	3

1 - Slightly; **2 - Moderately;** **3 - Substantially**

Syllabus:

Position analysis: Introduction and overview of the kinematics of machinery, position and systems, coordinate transformation, rotation, translation and combined motion, algebraic position analysis

Loop closure equations: position of any point on a linkage, transmission angles and toggle positions, position-based synthesis of planar mechanisms.

Kinematic analysis: plane motion of a rigid body, graphical velocity and acceleration analysis, instantaneous centers of velocity, centrodes, the velocity of rub, analytical solutions for velocity analysis – velocity of any point on a linkage, acceleration of any point on a linkage, coriolis acceleration, analytical solutions for velocity and acceleration analysis, case studies – four-bar pin joined linkage, four-link slider-crank.

Synthesis: types of kinematic synthesis – motion and path generation, number synthesis, dimensional synthesis, two-position synthesis for rocker output, precision points, comparison of analytical and graphical two-position synthesis, three-position synthesis

Cams: terminology, types of followers, follower motions, cams, svaj diagrams, law of cam design, single and double dwell cam design using SHM, cycloidal displacement, combined functions, critical path motion, practical design considerations.

Learning Resources:

Text Books:

1. Robert L Norton, Design of Machinery, an Introduction to the Synthesis and Analysis of Mechanisms and Machines, 2nd Edition, McGraw Hill reprint 2011.

Reference Books:

1. J. J. Uicker Jr., G. R. Pennock, J. E. Shigley, Theory of Machines and Mechanisms, 4th Edition, Oxford University Press, 2011
2. David H. Myszka, Machines and Mechanisms: Applied Kinematic Analysis, 4th Edition, Pearson, 2011

ME 1460 **3-0-0 (3)**

INDUSTRY 4.0 and IIoT

Pre-Requisites: **EE 1161**

Course Outcomes:

CO-1	Explore how Industry 4.0 will change the current manufacturing technologies and processes by digitizing the value chain
CO-2	Understand the drivers and enablers of Industry 4.0.
CO-3	Learn about various IIoT-related protocols
CO-4	Build simple IIoT Systems using Arduino, ESP32 and Raspberry Pi

Course Articulation Matrix:

	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6	PO-7	PO-8	PO-9	PO-10	PO-11	PO-12	PSO-1	PSO-2
CO-1	3		3	2	2				2			2	3	
CO-2	3		2		2				1		2		3	
CO-3	3	3	2		3		2	2	2				3	3
CO-4	3	2	2	2	3		2	2	2			2	3	2

1 - Slightly; **2 - Moderately;** **3 - Substantially**

Syllabus:

Introduction to Industry 4.0: Industry 4.0: Globalization and Emerging Issues, The Fourth Revolution, LEAN Production Systems,Smart and Connected Business Perspective, Smart Factories, Industry 4.0: Cyber Physical Systems and Next Generation Sensors, Collaborative Platform and Product Lifecycle Management, Augmented Reality and Virtual Reality, Artificial Intelligence, Big Data and Advanced Analysis

Introduction to IIoT: Architectural Overview, Design principles and needed capabilities, IoT Applications, Sensing, Actuation, Basics of Networking, M2M and IoT Technology Fundamentals- Devices and gateways, Data management, Business processes in IoT, Everything as a Service (XaaS), Role of Cloud in IoT, Security aspects in IoT.
Elements of IIoT: Hardware Components- Computing (Arduino, Raspberry Pi), Communication, Sensing, Actuation, I/O interfaces. Software Components- Programming API's (using Python/Node.js/Arduino) for Communication Protocols-MQTT, ZigBee, Bluetooth, CoAP, UDP, TCP.

IIoT Application Development: Solution framework for IoT applications- Implementation of Device integration, Data acquisition and integration, Device data storage- Unstructured data storage on cloud/local server, Authentication, authorization of devices. Case Studies: IoT case studies and mini projects based on Industrial automation, Transportation, Agriculture, Healthcare, Home Automation

Learning Resources:

Text Books:

1. Vijay Madisetti, ArshdeepBahga, Ïnternet of Things, "A Hands on Approach", University Press.
2. Dr. SRN Reddy, RachitThukral and Manasi Mishra, "Introduction to Internet of Things: A practical Approach", ETI Labs

3. Pethuru Raj and Anupama C. Raman, “The Internet of Things: Enabling Technologies, Platforms, and Use Cases”, CRC Press
4. Adrian McEwen, “Designing the Internet of Things”, Wiley.
5. Raj Kamal, “Internet of Things: Architecture and Design”, McGraw Hill.
6. CunoPfister, “Getting Started with the Internet of Things”, O Reilly Media

ME 1462 **3-0-0 (3)**

Virtual Reality & Augmented Reality

Pre-Requisites: **None**

Course Outcomes:

CO-1	Apply fundamental Computer Vision, Computer Graphics, and Human-Computer Interaction techniques to develop and enhance VR/AR applications effectively
CO-2	Explore geometric modeling techniques, investigate virtual environments, and assess VR/AR technologies comprehensively
CO-3	Utilize a variety of hardware devices and software in Virtual Reality systems to optimize functionality and performance.
CO-4	Build Virtual/Augmented Reality applications by formulating creative design strategies.

Course Articulation Matrix:

	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6	PO-7	PO-8	PO-9	PO-10	PO-11	PO-12	PSO-1	PSO-2
CO-1			3	2	2				3			2		
CO-2			2	3	2				2					
CO-3			2	2	3		2	2	3					
CO-4			2	2	3		2	2	2			2		

1 - Slightly; **2 - Moderately;** **3 - Substantially**

Syllabus:

I**ntroduction to Virtual Reality (VR):** Virtual Reality and Virtual Environment, Computer graphics, Real time computer graphics, Flight Simulation, Virtual environment requirement, benefits of virtual reality, Historical development of VR, Scientific Landmark

Computer Graphics and Geometric Modelling: The Virtual world space, positioning the virtual observer, the perspective projection, human vision, stereo perspective projection, Color theory, Conversion From 2D to 3D, 3D space curves, 3D boundary representation, Simple 3D modelling, 3D clipping, Illumination models, Reflection models, Shading algorithms, Geometrical Transformations: Introduction, Frames of reference Modelling transformations, Instances, Picking, Flying, Scaling the VE, Collision detection.

Virtual Environment: Input/Output Devices**:** Input (Tracker, Sensor, Digital Gloves, Movement Capture, Videobased Input, 3D Menus & 3D Scanner, etc.), Output (Visual/Auditory/Haptic Devices)

Generic VR system: Introduction, Virtual environment, Computer environment, VR technology, Model of interaction, VR Systems, Animating the Virtual Environment: Introduction, The dynamics of numbers, Linear and Nonlinear interpolation, the animation of objects, linear and non-linear translation, shape & object in between, free from deformation, particle system

Physical Simulation: Introduction, Objects falling in a gravitational field, Rotating wheels, Elastic collisions, projectiles, simple pendulum, springs, Flight dynamics of an aircraft.

Augmented Reality (AR): Taxonomy, Technology and Features of Augmented Reality, AR Vs VR, Challenges with AR, AR systems and functionality, Augmented Reality Methods, Visualization Techniques for Augmented Reality, Enhancing interactivity in AR Environments, Evaluating AR systems.

Development Tools and Frameworks: Human factors: Introduction, the eye, the ear, the somatic senses. Hardware**:** Introduction, sensor hardware, Head-coupled displays, Acoustic hardware, Integrated VR systems Software: Introduction, Modelling virtual world, Physical simulation, VR toolkits, Introduction to VRML

AR / VR Applications: Introduction, Engineering, Entertainment, Science, Training, Game Development

Learning Resources:

Text Books:

1. Coiffet, P., Burdea, G. C., Virtual Reality Technology," Wiley-IEEE Press, 2003
2. Schmalstieg, D., Höllerer, T., "Augmented Reality: Principles & Practice," Pearson, 2016
3. Norman, K., Kirakowski, J., Wiley Handbook of Human Computer Interaction," Wiley-Blackwell, 2018

Reference Books:

1. Craig, A. B., Understanding Augmented Reality, Concepts and Applications," Morgan Kaufmann, 2013
2. Craig, A. B., Sherman, W. R., Will, J. D., Developing Virtual Reality Applications, Foundations of Effective Design," Morgan Kaufmann, 2009.
3. John Vince, J., "Virtual Reality Systems, Pearson, 2002
4. Sanni Siltanen, S., "Theory and applications of marker-based augmented reality," Julkaisija –Utgivare Publisher, 2012
5. Fowler, A., Beginning iOS AR Game Development: Developing Augmented Reality Apps with Unity and C#," Apress, 2019.

Online Resources:

1. Manivannan, M., (2018), "Virtual Reality Engineering," IIT Madras, https://nptel.ac.in/courses/121106013
2. Misra, S., (2019), "Industry 4.0: Augmented Reality and Virtual Reality," IIT Kharagpur, https://www.youtube.com/watch?v=zLMgdYI82IE
3. Dube, A., (2020), "Augmented Reality - Fundamentals and Development," NPTEL Special Lecture Series, https://www.youtube.com/watch?v=MGuSTAqlZ9Q
4. http://cambum.net/course-2.htm

ME 1464 **3-0-0 (3)**

Biofluids and Bio-heat transfer

Pre-Requisites: **NONE**

Course Outcomes:

CO-1	Understand fluid mechanics of biological fluids inside the human body.
CO-2	Demonstrate of cardiovascular systems and significant fluid flow problems in large arteries
CO-3	Apply the knowledge of fluid mechanics to analyze the flow behavior in biological systems
CO-4	Apply bio-heat transfer models to analyze human body thermoregulation

Course Articulation Matrix:

	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6	PO-7	PO-8	PO-9	PO-10	PO-11	PO-12	PSO-1	PSO-2
CO-1			3	2	2				3			2		
CO-2			2	3	2				2					
CO-3			2	2	3		2	2	3					
CO-4			2	2	3		2	2	2			2		

1 - Slightly; **2 - Moderately;** **3 - Substantially**

Syllabus:

Introduction: Basic topics on human physiology and anatomy, Review of fluid mechanics concepts in the context of bio fluids, Shear stress in Aorta, viscosity of blood, dimensionless numbers, Blood – a multiphase fluid, Flow in Arteries – FSI problem, Heat transfer between blood and tissue

Cardiovascular System: Anatomy and physiology, blood flow through the heart, pressure-volume relationship in a Cardiac cycle, pulsatility index, heart valves

Blood Flow: Physiology of arterial and venous systems, blood rheology, wave propagation, Tube law, bifurcations, tapered and curved channels, pulsatile flow in arteries, oscillatory shear index, aneurysm

Respiratory System: Physiology, volumes, ventilation and perfusion, breathing mechanics, oxygen and carbon-di-oxide transport within the blood and the role of hemoglobin

Bio-heat transfer: The bioheat equation and other models, Human body thermoregulation - modeling and simulation of the human thermoregulatory system and its applications, Heat Transfer models of single organs, Heat and mass transfer in the respiratory system, Hypothermia and hyperthermia - techniques and applications, Analysis of thermal processes for treating tumors: cryosurgery and localized hyperthermia, Analysis of Skin Burns, Modeling and simulation of the human respiratory system – applications.

Learning Resources:

Text Books:

1. Rubenstein, David, Wei Yin, and Mary D. Frame. Biofluid mechanics: an introduction to fluid mechanics, macrocirculation, and microcirculation. Academic Press, 2015.
2. Lee Waite, Ph, and Jerry Fine. Applied biofluid mechanics. The McGraw-Hill Medical Companies, Inc., 2007.
3. Ostadfar, Ali. Biofluid mechanics: Principles and applications. Academic Press, 2016.
4. Ghassemi, Majid, and Azadeh Shahidian. Nano and bio heat transfer and fluid flow. Academic Press, 2017.

ME 1466 **3-0-0 (3)**

Heat Exchanger Design

Pre-Requisites: **NONE**

Course Outcomes:

CO-1	Understand the physics and the mathematical treatment of typical heat exchangers.
CO-2	Apply LMTD and Effectiveness - NTU methods in the design of heat exchangers
CO-3	Design the shell and tube heat exchanger.
CO-4	Apply the principles of boiling and condensation in the design of boilers and condensers

Course Articulation Matrix:

	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6	PO-7	PO-8	PO-9	PO-10	PO-11	PO-12	PSO-1	PSO-2
CO-1	3	3	3	2	2	1			3			2	2	2
CO-2	2	2	2	3	2	1			2				2	2
CO-3	2	2	2	2	3	1	2	2	3				2	2
CO-4	2	2	2	2	3	1	2	2	2			2	2	2

1 - Slightly; **2 - Moderately;** **3 - Substantially**

Syllabus:

Introduction to Heat Exchangers: Definition, Applications, Various methods of classification of heat exchangers with examples.

Governing Equation for heat exchangers: Derivation from steady-state steady-flow considerations.

Mathematical treatment of Heat Exchangers: Concept of Overall Heat Transfer Coefficient, Derivation of the concerned equations, Fouling, Fouling Factor, Factors contributing to fouling of a heat exchanger, Ill-Effects of fouling, Numerical Problems.

Concept of Logarithmic Mean Temperature Difference: Expression for single-pass parallel-flow and single-pass counter flow heat exchangers – Derivation from first principles, Special Cases, LMTD for a single-pass cross-flow heat exchanger – Nusselt's approach, Chart solutions of Bowman et al. pertaining to LMTD analysis for various kinds of heat exchangers, Numerical Problems, Arithmetic Mean Temperature Difference [AMTD], Relation between AMTD and LMTD, Logical Contrast between AMTD and LMTD, LMTD of a single-pass heat exchanger with linearly varying overall heat transfer coefficient [U] along the length of the heat exchanger.

Concept of Effectiveness: Effectiveness-Number of Transfer Units Approach, Effectiveness of single-pass parallel-flow and counter-flow heat exchangers, Physical significance of NTU, Heat capacity ratio, Different special cases of the above approach, Chart solutions of Kays and London pertaining to Effectiveness-NTU approach, Numerical Problems.

Hair-Pin Heat Exchangers: Introduction to Counter-flow Double-pipe or Hair-Pin heat exchangers, Industrial versions of the same, Film coefficients in tubes and annuli, Pressure drop, Augmentation of

performance of hair-pin heat exchangers, Series and Series-Parallel arrangements of hair-pin heat exchangers, Comprehensive Design Algorithm for hair-pin heat exchangers, Numerical Problems.

Shell and Tube Heat Exchangers: Single-Pass, One shell-Two tube [1S-2T] and other heat exchangers, Industrial versions of the same, Classification and Nomenclature, Baffle arrangement, Types of Baffles, Tube arrangement, Types of tube pitch lay-outs, Shell and Tube side film coefficients, Pressure drop calculations, Numerical Problems.

Principles of Boilers and Condensers: Boiling, Fundamentals and Types of boiling – Pool boiling curve, Various empirical relations pertaining to boiling, Numerical problems on the above, Condensation – Classification and Contrast, Types of condensers, Nusselt's theory on laminar film-wise condensation, Empirical Refinements, Several empirical formulae, Numerical problems.

Cooling Towers: Cooling towers – basic principle of evaporative cooling, Psychrometry, fundamentals, Psychrometric chart, Psychrometric Processes, Classification of cooling towers, Numerical problems.

Learning Resources:

Text Books:

1. Compact Heat Exchangers, Kays, W. M. and London, A. L., McGraw – Hill, New York, 2nd Edition.
2. Process Heat Transfer, Donald Q. Kern, McGraw – Hill, New York.

Reference Books:

1. Fundamentals of Heat and Mass Transfer, Incropera, F. P. and Dewitt, D. P., 4th Edition, John Wiley and Sons, New York.
2. Fundamentals of Heat Exchanger Design, Shah, R. K. and Sekulic, D. P., John Wiley and Sons, New Jersey.

ME 1468 **3-0-0 (3)**

Thermal Energy Storage

Pre-Requisites: **NONE**

Course Outcomes:

CO-1	Understand the principles, concepts, and operation of thermal energy storage systems.
CO-2	Select the suitable energy storage materials.
CO-3	Design thermal energy storage systems.
CO-4	Evaluate the performance of thermal energy storage systems for different applications.

Course Articulation Matrix:

	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6	PO-7	PO-8	PO-9	PO-10	PO-11	PO-12	PSO-1	PSO-2
CO-1	1	1	1	2	3	1			3			2	2	2
CO-2	1	1	1	2	3	1			2				2	2
CO-3	1	1	2	3	3	1	2	2	3				2	2
CO-4	1	1	2	3	3	1	2	2	2			2	2	2

1 - Slightly; **2 - Moderately;** **3 - Substantially**

Syllabus:

Introduction: Classification of Energy Resources, Energy Scenario in the World and India, Need for Energy Efficiency, Energy Conservation and Management.

Introduction to Thermal Energy Storage Systems: Introduction, Thermodynamics of Energy Storage, System Types, Environmental Impact.

Sensible Heat Storage Systems: Introduction, Types, Principles of Sensible Heat Storage Systems, Limitations, Advantages and Future Trend.

Latent Heat Storage Systems (Phase Change Materials): Introduction, Types, Selection Criteria, Thermophysical Properties, Thermal Stability, Corrosion, Phase Segregation, Sub Cooling, Applications.

Microencapsulation and Nanoencapsulation of Phase Change Materials: Introduction, Microencapsulation and Nanoencapsulation of Phase Change Materials, Methods, Shape Stabilized Phase Change Materials, Applications.

Design of Latent Heat Storage System: Introduction, Requirements and Considerations for the Design, Design Methodologies, Applications of Latent Heat Storage Systems Incorporating Pcms, Future Trends.

Modelling of Heat Transfer in Phase Change Materials (PCMS): Introduction, Inherent Physical Phenomena in Phase Change Materials, Modelling Methods and Approaches for the Simulation of Heat Transfer in Pcms for Thermal Energy Storage, Examples of Modelling Applications, Future Trends.

Phase Change Materials for Energy Conservation in Buildings: Introduction, Integration of Pcms into Building Envelop, PCM Containment, Measurement of Thermal Properties of PCM Integrated in Buildings, Experimental and Numerical Studies.

Thermochemical Heat Storage: Introduction, Phenomena and Principles, Thermochemical Energy Storage Systems, Applications, Remarks.

Thermal Energy Storage Systems Applications: Introduction, Solar Air Heating, Solar Water Heating, District Heating, Heat to Waste, Cogeneration and Trigeneration Systems, Concentrated Solar Power, Cooling.

Learning Resources:

Text Books:

1. Kalaiselvam, S., Parameshwaran, R., Thermal Energy Storage Technologies for Sustainability Systems Design, Assessment and Applications, Elsevier, 2014.
2. Luisa F. Cabeza .,Advances in Thermal Energy Storage Systems - Methods and Applications, , Elsevier, 2015.

Reference Books:

1. Ibrahim Dinçer., Thermal Energy Storage: Systems and Applications, Marc A. Rosen, John Wiley & Sons Ltd., 2010.

Open Electives

ME 1473 **2-0-0 (2)**

Alternate Sources of Energy

Pre-Requisites: **None**

Course Outcomes:

CO-1	Identify renewable energy sources and their utilization.
CO-2	Understand basic concepts of solar radiation and analyze solar thermal systems for its utilisation.
CO-3	Understand working of solar cells and its modern manufacturing technologies.
CO-4	Understand concepts of Fuel cells and their applications
CO-5	Identify methods of energy storage.
CO-6	Compare energy utilization from wind energy, geothermal energy, biomass, biogas and hydrogen.

Syllabus:

Introduction: Overview of the course; Examination and Evaluation patterns; Global warming; Introduction to Renewable Energy Technologies
Energy Storage: Introduction; Necessity of Energy Storage; Energy Storage Methods
Solar Energy: Fundamentals; Solar Radiation; Estimation of solar radiation on horizontal and inclined surfaces; Measurement of solar radiation data
Solar Thermal systems: Introduction; Basics of thermodynamics and heat transfer; Flat plate collector; Evacuated Tubular Collector; Solar air collector; Solar concentrator; Solar distillation; Solar cooker; Solar refrigeration and air conditioning; Thermal energy storage systems
Solar Photovoltaic systems: Introduction; Solar cell Fundamentals; Characteristics and classification; Solar cell: Module, panel and Array construction; Photovoltaic thermal systems.
Wind Energy: Introduction; Origin and nature of winds; Wind turbine siting; Basics of fluid mechanics; Wind turbine aerodynamics; wind turbine types and their construction; Wind energy conversion systems
Fuel cells: Overview; Classification of fuel cells; operating principles; Fuel cell thermodynamics Biomass Energy: Introduction; Photosynthesis Process; Biofuels; Biomass Resources; Biomass conversion technologies; Urban waste to energy conversion; Biomass gasification.
Other forms of Energy: Introduction: Nuclear, ocean and geothermal energy applications; Origin and their types; Working principles

Learning Resources:

Text Books:

1. Sukhatme S.P. and J.K.Nayak, Solar Energy - Principles of Thermal Collection and Storage, Tata McGraw Hill, New Delhi, 2008.
2. Khan B.H., Non-Conventional Energy Resources, Tata McGraw Hill, New Delhi, 2006.
3. J.A. Duffie and W.A. Beckman, Solar Energy - Thermal Processes, John Wiley, 2001.

Other Suggested Readings:

1. NPTEL Courses
2. MIT Open Course Ware, etc.

ME 1475 **2-0-0 (2)**

3D Printing

Pre-Requisites: **None**

Course Outcomes:

CO-1	Develop preprocess data for the 3D Printing
CO-2	Identify properties of 3DP materials and their influence on final part quality
CO-3	Describe the working principles of each 3D Printing technology
CO-4	Apply suitable 3D Printing technology for any given industrial application
CO-5	Select the postprocessing and testing method for the given application
CO-6	Develop preprocess data for the 3D Printing

Syllabus:

Computer Aided Design (CAD) and Preprocessing Data for 3D Printing: Introduction to Geometric Modelling of Curves, Parametric Representation of Freeform Surfaces and Solids. CAD Data Exchange Formats, Input File Sources and Characteristics, 3D Printing Data File Formats and Software, STL File Errors and Manipulation, 3D Printing Process Chain, Part Orientation and Support Generation, Model Slicing and Contour Data Organisation, Hatching Strategies, 3D Printing Toolpaths Generation and Process Plan, Build Preparation and 3D Printing Process Simulation.

3D Printing Materials and Characterisation: Nature of Thermoplastics and Thermosetting Polymers, Properties of Metal and Ceramics. *3DP Liquid Materials:* Rheology and Wetting Behaviour. *3DP Solid Materials:* Filament Diameter Consistency, Density, Porosity, Moisture Content, Thermal Properties, Microstructure of Composite Filament, Mechanical Properties of Filament. *3DP Powder Materials:* Powder Size Measurements, Morphology, Chemical Composition, Flow Characteristics, Density, Energy Absorption Characteristics of Powder.

3D Printing Processes: Classification of 3D Printing Processes. Description, Process Parameters, Material Selection and Characterisation, Applications, Strengths and Weaknesses of Vat Photopolymerization, Material Jetting, Binder Jetting, Material Extrusion, Sheet Lamination, Powder Bed Fusion and Directed Energy Deposition Processes; *Other Processes:* Aerosol Printing and Bio-plotter. *Construction of DIY Printers:* Motion System, Frame/Chassis, Print Bed, Extruder, Electronics.

3D Printing Applications: An Overview of 3D Printing Applications, *Aerospace:* Aerospace Materials and their Requirements, Qualification and Certification of Parts, Aerospace Case Studies. *Medical:* Medical Scanning Technologies, Biomaterials, Planning and Simulation of Complex Surgeries, Design and Fabrication of Customized Implants, Medical Case Studies. *Automobile:* Prototyping, Jigs and Fixtures, Components of Electric Vehicles, Formula 1, Cooling Ducts, Intake Manifolds, Automobile Case Studies. *Other Applications of 3DP:* Marine, Railway, Oil and Gas, Construction, Retail Industry, Arts and Architecture, Fashion and Textile, Jewellery, Cion and Tableware, Weapons, Food, Packaging, and Toy Industry.

Postprocessing and Testing of 3DP Parts: Need for Postprocessing in 3DP, *Surface Treatment Methods:* Subtractive Machining Methods, Thermal-based Methods, Abrasive-based Methods, Chemical Methods. *Surface Protection, Functionalization, and Decorative Methods.* Heat Treatment and Aging. Establish a Relationship between Processing Parameters, Resulting Microstructure, Mechanical Properties, Fatigue, Creep and Corrosion Resistance of 3DP Parts. *Testing of 3DP Parts:* Metrology Measurement Methods, Porosity and Density, Dimensions, Mechanical Measurement Methods, NDT Methods of 3DP Parts, 3DP Safety, 3DP Standards.

Learning Resources:

Text Books:

1. David F. Rogers, J. A. Adams, Mathematical Elements for Computer Graphics, TataMcGrawHill, 2008.
2. Damir Godec, Joamin Gonzalez-Gutierrez, Axel Nordin, Eujin Pei, Julia Urena Alcazar, A Guide to Additive Manufacturing, Springer, 2022.
3. Ian Gibson, David Rosen, Brent Stucker, and Mahyar Khorasani, Additive Manufacturing Technologies, 3rd Edition, Springer, 2021.
4. Diegel, Olaf, Axel Nordin, and Damien Motte, A Practical Guide to Design for Additive Manufacturing, Springer, 2020.
5. Zafar Alam Faiz Iqbal, Dilshad Ahmad Khan, Post-processing Techniques for Additive Manufacturing, CRC Press, 2024.

Reference Books:

1. Michael E.Mortenson, Geometric Modeling, McGrawHill, 2013.
2. Patri K. Venuvinod and Weiyin Ma, Rapid Prototyping: Laser-based and Other Technologies, Springer, 2004.
3. Sanjay Joshi, Richard P. Martukanitz, Abdalla R. Nassar, Pan Michaleris, Additive Manufacturing with Metals: Design, Processes, Materials, Quality Assurance, and Applications, Springer, 2023.
4. L.Lu, J. Y. H. Fuh and Y.S.Wong, Laser-Induced Materials and Processes for Rapid Prototyping, Springer, 2001.
5. Chua Chee Kai, Leong Kah Fai, Rapid Prototyping: 3D Printing and Additive Manufacturing Principles & Applications, World Scientific, 5th Edition, 2019.
6. Gurminder Singh, Ranvijay Kumar, Kamalpreet Sandhu, Eujin Pei, and Sunpreet Singh, Handbook of Post-Processing in Additive Manufacturing: Requirements, Theories, and Methods, CRC Press, 2024.

ME 1477 **2-0-0 (2)**

Composite Materials

Pre-Requisites: **None**

Course Outcomes:

CO-1	Understand composite material and their reinforcements
CO-2	Select constituent materials for preparing appropriate composites
CO-3	Analyze interfaces of composites for predicting their mechanical properties.
CO-4	Develop metal matrix, ceramic matrix and polymer matrix composites with given proportions of constituents

Syllabus:

Introduction: Overview of the course, history and basic concept of composites, Types and constituents, reinforcement and matrices, interface and mechanism of strengthening.

Fundamental concepts: Definition and Classification of Composites, particulate and dispersion hardened composites, continuous and discontinuous fibre reinforced composites MMC, PMC, CMC.

Metal Matrix Composites Processing: Liquid state processes, solid state processes and in situ processes.

Polymer Matrix Composites Processing: Hand lay-up and spray technique, filament winding, pultrusion, resin transfer moulding, bag and injection moulding, sheet moulding compound. Matrix resins-thermoplastics and thermosetting matrix resins. Reinforcing fibres- Natural fibres (cellulose, jute, coir etc), carbon fiber, glass fiber, Kevlar fiber, etc. Particulate fillers-importance of particle shape and size. Coupling agents-surface treatment of fillers and fibres, significance of interface in composites. short and continuous fibre reinforced composites, critical fibre length, and anisotropic behaviour.

Ceramic Matrix Composites Processing: Cold pressing & sintering, hot pressing reaction bonding processes, infiltration, in-situ chemical reaction, Sol-Gel and polymer pyrolysis, self- propagating high temperature synthesis. Carbon- carbon composites, Interfaces.

Rule of mixtures. Stress, strain transformations.

Learning Resources:

Text Books:

1. Chawla, Composite Materials Science and Engineering, Springer
2. Hull, An introduction to composite materials, Cambridge
3. Steven L. Donaldson, ASM Handbook Composites Volume 21, 2001.
4. Krishan K. Chawla, Composite Materials, Science and Engineering, Springer, 2001.
5. Suresh G. Advani, E. Murat Sozer, Process Modelling in Composites Manufacturing, 2nd Ed. CRC Press.

ME 1479 **2-0-0 (2)**

Industrial Management

Pre-Requisites: **None**

Course Outcomes:

CO-1	Understand the evolutionary development of management thought and general principles of management
CO-2	Apply marketing concepts and tools for successful launch of a product
CO-3	Understand the role of productivity in streamlining a production system
CO-4	Apply the inventory management tools in managing inventory
CO-5	Apply quality engineering tools to the design of the products and process controls
CO-6	Apply project management tools to manage projects

Syllabus:

General Management: Evolution of industry and professional management; functions of management; design of an organization structure, Hawthorn experiments, primary groups and informal organizational structures, leadership styles and characteristics of effective leadership, Mc Gregor's Theory X and Theory Y, Maslow's and Hertzberg's motivational theories, Japanese Management.

Marketing Management: Marketing management process and the four Ps of marketing mix; market segmentation, targeting and positioning; product life cycle and marketing strategies in different stages of product life cycle.

Productivity and Work Study: Productivity definition, its role in the economy, techniques for improving productivity, method study procedure, flow process chart and flow diagram, two handed process chart, principles of motion economy, work sampling, stop watch time study.

Quality Management: control charts - and R, p & c charts, Sampling plan –design of single sampling plan using OC curve, rectifying inspection and AOQL; Taguchi's method of total quality control, Quality function deployment, Introduction to TQM

Inventory Management: Purposes of inventories, inventory costs, ABC classification, EOQ,P and Q systems of inventory control.

Project Management: Network diagrams, critical path method, total slack and free slack, crashing of activities and resource levelling, PERT.

Learning Resources:

Text Books:

1. Donald J clough. "Concepts in Management science", Prentice Hall of India.
2. Philip Kotler, "Marketing Management", Prentice Hall of India, New Delhi, 2020.
3. Koontz, H. et. al., "Essentials of Management" - Mc Graw Hill Book Co., New York, 2019.
4. Chase and Aquilano - Operations Management -Mc Graw Hill Pub. Books Co. New York, 2019.

SYLLABI

Minor: Mechanical Engineering

ME M01 **3-0-0 (3)**

Fluid Mechanics and Applied Thermodynamics

Pre-Requisites: **None**

Course Outcomes:

CO-1	Evaluate the hydrostatic forces acting over a plane solid surface of any orientation
CO-2	Apply the conservation equations to fluid flow problems and also estimate the losses in pipe flows
CO-3	Evaluate the heat transfer rate for one-dimensional regular geometries
CO-4	Understand the laws of thermodynamics to analyze thermal power plants and refrigerators
CO-5	Apply the principles of heat transfer and analyze thermal equipment

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

Kinematics of Fluids: Lagrangean and Eulerian description, Velocity potential, Streamfunction and Vorticity.

General theory of Stress and Rate of Strain: Stress-strain relations.

Fundamental Conservation Equations: Integral and differential forms.

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

Dimensional Analysis: Flow over a bluff body – Lift and Drag, Dimensional analysis and similitude.

Thermodynamics: Thermodynamic System, State, Properties, Zeroth law of Thermodynamics, Work & Heat, First law – cyclic process, Limitations of First law, heat engine, Heat pump/Refrigerator, Second law, Carnot cycle, Entropy, T-s and P- V diagrams, Rankine cycle, thermal power plant and its components

Heat Transfer: Basic modes of heat transfer: Conduction, Convection and radiation, General Heat Conduction Equation, Forced and free convection; Internal and external flows, Fundamental principles of radiation heat transfer, Heat Exchangers,

Refrigeration and Air Conditioning: Carnot Refrigeration Cycle, Vapor compression Refrigeration cycle and its components, Desirable properties of Refrigerants, Psychrometry and psychrometric processes.

Learning Resources:

Text Books:

1. Fox, R. W., McDonald, A. T., & Pritchard, P. J. Hoboken, N.J, Introduction to fluid mechanics, Wiley 2008.
2. P.K.Nag, Engineering Thermodynamics, McGraw Hill Education, 2017, 6th Edition..
3. Arora, R.C., Refrigeration & Air conditioning, PHI, 2010

4. Yunus A. Çengel, Michael A. Boles, and Mehmet Kanoğlu,Thermodynamics-An Engineering Approach, McGraw-Hill Education, 2019, 9th Edition.

Reference Books:

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

Other Suggested Readings:

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/#)

ME M02 **3-0-0 (3)**

Kinematics and Dynamics of Machinery

Pre-Requisites: **None**

Course Outcomes:

CO-1	Understand the principles of Four bar mechanism and planar mechanisms
CO-2	Understand the Velocity and Acceleration Analysis
CO-3	Characterize and design flywheels
CO-4	Design centrifugal governors
CO-5	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. Amitabha Ghosh and Ashok Kumar Mallik, Theory of Mechanisms and Machines, East West Press Pvt. Ltd., New Delhi, 2017, 3rd edition.
2. S.S.Rattan, Theory of Machines, McGraw-Hill Publications, New Delhi, 2011, 3rd edition.
3. Shigley J. E. and John Joseph Uicker, Theory of Machines and Mechanisms, McGraw- Hill international edition 2003, 2nd edition.
4. Robert Norton, Design of Machinery: An Introduction to the Synthesis and Analysis of Mechanisms and Machines, McGraw-Hill, 2003, 5th edition.

ME M03 **3-0-0 (3)**

Manufacturing Processes

Pre-Requisites: **None**

Course Outcomes:

CO-1	Design patterns and cores for metal casting process
CO-2	Design near net shaped components from metal and ceramic powders
CO-3	Develop joints using solid state and fusion joining, brazing and soldering techniques
CO-4	Develop process-maps for metal forming processes using plasticity principles
CO-5	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. Amitabha Ghosh and Mallick A. K, Manufacturing Science, Affiliated East-West Press Pvt. Ltd. 2010
2. P N Rao,Manufacturing Technology Vol1 – Foundry, Forming and Welding, 2018, 5th Edition
3. P N Rao, Manufacturing Technology Vol2 – Metal Cutting and Machine Tools, 2018, 4th Edition

Reference Books:

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

Other Suggested Readings:

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

ME M04 **3-0-0 (3)**

Engineering Design

Pre-Requisites: **None**

Course Outcomes:

CO-1	Determine the resistance and deformation in machine members subjected to axial, flexural and torsional loads
CO-2	Design the machine elements under static loading conditions
CO-3	Make use of the concept of finite element method for solving machine design problems
CO-4	Solve problems in 1-D and 2-D structural systems involving bars, trusses, beams and frames
CO-5	Compare the design of machine elements using numerical and analytical techniques

Syllabus:

Resistance and Deformation: Concept of Resistance and deformation - Determinate and Indeterminate problems in Tension and Compression - Thermal Stresses - 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 - Strain energy in tension and compression - Impact loading.

Shear Force and Bending Moment: Types of supports - Types of beams - Types of loads - articulated beams - Shear Force and Bending Moment diagrams.

Theory of Simple Bending: Assumptions - Bending stresses in beams - Efficiency of various cross sections - Composite beams.

Shear Stress Distribution: Flexural shear stress distribution in different cross sections of beams.

Deflection of Beams: Slope and deflection of beams - Double Integration method- Macaulay's method - strain energy method.

Torsion of Circular cross sections: Theory of pure torsion - transmission of Power in Solid and Hollow circular shafts - Combined bending and torsion.

Historical Perspective of FEM and applicability to mechanical engineering design problems

Finite Element Analysis for One Dimensional Structural problems: Structural problems with one dimensional geometry. Bar element: formulation of stiffness matrix, consistent and lumped load vectors, Formulation for Truss elements.

Beams and Frames: Review of bending of beams, higher order continuity (C^0 and C^1 Continuity), interpolation for beam elements and formulation of FE characteristics, Plane and space frames and examples problems involving hand calculations. Algorithmic approach for developing computer codes involving 1-D & 2D elements.

Verify the FE analysis with the analytical methods for design of simple machine elements like Shaft, Beam, Springs, Frames, Structural members etc.

Learning Resources:

Text Books:

1. Timoshenko and Gere, Mechanics of Materials, CBS Publishers, 2011, 2nd Edition.
2. E.P.Popov,Engineering Mechanics of Solids, Pearson, 2015, 2nd Edition.
3. S. B. Junarkar, Mechanics of Structures, Charotar Publishers, 2012.
4. Singiresu S.Rao, Finite element Method in Engineering, 5ed, Elsevier, 2012.
5. Reddy, J.N., Finite Element Method in Engineering, Tata McGraw Hill, 2017.

Reference Books:

1. Pytel & Singer, Strength of Materials, Harper & Row Publishers, 2018, 4th Edition.
2. L.S Srinath, Advanced Mechanics of Solids, McGraw Hill Education, 2017, 3rd Edition.
3. Beer and Johnston, Mechanics of Materials, McGraw Hill India Pvt. Ltd., 2020, 8th Edition (SI Units).
4. Zeincowicz, The Finite Element Method 4 Vol set, 4th Edition, Elsevier 2007.

ME 1307 **3-0-0 (3)**

Management Science and Productivity

Pre-Requisites: **None**

Course Outcomes:

CO-1	Understand the role of production systems to support a given competitive strategy
CO-2	Understand the role of productivity in streamlining a production system.
CO-3	Apply the inventory management tools in managing inventory.
CO-4	Apply quality engineering tools in designing products and process controls.
CO-5	Apply PERT and CPM in the management of projects.

Syllabus:

Production Systems: Evolution of production systems, Classification and characterization, Competitive strategies, Production and Inventory control strategies, Process management, Facility Design.

Productivity and Work study: Productivity and its role in the economy, Techniques for improving productivity, Method study, Principles of motion economy, Stopwatch time study, Work sampling, Predetermined Time Standards.

Quality Management: Dimensions of quality, Process control charts, Acceptance sampling, Quality function deployment, Taguchi's Quality Engineering, Introduction to TQM.

Inventory Management: Purpose of inventories, Inventory costs, ABC classification, Economic Order Quantity (EOQ), P and Q systems of inventory control.

Project Management: Project activities, Network diagrams, CPM, PERT, Project Feasibility studies.

Learning Resources:

Text Books:

1. Chase, Operations and Supply Chain Management, Tata McGraw Hill, 2024, 17th Edition.
2. Krajewski L.J. and Ritzmen L.P, Operations Management: Strategy and Analysis, Pearson Education, 2021, 11th Edition.
3. Mahadevan. B, Operations Management: Theory and Practice, Pearson Education, 2015, 3rd Ed.

Reference Books:

1. Hopp W. J. and Spearman M. L., Factory Physics: Foundations of Manufacturing Management, McGraw Hill International Edition, 2008, 3rd Edition.

SYLLABI

Honors-1: Thermal Engineering

ME 16001 **3-0-0 (3)**

Advanced Fluid Mechanics

Prerequisites: None

Course Outcomes:

At the end of the course, the student will be able to:

CO-1	Ascertain basic concepts of the fluid mechanics and apply the concepts in the analysis of fluid flow problems
CO-2	Analyze the stress, strain and forces involving in the fluid element and to derive the governing equations
CO-3	Find the exact and approximate solutions of the governing equations for realistic flow situations
CO-4	Analyze the performance of fluid flow in laminar and turbulent flows
CO-5	Differentiate compressible and incompressible flows and solve compressible flow problems

Syllabus:

Introduction: Review of the fundamentals of Fluid mechanics.

Kinematics of Fluids: Lagrangean and Eulerian systems, Velocity potential, Stream function and Vorticity.

General theory of Stress and Rate of Strain: Stress-strain relations.

Fundamental Conservation Equations: Integral and differential forms.

One-dimensional Inviscid Incompressible Flow: Euler's equation and Bernoulli's equation-applications of Bernoulli's equation.

Exact solutions of Navier-Stokes Equations: Couette flow, Hagen-Poiseuille flow, Flow between coaxial and concentric rotating cylinders, Hydrodynamic theory of lubrication, Creeping flows, Unsteady motion of flat plate.

The Laminar Boundary Layer: Prandtl's Boundary Layer Equations, Blasius solution, Momentum-integral equations and its applications, Boundary layer separation and control.

Turbulent Flows: Introduction to Turbulent Flow, Reynolds modification of N-S equations, Semi - empirical theories, Turbulent boundary layer for internal and external flows, Turbulence modelling.

Dimensional Analysis: Flow over a bluff body – Lift and Drag, Dimensional analysis and similitude.

Introduction to Compressible Flow: Isentropic flow, Flow across normal and oblique shocks, Fanno flow, Rayleigh flow, Expansion waves.

Learning Resources:

Text Books:

1. Fox, R.W., Pritchard, P. J. and McDonald, A. T., Introduction to Fluid Mechanics, Wiley, 2018, 8th Edition.
2. White, F. M., Viscous Fluid Flow, Tata McGraw Hill Book Company, 2021, 4th Edition.

Reference Books:

1. Yuan, S. W., Foundations of Fluid Mechanics, Prentice Hall of India, 2000
2. Yahya, S. M., Fundamentals of Compressible Flow with Aircraft and Rocket Propulsion, New Age International Publishers, 2018, 6th Edition.
3. Yahya, S. M., Anderson, J. D. Jr., Modern Compressible Flow –with Historical Perspective, TMH,

2020, 4th edition.
4. Schlichting, H and Gersten, K, Boundary Layer Theory, Springer, 2018, 9th Edition.
5. Muralidhar, K and Biswas, G., Advanced Engineering Fluid Mechanics, Alpha Science International Ltd., 2018, 3rd Edition.

Other Suggested Readings:

1. Advanced Fluid Mechanics by Dr. Suman Chakraborty (IIT Kharagpur), NPTEL Course (Link: https://nptel.ac.in/courses/112/105/112105218/#)
2. Introduction to Turbulence by Prof. Gautam Biswas (IIT Kanpur), NPTEL Course (Link: https://nptel.ac.in/courses/112/104/112104120/)

ME 16005 **3-0-0 (3)**

Advanced Heat and Mass Transfer

Prerequisites: **None**

Course Outcomes:

At the end of the course, the student will be able to:

CO-1	Understand physical and mathematical aspects of heat and mass transfer.
CO-2	Develop mathematical models for steady and unsteady state heat transfer problems.
CO-3	Analyze free and forced convection for internal and external flow problems.
CO-4	Design heat exchangers
CO-5	Apply the concepts of radiation heat transfer for enclosure analysis.

Syllabus:

Introduction: Review of the fundamentals of heat transfer and modes of heat transfer.

One – Dimensional Steady State Heat Conduction: General Heat Conduction Equation in (i) Cartesian, (ii) Polar and (iii) Spherical Coordinate Systems, Heat generation, Variable thermal conductivity, Extended surfaces –Uniform and Non-Uniform cross sections. Inverse heat transfer problems.

Steady- State Two-Dimensional Heat Conduction: Governing equations and solutions, Use of Bessel's functions.

Transient Heat Conduction: Lumped heat capacity system, Infinite plate of finite thickness and Semi-infinite Solid, Heisler and Grober charts for Transient Conduction.

Forced Convection: Conservation equations, Integral and analytical solutions, Boundary layer analogies, Internal and external flows, Laminar and turbulent flows, Empirical relations, cooling of electronic equipment.

Free convection: Governing equations, Laminar and turbulent flows, Analytical and empirical solutions.

Boiling and Condensation: Pool boiling and convective boiling, Film condensation and dropwise condensation.

Thermal Radiation: Fundamental principles, Radiation exchange between surfaces - View factor, Radiation shields, Multimode heat transfer.

Heat Exchangers: Types of heat exchangers, LMTD method and Effectiveness – NTU method, plate and tube heat exchangers, industrial standards for design of heat exchangers.

Mass Transfer: Fick's law of diffusion, Analogy between heat transfer and mass transfer, Mass diffusion and mass convection.

Learning Resources:

Text Books:

1. Incropera, F. P. and De Witt, D. P., Fundamentals of Heat and Mass Transfer, 5th Edition, Wiley, Indian Edition, 2018.
2. Yunus A. Çengel and Afshin Jahanshahi Ghajar, Heat and Mass Transfer: Fundamentals and Applications, McGraw-Hill Education, 2020, 6th Edition.

3. Sadik Kakac and Yaman Yener., Heat Conduction, Taylor & Francis, 2018, 5th Edition.
4. Kays, W. M. and Crawford, M. E., Convective Heat and Mass TransferTata McGraw Hill, 2017, 4th Edition.
5. Bejan A., Convection Heat Transfer, Wiley, 2013, 4th Edition.

Reference Books:

1. Ghiaasiaan, S.M., Convective Heat and Mass Transfer, Cambridge, 2015.
2. Siegel, R., M. Pinar Menguc and Howell, J. R., Thermal Radiation Heat Transfer, Taylor and Francis, 2020, 7th Edition.
3. Ozisik, M.N., and Orlande, H.R.B., Inverse Heat Transfer:Fundamentals and Applications, Taylor and Francis, 2021, 2nd Edition.

Other Suggested Readings:

1. Heat transfer by Prof. Ganesh A. Viswanathan (IIT Bombay), NPTEL Course (Link: https://nptel.ac.in/courses/103/101/103101137/#)
2. Convective Heat Transfer by Prof. Saptarshi Basu (IISc Bangalore), NPTEL Course (Link: https://nptel.ac.in/courses/112/108/112108246/)
3. Transport Processes I: Heat and Mass Transfer, Prof. V. Kumaran (IISc Bangalore), NPTEL Course (Link: https://nptel.ac.in/courses/103/108/103108123/)

ME 16002 **3-0-0 (3)**

Prime Movers and Propulsion

Pre-Requisites: **None**

Course Outcomes:

CO-1	Understand the importance of prime movers and propulsion devices and compare performance based on thermodynamic cycles and combustion processes.
CO-2	Identify harmful emissions and examine the advances in prime movers for improved performance and reduced pollutant emissions.
CO-3	Analyse and evaluate the configurations of battery, hybrid and fuel-cell electric Vehicles.
CO-4	Analyze the ideal and practical gas turbine cycles of air-breathing propulsion devices and industrial gas turbines.

Syllabus:

Internal Combustion Engines: Classification of Prime movers; IC Engines as Prime movers; classification and brief treatment of different types.

Combustion in SI and CI Engines: Brief treatment on Normal and Abnormal combustion phenomena in SI and CI engines-Octane rating and Cetane rating, Combustion Chambers for SI and CI Engines.

Supercharging of IC Engines: Need of Supercharging and advantages, Configurations of Supercharging-Numerical problems on turbocharging.

Pollutant emissions from IC Engines: Pollutants from SI and CI Engines: Measurement of engine emissions-instrumentation and Pollution Control Strategies, Emission norms.

Modern Trends in Automotive Engines: Alternative Combustion Concepts, Alternative Fuels for Engines- Alternative prime movers for IC engines for automotive vehicles-Hybrid Electric vehicles, Electric vehicles, Fuel Cell, Battery.

Turbomachines: Gas Turbine Cycles for Shaft Power: Ideal and practical shaft power cycles and their analysis., Axial and Radial Flow Turbines**:** Brief Details-Vortex theory, stage performance, Overall turbine performance, Turbine blade cooling, Radial flow turbines.

Propulsive devices: Performance criteria, Gas turbine cycles for turbojet, turbofan, turboprop, and turbo-shaft engines, Thrust augmentation techniques.

Fundamentals of Rotating Machines: Impulse and reaction machines, Degree of reaction, Flow over an aerofoil, Lift and drag.

Centrifugal and Axial Flow Compressors: Construction and principle of operation, Factors affecting stage pressure ratio, Compressibility effects, Surging and choking, and Performance characteristics. Design process, Blade design.
Gas Turbine Combustion System: Combustion process, Flame stabilization, Combustion chamber performance, Practical problems—gas turbine emissions.

Learning Resources:

Text Books:

1. Heywood John.B., Internal Combustion Engine Fundamentals, McGraw Hill Co.2018,2nd Edition.
2. Sarvanamuttoo, H.I.H., Rogers, G. F. C. and Cohen, H., Gas Turbine Theory, Pearson Prentice Hall, 2017, 7th Edition.
3. Ganesan V., Gas Turbines., Tata McGraw Hill, 2017, 3rd Edition.

Reference Books:

1. Ehsani M., Gao Y., Longo S.,Ebrahimi K.,Modern Electric, Hybrid Electric, and Fuel Cell Vehicles, CRC Press, 2018, 2nd Edition.
2. Flack, R.D., Fundamentals of Jet Propulsion with Applications, Cambridge University Press, 2011.

Other Suggested Readings:

1. Introduction to Hybrid and Electric vehicles by Dr. Praveen Kumar and Prof. S. Majhi (IIT Guwahati), NPTEL Course (Link: https://nptel.ac.in/courses/108/103/108103009/
2. Aircraft Propulsion by Prof. Vinayak N. Kulkarni, NPTEL Course (Link: https://nptel.ac.in/courses/112/103/112103281/).
3. Jet Aircraft Propulsion by Prof. Bhaskar Roy and Prof. A M Pradeep (IIT Bombay), NPTEL Course (Link: https://nptel.ac.in/courses/101/101/101101002/).

ME 16024 **3-0-0 (3)**

Advanced Computational Fluid Dynamics

Pre-Requisites: **None**

Course Outcomes:

CO-1	Outline the steps involved in solving a fluid dynamics problem using computational methods
CO-2	Derive the governing equations and understand the behaviour of the equations
CO-3	Analyze the consistency, stability and convergence of various discretization Schemes for parabolic, elliptic and hyperbolic partial differential equations.
CO-4	Analyze variations of SIMPLE schemes for incompressible flows and variations of Flux Splitting algorithms for compressible flows.
CO-5	Select methods of grid generation techniques and application of finite difference and finite volume methods to thermal problems.

Syllabus:

Introduction: Revision of Fluid Mechanics and Heat transfer, Derivation of Conservation equations of Mass, momentum and energy.

Governing equations of fluid dynamics: The continuity equation, The momentum equation, The energy equation, Navier-Stokes equations for viscous flow, Euler equations for inviscid flow, Physical boundary conditions, Forms of the governing equations suited for CFD, Conservation form of the equations, shock fitting and shock capturing, Time marching and space marching.

Finite volume method for 1-D, 2-D and 3-D steady state diffusion problems: Finite volume method for Steady 1-D convection-diffusion problems, Conservativeness, Boundedness and Transportiveness, Central, Upwind, Hybrid and Power law schemes, QUICK and TVD schemes.

Pressure Velocity Coupling in steady flows: Staggered grid, SIMPLE algorithm, Assembly of a complete method, SIMPLER, SIMPLEC and PISO algorithms, Worked examples of the above algorithms.

Finite volume method for 1-D unsteady heat conduction: Explicit, Crank-Nicolson and fully implicit schemes, Transient problems with QUICK, SIMPLE schemes, Implementation of boundary conditions: Inlet, Outlet, and Wall boundary conditions, Pressure boundary condition, Cyclic or Symmetric boundary condition.

Errors and uncertainty in CFD modelling: Numerical errors, Input uncertainty, Physical model uncertainty, Verification and validation, Guidelines for best practices in CFD, Reporting and documentation of CFD results.

CFD modelling of turbulent flows: Characteristics of turbulence, Effect of turbulent fluctuations on mean flow, Turbulent flow calculations, Turbulence modelling, Large Eddy Simulation, Direct Numerical Simulation.

Grid Generation: Unstructured grid generation, Domain nodalization, Domain triangulation, Advancing front methods, The Delaunay method, The respective algorithms with examples.

CFD for radiation heat transfer: Governing equations for radiation heat transfer, Popular radiation calculation techniques using CFD, The Monte Carlo method, The discrete transfer method, Raytracing, The discrete ordinates method.

Learning Resources:

Text Books:

1. H.K. Versteeg, W. Malalasekera, An introduction to computational fluid dynamics: the finite volume method, Longman Group, England, 1996
2. Anderson, J.D(Jr), Computational Fluid Dynamics, McGraw-Hill Book Company, 2017.

Reference Books:

1. Hoffman, K.A., and Chiang, S.T., Computational Fluid Dynamics, Vol. I, II and III, Engineering Education System, Kansas, USA, 2000.
2. T.J. Chung, Computational Fluid Dynamics, Cambridge University Press, 2014, 2nd Edition.
3. D.A. Anderson, J.C. Tannehill, and R.H. Pletcher, Computational Fluid Mechanics and Heat Transfer, CRC Press, 2013, 3rd Edition.

Other Suggested Readings:

1. Computational Fluid Dynamics using Finite Volume Method by Dr. Kameswararao Anupindi (IIT Madras), NPTEL Course (Link: https://nptel.ac.in/courses/112/106/112106294/)
2. Foundations of Computational Fluid Dynamics by Prof. S. Vengadesan (IIT Madras), NPTEL Course (Link: https://nptel.ac.in/courses/112/106/112106186/)
3. Computational Fluid Dynamics by Prof. Suman Chakraborty (IIT Kharagpur), NPTEL Course (Link: https://nptel.ac.in/courses/112/105/112105045/

ME 16022 **3-0-0 (3)**

Heating, Ventilation And Air- Conditioning (HVAC)

Pre-Requisites: Refrigeration and Air Conditioning

Course Outcomes:

CO-1	Understand the fundamentals of Psychrometry
CO-2	Apply human comfort indices and comfort charts to design indoor conditions of HVAC systems.
CO-3	Estimate heating and cooling loads for buildings according to ASHRAE procedures and standards.
CO-4	Design and evaluate a complete air distribution system including fan, duct, and installation requirements for a typical HVAC system.

Syllabus:

Introduction: brief history of air conditioning and impact of air conditioning. HVAC systems and classifications, Heat Pumps

Psychrometry of Air Conditioning Processes: Thermodynamic properties of moist air, Important Psychrometry properties, Psychrometric chart; Psychrometric process in air conditioning equipment, applied Psychrometry, air conditioning processes, air washers.

Comfort Air Conditioning: Thermodynamics of human body, metabolic rate, energy balance and models, thermoregulatory mechanism. Comfort & Comfort chart, Effective temperature, Factors governing optimum effective temperature, Design consideration. Selection of outside and inside design conditions.

Heat Transfer Through Building Structures: Solar radiation; basic concepts, sun-earth relationship, different angles, measurement of solar load, Periodic heat transfer through walls and roofs. Empirical methods to calculate heat transfer through walls and roofs using decrement factor and time lag method. Infiltration, stack effect, wind effect. CLTD/ETD method – Use of tables, Numerical and other methods, Heat transfer through fenestration – Governing equations, SHGF/SC/CLF Tables

Load Calculation: Types of air-conditioning systems, General consideration, internal heat gains, system heat gain, cooling and heating load estimate.

Ventilation System: Introduction- Fundamentals of good indoor air quality, need for building ventilation, Types of ventilation system, Air Inlet system. Filters heating & cooling equipment, Fans, Duct design, Grills, Diffusers for distribution of air in the workplace

Learning Resources:

Text Books:

1. Gosney W.B., Principles of Refrigeration, Cambridge University Press, 1982.
2. Threlkeld J.L., Thermal Environmental Engineering, Prentice Hall, New Jersey 1962.

Reference Books:

1. Dossat, R.J. and Horan, T.J., Principles of Refrigeration, Prentice Hall, 2001, 5th Edition.

2. Arora, R.C., Refrigeration & Air conditioning, PHI, 2010.

Other Suggested Readings:

1. Refrigeration and Air-Conditioning by Prof. M Ramgopal (IIT Kharagpur), NPTEL Course (Link: https://nptel.ac.in/courses/112/105/112105129/)
2. NOC:RAC Product Design by Prof. Sanjeev Jain (IIT Delhi) and Prof. Bhupinder Godara (IIT Delhi), NPTEL Course (Link: https://nptel.ac.in/courses/112/102/112102248/)

ME 16023 **3-0-0 (3)**

Power Plant Engineering

Prerequisites: **None**

Course Outcomes:

At the end of the course, the student will be able to:

CO-1	Apply the principles of thermodynamics to analyse the performance of steam, gas, combined and nuclear power plants
CO-2	Design and develop power plant components for optimum performance
CO-3	Select appropriate site and technology for power plants
CO-4	Evaluate economic and environmental implications on power plants.

Syllabus:

Introduction: Energy resources and their availability, types of power plants, selection of the plants, review of basic thermodynamic cycles used in power plants.

Steam Power Plants: Flow sheet and working of modern-thermal power plants, site selection, plant efficiency

Steam generators and their accessories: High pressure Boilers, design of accessories, Steam generator control, Draught system.

Fuel and combustion: coal storage and preparation, coal handling systems, coal combustion, mass and energy balance of steam generator, feeding and burning of pulverized fuel, Fluidized bed combustion system, ash handling systems, dust collection -mechanical dust collector and electrostatic precipitator.

Condensers: Direct Contact Condenser, Surface Condensers, Effect of various parameters on condenser performance, Design of condensers, Cooling towers and cooling ponds

Combined Cycles: Gas turbine power plants, Arrangements of combined plants (steam & gas turbine power plants), parameters affecting thermodynamic efficiency of combined cycles, Integrated gasification combined cycle, PFBC based combined cycle, re-powering of thermal power plant.

Nuclear Power Plants: Principles of nuclear energy, basic nuclear reactions, Nuclear cross-section, different components of nuclear power station, PWR, BWR, CANDU, liquid metal cooled, gas cooled, fast breeder, nuclear waste disposal.

Non-conventional energy generation: Geothermal power plant, Tidal and wave power plant, solar power plant, wind power generation, direct to electricity method - Magneto-hydrodynamic (MHO) power generation

HydroElectric Power Plants: Rainfall and run-off measurements and plotting of various curves for estimating stream flow and size of reservoir, comparison with other types of power plants.

Power Plant Economics: load curve, different terms and definitions, base load and peak load plants, energy storage, cost of electrical energy, tariffs, methods of electrical energy, performance & operating characteristics of power plants - incremental rate theory, input-output curves, efficiency, heat rate, economic load sharing, Problems.

Learning Resources:

Text Books:

1. P. K. Nag., Power Plant Engineering, McGraw Hill Education; 2017,4th Edition.

Reference Books:

1. P. C. Sharma., Power Plant engineering, S.K. Kataria & Sons, New Delhi, 2010.

Other Suggested Readings:

1. NOC:Power Plant Engineering by Prof. Ravi Kumar (IIT Roorkee), NPTEL Course (Link: https://nptel.ac.in/courses/112/107/112107291/)

SYLLABI

Honors-2: Design Engineering

ME 46001 **3-0-0 (3)**

Mechanical Design

Pre-Requisites: **None**

Course Outcomes:

CO-1	Analyze material failure modes and establish various stresses and failure theories on static and dynamic loading
CO-2	Analyze high, low cycle fatigue and interpretation of data by combined loading
CO-3	Design and predict the fracture strength of mechanical components
CO-4	Design mechanical components involving contacts avoiding the surface failures.

Syllabus:

Introduction: Material selection for design; Engineering Design process and the role of materials; Materials classification and their properties; Types of Material Failure – Elastic & Plastic Deformation, Creep deformation. The role of failure prevention analysis in Mechanical Design, Modes of Mechanical failure and their identification

Combined stress theories of failure: State of stress, Differential equations of equilibrium and relation between stress and strain. Static loading, Dynamic loading. Theories of failure and their Use in Design.

High-Cycle and low cycle fatigue system: Fatigue failure theories and models; Fatigue life; Estimation of theoretical fatigue strength; Correction factors to the theoretical fatigue strength; Stress concentration; Cumulative damage and life exhaustion; Effect of mean stress on the fatigue failure; Designing for fully reversed uniaxial stresses; Designing for fluctuating uniaxial stresses; Designing for multi-axial stresses in fatigue.

Introduction to Fracture Mechanics, Creep mechanisms and their principles for Design: Theoretical cohesive strength, Griffith crack theory, Strain energy release rate, Energy release rate and stress field approaches, Fracture toughness of engineering alloys, Crack tip plasticity effects, Use of Fracture Mechanics principles for design. Fatigue crack growth properties, Applications to life analysis and design, Damage Tolerance and Fracture Control Applications in Design. Creep mechanisms - day to day examples; Temperature dependence of creep; Creep and Superplasticity: Correlations to determine rupture time under creep condition – Larson – Miller, Manson and Haferd, Orr-Sherby Dorn.

Design for failure prevention: Surface Geometry; Mating surfaces; Friction; Surface failures - Adhesive wear, Abrasive wear, Corrosion wear, Surface fatigue wear; Static and Dynamic Contact stresses – Spherical contact, Cylindrical contact and General contact, Design Case Studies – Ball bearing, Cylindrical roller bearing, Cam-follower contact.

Learning Resources:

Text Books:

1. Jacks A. Collins, Failure of Materials in Mechanical Design: Analysis, Prediction and Prevention, John Wiley & Sons, 1993, 2nd Edition.
2. Robert L Norton, Machine design an integrated approach, Pearson Education, 2018, Fifth Edition.

Reference Books:

1. L.S. Srinath, Advanced Mechanics of Solids, TMH, 2017, 3rd Edition
2. Richard G. Budynas, J Keith Nisbett, Shigley's Mechanical Engineering Design, Mc Graw Hill, 2014, Tenth Edition.
3. Prashanth Kumar, Elements of Fracture Mechanics, Mc-Graw Hill, 2017.
4. Norman E. Dowling, Mechanical behaviour of Materials, Pearson, 2012, 4th edition.
5. S. Suresh, Fatigue of Materials, Cambridge University Press, 2012, 2nd Edition.
6. Ashby, M.F., Materials Selection in Design, Butterworth-Heinemann, 2016, 5TH Edition.
7. Failure Analysis and Prevention (ASM Hand Book), Metals Hand Book, Vol.11, 2002, 9th Edition.

3-0-0 (3)

ME 46005

Advanced Materials for Design

Pre-Requisites: **None**

Course Outcomes:

CO-1	Describe the various advanced materials and their unique properties used in industries.
CO-2	Understand the application of advanced composites, smart materials, FGMS, and nano-materials.
CO-3	Understand the structure and function of various materials such as FGMs, composites, Shape Memory Alloys etc.
CO-4	Apply the understanding gained for designing materials for design applications.

Syllabus:

Composite Materials: Composite constituents; principles of fibre- reinforced composites, composites classes, PMCs, MMCs, CMCs, CCCs, hybrid composites, PFMS, fibers and matrices, different types of fibers, whiskers, different matrices materials, polymers, metal, ceramic matrices, toughening mechanism, interfaces, blending and adhesion, Natural fiber composites, Important properties and applications of these materials.

Nanomaterials: Origin of nanotechnology, Classification of nanomaterials, Physical, chemical, electrical, mechanical properties of nanomaterials. Nano-materials for product design; mechanical and thermal properties of nano-composite materials. Preparation of nanomaterials by plasma arcing, physical vapour deposition, chemical vapour deposition (CVD), Sol-Gel, electro deposition, ball milling, carbon-nano tubes(CNT).Synthesis, preparation of nanotubes, nanosensors, Quantum dots, nanowires, nanobiology, nanomedicines.

Functional Graded Material: Introduction to Functionally Graded Materials (FGM), Types of Functionally Graded Materials and their Areas Of Application.- Processing Methods of Functionally Graded Materials.- Additive Manufacturing of Functionally Graded Materials.- Experimental Analysis of Functionally Graded Materials from Laser Deposition Process (Case Study), Structural and functional characterization of FGM, Properties required for low temperature applications, Materials available for low temperature applications, Requirements of materials for high temperature applications, Materials available for high temperature applications, Applications of low and high temperature materials.

Shape Memory Alloys (SMA): Phenomena & mechanisms of temperature-controlled shape memory effect, critical temperatures, stress effect on critical temperatures, mechanical properties of SMA at different phases and temperatures, shape memory and superelasticity, major impediments to applications of SMA.

Ceramics and Bio Glasses: Overview of biomaterials Bio-ceramics: Nearly inert ceramics, bio-reactive glasses and glass ceramics, porous ceramics; Calcium phosphate ceramics: grafts, coatings Physico-chemical surface modification of materials used in medicine. biomaterials in ophthalmology, orthopedic implants, dental materials, other advanced materials.

Learning Resources:

Text Books:

1. T. W. Clyne, D. Hull, An Introduction to Composite Materials, Cambridge University Press, 2019, 3rd Edition
2. Dieter Vollath, Nanomaterials: An Introduction to Synthesis, Properties and Applications, Wiley, 2013, 2nd Edition
3. Rasheedat Modupe Mahamood, Esther Titilayo Akinlabi, Functionally Graded Materials, Springer, 2017, 1st Edition
4. P.K. Kumar, D.C. Lagoudas, Dimitris C. Lagoudas, Shape Memory Alloys: Modeling and Engineering Applications, Springer, 2008, 1st Edition
5. Julian R. Jones, Alexis G. Clare, Bio-Glasses: An Introduction, Wiley, 2012, 1st Edition

Reference Books:

1. Pulak M. Pandey, Sandeep Rathee, Manu Srivastava, Prashant K. Jain, Functionally Graded Materials (FGMs): Fabrication, Properties, Applications, and Advancements, CRC Press, 2021, 1st Edition
2. Sri Bandyopadhyay, Raghavendra Gujjala, Toughened Composites Micro and Macro Systems, CRC Press, 2022, 1st Edition

ME 46021 **3-0-0 (3)**

Computer-Aided Geometric Design

Pre-Requisites: **None**

Course Outcomes:

CO-1	Apply geometric transformations and projection methods in CAD
CO-2	Develop geometric models to represent curves
CO-3	Design surface and solid models for engineering design
CO-4	Apply mesh generation techniques for engineering analysis

Syllabus:

Introduction: Introduction to CAE, CAD. Role of CAD in Mechanical Engineering, Design process, software tools for CAD, Geometric modelling.

Transformations in Geometric Modeling: Introduction, Translation, Scaling, Reflection, Rotation in 2D and 3D. Homogeneous representation of transformation, Concatenation of transformations. Computer-Aided assembly of rigid bodies, Applications of transformations in design and analysis of mechanisms, etc. Implementation of the transformations using computer codes.

Projections: Projective geometry, transformation matrices for Perspective, Axonometric projections, Orthographic and Oblique projections. Implementation of the projection formulations using computer codes.

Introduction to Geometric Modeling for Design: Introduction to CAGD, CAD input devices, CAD output devices, CAD Software, Display Visualization Aids, and Requirements of Modelling.

Curves in Geometric Modeling for Design: Differential geometry of curves, Analytic Curves, PC curve, Ferguson's Cubic Curve, Composite Ferguson, Curve Trimming and Blending. Bezier segments, de Casteljau's algorithm, Bernstein polynomials, Bezier-subdivision, Degree elevation, Composite Bezier. B-spline basis functions, Properties of basic functions, Knot Vector generation, NURBS, Conversion of one form of curve to other. Implementation of the all the curve models using computer codes in an interactive manner.

Surfaces in Geometric Modeling for Design: Differential geometry of surfaces, Parametric representation, Curvatures, Developable surfaces. Surfaces entities (planar, surfac of revolution, lofted etc). Free-for surface models (Hermite, Bezier, B-spline surface). Boundary interpolating surfaces (Coon's). Implementation of the all the surface models using computer codes.

Solids in Geometric Modeling for Design: Solid entities, Boolean operations, Topological aspects, Invariants. Write-frame modeling, B-rep of Solid Modelling, CSG approach of solid modelling. Popular modeling methods in CAD softwares. Data Exchange Formats and CAD Applications:

Meshing Methods for Engineering Analysis: FEM, Meshing, Quality of meshing, Mesh generation methods

Learning Resources:

Text Books:

1. Michael E. Mortenson, Geometric Modeling, Tata McGraw Hill, 2013.
2. Saxena and B. Sahay, Computer-Aided Engineering Design, Anamaya Publishers, New Delhi, 2005.

Reference Books:

1. Rogers, David F.Morgan, An introduction to NURBS: with historical perspective, Kaufmann Publishers, USA, 2001.
2. David F. Rogers, J. A. Adams, Mathematical Elements for Computer Graphics, TMH, 2008.
3. Kunwoo Lee, Principles of CAD/CAM/CAE systems, Addison-Wesley, 1999.

ME 46003 **3-0-0 (3)**

Mechanical Vibrations

Pre-Requisites: **None**

Course Outcomes:

CO-1	Analyze the causes and effects of vibrations in mechanical systems and identify discrete and continuous systems.
CO-2	Model the physical systems into schematic models and formulate the governing equations of motion.
CO-3	Compute the free and forced vibration responses of multi degree of freedom systems through modal analysis and interpret the results.
CO-4	Analyse and design systems involving unbalance, transmissibility, vibration isolation and absorption.
CO-5	Analyse and design to control and reduce vibration effects in machinery.

Syllabus:

Introduction: Causes and effects of vibration, Classification of vibrating system, Discrete and continuous systems, degrees of freedom, Identification of variables and Parameters, Linear and nonlinear systems, linearization of nonlinear systems, Physical models, Schematic models and Mathematical models.

Single Degree of Freedom (SDF) systems: Formulation of equation of motion: Newton –Euler method, De Alembert's method, Energy method, Free Vibration: Undamped Free vibration response, Damped Free vibration response, Case studies on formulation and response calculation. Forced vibration response of SDF systems: Response to harmonic excitations, solution of differential equation of motion, Vector approach, Complex frequency response, Magnification factor Resonance, Rotating/reciprocating unbalances.

Dynamics of Rotors: Whirling of rotors, Computation of critical speeds, influence of bearings, Critical speeds of Multi rotor systems.

Design case studies: Design case studies dealing with Transmissibility of forces and motion, Vehicular suspension, Analysis of Vehicles as single degree of freedom systems -vibration transmitted due to unevenness of the roads, preliminary design of automobile suspension. Design of machine foundations and isolators.

Two degree of freedom systems: Introduction, Formulation of equation of motion: Equilibrium method, Lagrangian method, Case studies on formulation of equations of motion, Free vibration response, Eigen values and Eigen vectors, Normal modes and mode superposition, Coordinate coupling, decoupling of equations of motion, Natural coordinates, Response to initial conditions, coupled pendulum, free vibration response case studies, Forced vibration response, Automobile as a two degree of freedom system – bouncing and pitching modes undamped vibration absorbers, Case studies on identification of system parameters and design of undamped vibration absorbers. Analysis and design of damped vibration absorbers.

Multi degree of freedom systems: Introduction, Formulation of equations of motion, Free vibration response, Natural modes and mode shapes, Orthogonally of modal vectors, normalization of modal

vectors, Decoupling of modes, modal analysis, mode superposition technique, Free vibration response through modal analysis, Forced vibration analysis through modal analysis, Modal damping, Rayleigh's damping, Introduction to experimental modal analysis.

Continuous systems: Introduction to continuous systems, discrete vs continuous systems, Exact and approximate solutions, free vibrations of bars and shafts, Free vibrations of beams, Forced vibrations of continuous systems Case studies, Approximate methods for continuous systems and introduction to Finite element method.

Vibration control in structures: Introduction, State space representation of equations of motion. Passive control, active control and semi active control, Free layer and constrained damping layers, Piezo electric sensors and actuators for active control, semi active control of automotive suspension systems.

Learning Resources:

Text Books:

1. L. Meirovich, Elements of Vibration Analysis, Tata Mc-Grawhill, 2007, 2nd Edition.
2. Singiresu S Rao, Mechanical Vibrations, Pearson education, 2011, 4th Edition.

Reference Books:

1. W.T, Thomson, Theory of Vibration, CBS Publishers, 2002, 3rd Edition.
2. Clarence W. De Silva, Vibration: Fundamentals and Practice, CRC Press LLC, 2000.
3. Venkatachalam R., Mechanical Vibrations, PHI Publications, 2018.

ME 46002 **3-0-0 (3)**

Product Design And Development

Pre-Requisites: **None**

Course Outcomes:

CO-1	Develop conceptual product models using creativity and product design techniques
CO-2	Apply embodiment principles in the product development process.
CO-3	Develop products by considering the social, environmental and ethical concerns.
CO-4	Experience by developing CAD/ physical models using the concepts of product design theory.

Syllabus:

Introduction: Design thinking philosophy - Empathy, Define, Ideate, Prototype, Test. Product design context- types of designs, Asimov model, Design method vs scientific method, Considerations of a good design, Design activities/ Process, Product life and technological insertion cycles, organisational structures, business models, Design in teams-Team behavior and dynamics. Team formation and Course project assignment.
Problem identification: Need analysis, customer study and need identification tools, Product Quality and classification of Customer requirements, Kano Diagram. Establishing Engineering characteristics- Benchmarking, Quality Function Deployment- HOQ, Preparation of Initial PDS for the Course Project.
Gathering Information: Transformation from Data to knowledge, types and sources of information, intellectual property rights- classification, Patent searching, stages of patent filing. Importance of Codes and standards in Product Design
Concept Generation/Improvement and Decision making: Creative thinking models, creative thinking aids and barriers, structured and unstructured creative design methods/theories- Brainstorming techniques, Random input technique and Synectics, concept map, Functional decomposition, Morphological analysis, TRIZ, Axiomatic Design, practice exercises. Decision making theories- criteria based selection, Pugh's concept, AHP.
Embodiment and Detailed Design: Product Architecture, Configuration and Parametric design Concepts, Detailed design, Engineering Requirements- failure mode and effects analyses, Legal and ethical issues in design. DFX, Course Project Reviews

Learning Resources:

Text Books:

1. George E Dieter, Engineering Design, Publisher, McGraw Hill, 4th edition.

Reference Books:

1. Kevin N. Otto, Kristin L. Wood, "Product Design", Pearson Education, 2004.
2. W. Ernest Eder, S. Hosendl., "Design Engineering", CRC Press, 2008.

Other Suggested Readings:

1. https://nptel.ac.in/courses/107/103/107103082/

ME 46022 **3-0-0 (3)**

AI & ML for Engineering Analysis

Pre-Requisites: **None**

Course Outcomes:

CO-1	Understand the principles of statistics for Machine learning/deep learning
CO-2	Explore various supervised and unsupervised techniques for Machine learning and Deep learning
CO-3	Learn the programming skills for applying to ML/DL algorithms
CO-4	Apply the above skills to solve design and analysis problems
CO-5	Synthesize cams and followers for specified motion profiles

Syllabus:

Basics of Engineering Design and Statistics: Introduction to Statistics – descriptive statistics, dispersion measures, central tendency measures, hypothesis testing, inferential statistics, correlation and regression, p-value, central limit theorem, feature engineering

Machine Learning Algorithms: Basics of AI, ML, & DL. Fundamentals of ML - supervised, unsupervised, reinforcement learning. Supervised machine learning – Regression: linear regression, multilinear regression, non-linear regression, logistic regression. Classification: neural networks, decision trees, random forests, support vector machine, k-nearest neighbor. Unsupervised machine learning – mixture models, hierarchical k-means clustering, principal component analysis

Deep learning Algorithms: Deep feedforward neural nets, Convolutional neural networks, Long short-term memory (LSTM) networks. Introduction to Graph Neural networks, Generative Adversarial Networks, and Reinforcement Learning

Python for Machine Learning: Getting started with Python, Basic Commands, working with Python libraries, Loops, Variables, Data types, and Data visualization, exploring AI through python- neural networks and machine learning in python.

Applications: SHM Paradigm, feature extraction, feature importance, correlation, and eigenvalue analyses, feature augmentation, performance and validation of ML/DL models in mechanical engineering applications

Learning Resources:

Text Books:

1. Thomas Nield, Essential Math for data science, Oreilly, June 2022

Reference Books:

1. Marc peter, Aldo Faisal, Cheng soon, Mathematics for Machine learning, Cambridge, 2021

ME 46030 **3-0-0 (3)**

Robotics

Pre-Requisites: **None**

Course Outcomes:

CO-1	Classify robots based on joints and arm configurations.
CO-2	Design application specific End Effectors for robots.
CO-3	Compute forward and inverse kinematics of robots and determine trajectory plan.
CO-4	Program robot to perform typical tasks including Pick and Place, Stacking and Welding
CO-5	Design and select robots for Industrial and Non-Industrial applications.

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 TransformationMatrix, 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 & Control: Motion Control- Interaction control, Rigid Body mechanics, Control architecture- position, path velocity and force control systems, computed torque control, adaptive control, and Servo system for robot control. Demonstrate trajectory planning using simulation tools.

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

Programming of Robots: Overview of various programming languages.

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. Craig, J.J., Introduction to Robotics Mechanics and Control, Addison Wesley,1999.
2. Fu, K.S., Gonzalez, R.C., and Lee, C.S.G., Robotics control, Sensing, Vision and Intelligence, McGraw-Hill Publishing company, New Delhi, 2003.

Reference Books:

1. Klafter, R.D., Chmielewski, T.A., and Negin. M, Robot Engineering: An Integrated Approach, Prentice Hall of India, New Delhi, 2002.
2. Kevin M. Lynch, Frank C. Park, Modern Robotics: Mechanics, Planning, and Control, Cambridge University Press, 2017

SYLLABI

Honors-3: Smart Manufacturing

ME 26003 **3-0-0 (3)**

Advanced CAM and Intelligent Manufacturing Systems

Pre-Requisites: **None**

Course Outcomes:

CO-1	Classify and distinguish NC, CNC and DNC systems
CO-2	Assess the performance of manufacturing systems
CO-3	Develop a systematic approach for design and implementation of manufacturing systems
CO-4	Suggest new procedures to improve the productivity of existing manufacturing systems
CO-5	Utilise online collaboration tools to work in complex teams

Syllabus:

CNC Technology:
Introduction, Classification, Advantage, Disadvantages and applications of NC/CNC/DNC and Machine Tool, product cycle and automation in CAD/CAM, Need of CAD/CAM, Computer Aided Process Planning (CAPP), Basic concepts of process planning, Constructional features of CNC machine tools, Design at ion of axis in CNC systems, NC coordinate system, positional control, system devices; drives, ball screws, transducers, feedback devices

Computer Integrated Manufacturing Systems Structure and functional areas of CIM system - CAD, CAPP, CAM**,** CAQC, ASRS. Advantages of CIM. Manufacturing Communication Systems - MAP/TOP, OSI Model, Data Redundancy, Top- down and Bottom-up Approach, Volume of Information. Intelligent Manufacturing System Components, System Architecture and Data Flow, System Operation.

Knowledge Based Systems - Basic Components of Knowledge Based Systems, Knowledge Representation, Comparison of Knowledge Representation Schemes, Interference Engine, Knowledge Acquisition.

Machine Learning - Concept of Artificial Intelligence, Conceptual Learning, Artificial Neural Networks - Biological Neuron, Artificial Neuron, Types of Neural Networks, Applications in Manufacturing.

Automated Process Planning - Variant Approach, Generative Approach, Expert Systems for Process Planning, Feature Recognition, Phases of Process planning. Knowledge Based System for Equipment Selection (KBSES) - Manufacturing system design. Equipment Selection Problem, Modeling the Manufacturing Equipment Selection Problem, Problem Solving approach in KBSES, Structure of the KRSES.

Group Technology: Models and Algorithms Visual Method, Coding Method, Cluster Analysis Method, Matrix Formation - Similarity Coefficient Method, Sorting-based Algorithms, Bond Energy Algorithm, Cost Based method, Cluster Identification Method, Extended CI Method. Knowledge Based Group Technology - Group Technology in Automated Manufacturing System. Structure of Knowledge based system for group

technology (KBST) — Data Base, Knowledge Base, Clustering Algorithm.

Learning Resources:

Text Books:

1. Andrew Kusiak, Intelligent Manufacturing Systems, Prentice Hall.
2. Yagna Narayana, Artificial Neural Networks, PHI, 2006
3. Groover M.P, Automation, Production Systems and CIM, PHI, 2007
4. Simon Haykin, Neural networks: A comprehensive foundation, PHI.
5. B. Vegnanarayana, Artificial neural networks, PHI
6. Li Min Fu, Neural networks in Computer intelligence, TMH, 2003
7. James A Freeman, David M S kapura, Neural networks, Pearson education/2004
8. Jacek M. Zurada, Introduction to Artificial Neural Systems, JAICO Publishing House Ed. 2006.

ME 26001 **3-0-0 (3)**

Advanced Manufacturing Technology

Pre-Requisites: **None**

Course Outcomes:

CO-1	Understand the advances in manufacturing processes including stir casting, cold metal transfer welding and inter pulse TIG welding
CO-2	Apply the knowledge in welding of dissimilar materials and characterization by using Friction stir welding, laser and hybrid welding process
CO-3	Design and analyze the component by WAAM and Powder bed fusion process
CO-4	Apply advanced casting methods including stir casting and centrifugal casting for making composite materials and its characterization
CO-5	Analyze the forming components using a high energy rate forming process

Syllabus:

Advances in welding: Classification of solid state and fusion welding processes, Friction welding, process parameters, design of friction welded joints and applications, Friction stir welding: process parameters, tool design, selection of tool materials, fixture design, advantages, limitations and applications, Inter pulse TIG welding, cold metal transfer welding : effect of process parameters on weld strength, Electron beam welding process, Laser beam welding effect of process variables on mechanical properties of welded joints, Laser surfacing, laser hardening and cladding Hybrid welding process;-Process parameters, applications, advantages and limitations. Wire arc additive Manufacturing processes, the effect of build direction on mechanical properties, applications, advantages, and limitations and Powder Bed Fusion AM Processes.

Advances in casting: Introduction to advances in casting processes, Stir casting process, variables in stir casting process, stirrer design, factors affecting stir casting process, the effect of size and shape of the reinforcement particle in preparation of composite preparation, analysis of composite. Centrifugal casting, production of composites by centrifugal casting process, the effect of process variables on mechanical properties of composites, applications, advantages and limitations. Microwave casting advantages and limitations.

Advances in forming: Introduction forming processes, advantages, limitations and applications, Vacuum forming and hydroforming, the effect of process parameters on forming process, high energy rate forming process: Explosive forming, process parameters, design of explosive forming process, advantages and applications, High velocity forming and Mar forming, advantages and applications, Electromagnetic forming, process variables, advantages and applications.

Material characterization and design considerations: Optical microscopy, microhardness, SEM, and XRD analysis of AM and welded structures.

Learning Resources:

Text Books:

1. R. S. Mishra, Friction Stir Welding and Processing, ASM International, 2007.
2. R.S.Parmar, Welding processes and Technology, Khanna Publishers, 2012
3. J Paulo Davim, Modern Machining Technology, A Practical Guide, 1st Edition, Woodhead Publishing in Mechanical Engineering
4. Materials Characterization, ASM Handbook, volume No 10, ASM International,1998
5. Casting , ASM Handbook, volume No 15, ASM International,1998
6. Forming , ASM Handbook, volume No 14, ASM International,1998

ME 26005 **3-0-0 (3)**

MACHINING PHYSICS

Pre-Requisites: **None**

Course Outcomes:

CO-1	Develop interrelations among ASA, ORS and NRS systems of tool geometry.
CO-2	Analyse cutting forces, temperature, power and specific energy along the shear and rak planes in single point and multi point machining processes
CO-3	Evaluate shear angle relationships and coefficient of friction in natural and controlled conta cutting
CO-4	Analyse the cutting forces in Oblique machining process
CO-5	Select modern machining processes for machining a given material and required pa accuracies.

Syllabus:

Introduction: Overview of the course, Examination and Evaluation patterns, Classification of Manufacturing Processes, History of Machining, Scope and Significance of Machining

Geometry of Cutting Tools: Geometry of single-point cutting tool: Tool-in hand system, ASA system, Significance of various angles of single point cutting tools, Orthogonal Rake System (ORS), Conversions between ASA and ORS systems – Graphical and Analytical Methods, Normal Rake System (NRS) & relation with ORS

Theories of Metal Cutting: Orthogonal and Oblique cutting, Mechanics of Chip formation: Types of chips, chip-breakers, Chip reduction coefficient, shear angle, shear strain, Built-Up-Edge and its effect in metal cutting, Merchant's analysis of metal cutting process - Various forces, power and specific energy in cutting, Theories of Metal Cutting: Ernst & Merchant, theory, Modified Merchant's theory, Lee & Shaffer Theory, Chip-tool Natural Contact Length – Hahn's Analysis, Stress distribution at Chip-Tool Interface – Zorev's Analysis, Machining with controlled contact cutting, Chip breakers.

Thermal aspects in machining: Sources of heat generation, Effects of temperature, Determination of cutting temperature using analytical methods, Determination of cutting temperature using experimental methods, Methods of Controlling Cutting Temperature,

Cutting Tool Materials: Desirable Properties of tool materials, Characteristics of Cutting Tool Materials, indexable inserts, coated tools.

Mechanics of Multipoint Machining processes: Drill geometry & Mechanics of drilling process, Geometry of milling cutters and Mechanics of milling process, Mechanics of grinding (plunge grinding and surface grinding), Grinding wheel wear

Oblique Cutting: Inclination Angle, Chip Flow angle, Mechanics of oblique cutting

Material Removal Mechanism of Advanced Machining Processes:
Mechanical energy-based machining processes: Abrasive jet machining, Ultrasonic machining, Water jet machining, Abrasive water jet machining. Thermo-electric energy-based machining processes: Laser beam machining, Electron beam machining, Electric discharge machining, Plasma arc

machining.Chemical energy-based machining processes: Chemical machining, Electro-Chemical machining

Learning Resources:

Textbooks:

1. M. C. Shaw, Metal Cutting - Principles and Practices, Cambridge University Press. 2005
2. A B Chattopadhyay, Machining and Machine Tools, 2ed, Wiley, 2017
3. P. N. Rao, Manufacturing Technology–Metal Cutting and Machine Tools, TMH, New Delhi, 2013
4. A. Bhattacharya, Metal Cutting: Theory and Practice, New Central Book Agency, Kolkata, 2007
5. V. K. Jain, Advanced Machining Processes, Allied Publisher, Mumbai, 2009

Reference Books:

1. Winston A. Knight and Geoffrey Boothroyd, Fundamentals of Machining and Machine Tools, Taylor and Francis Group, 2005.
2. P. C. Pandey and H. S. Shah, Modern Machining Processes, TMH, 1981
3. A Ghosh and AK Mallik, Manufacturing Science, EWP
4. B L Juneja and G S Sekhon, Fundamentals of Metal Cutting and Machine Tools, New Age International.
5. Helmi A Youssef and Hassan El-Hofy, Machining Technology – Machine Tools and Operations, CRC Press
6. JE McGeough, Advanced Machining Methods, Pergamon Press

Other Suggested Readings:

1. NPTEL Lectures: https://nptel.ac.in/courses/112/105/112105126/
2. NPTEL Lectures: https://nptel.ac.in/courses/112/105/112105127/

ME 36004 **3-0-0 (3)**

Industry 4.0 and IIoT

Pre-Requisites: **None**

Course Outcomes:

CO1	Explore how Industry 4.0 transforms manufacturing through digitization of the value chain and digital twin technologies
CO2	Design, integrate, optimize mechatronic devices, and implement control systems for automation solutions
CO3	Select sensors/actuators, program, simulate, and innovate for addressing automation challenges effectively
CO4	Explore IIoT protocols, build simple IIoT systems with Arduino, ESP32, and Raspberry Pi for practical application
CO5	Explore how Industry 4.0 transforms manufacturing through digitization of the value chain and digital twin technologies

Syllabus:

Introduction to Industry 4.0: Industry 4.0: Globalization and Emerging Issues, The Fourth Revolution, LEAN Production Systems, Mass Customization, Smart and Connected Business Perspective, Smart Factories, Industry 4.0: Cyber Physical Systems and Next Generation Sensors, Collaborative Platform and Product Lifecycle Management, Augmented Reality and Virtual Reality, Artificial Intelligence, Big Data and Advanced Analysis

Introduction to IIoT: Architectural Overview, Design principles and needed capabilities, IoT Applications, Sensing, Actuation, Basics of Networking, M2M and IoT Technology Fundamentals- Devices and gateways, Data management, Business processes in IoT, Everything as a Service (XaaS), Role of Cloud in IoT, Security aspects in IoT.

Elements of IIoT: Hardware Components- Computing (Arduino, Raspberry Pi), Communication, Sensing, Actuation, I/O interfaces. Software Components- Programming API's (using Python/Node.js/Arduino) for Communication Protocols-MQTT, ZigBee, Bluetooth, CoAP, UDP, TCP.

IIoT Application Development: Solution framework for IoT applications- Implementation of Device integration, Data acquisition and integration, Device data storage- Unstructured data storage on cloud/local server, Authentication, authorization of devices. Case Studies: IoT case studies and mini projects based on Industrial automation, Transportation, Agriculture, Healthcare, Home Automation.

Learning Resources:

Text Books:

1. Sudip Misra, Chandana Roy, Anandarup Mukherjee, Introduction to Industrial Internet of Things and Industry 4.0, CRC Press, 2020.
2. Vijay Madisetti, Arshdeep Bahga, A Hands on Approach, Ïnternet of Things, University Press, 2009.
3. Dr. SRN Reddy, RachitThukral and Manasi Mishra, Introduction to Internet of Things: A practical Approach", ETI Labs, 2010
4. Pethuru Raj and Anupama C. Raman,The Internet of Things: Enabling Technologies, Platforms, and Use Cases", CRC Press, 2012
5. Adrian McEwen, Designing the Internet of Things", Wiley, 2015

Reference Books:

1. Raj Kamal, Internet of Things: Architecture and Design, McGraw Hill., 2005.
2. CunoPfister, Getting Started with the Internet of Things, O Reilly Media, 2007.

Other Suggested Readings:

1. https://onlinecourses.nptel.ac.in/noc21_cs17/preview

ME 26002 **3-0-0 (3)**

Additive Manufacturing

Pre-Requisites: **None**

Course Outcomes:

CO1	Develop build preparation data for the additive manufacturing process
CO2	Identify properties of AM materials and their influence on final part quality
CO3	Describe the working principles and applications of each AM process
CO4	Apply design for AM guidelines to fabricate optimized components
CO5	Select the postprocessing and testing method for the given application

Syllabus:

Computer Aided Design (CAD) and Additive Manufacturing (AM) Build Preparation: Introduction to Geometric Modelling. Modelling of Synthetic Curves like Hermite, Bezier and B-spline; Parametric Representation of Freeform Surfaces and Solids. CAD Data Exchange Formats, Input File Sources and Characteristics, AM Data File Formats and Software, STL File Errors and Manipulation, AM Process Chain, Part Orientation and Support Generation, Model Slicing and Contour Data Organisation, Hatching Strategies, AM Toolpaths Generation and Process Plan, Build Preparation and AM Process Simulation.

AM Materials and Characterisation: Nature of Thermoplastics and Thermosetting Polymers, Properties of Metal and Ceramics. AM Liquid Materials: Rheology and Wetting Behaviour. AM Solid Materials: Filament Diameter Consistency, Density, Porosity, Moisture Content, Thermal Properties, Microstructure of Composite Filament, Mechanical Properties of Filament. AM Powder Materials: Powder Size Measurements, Morphology, Chemical Composition, Flow Characteristics, Density, Energy Absorption Characteristics of Powder.

Additive Manufacturing Processes: Classification of AM Processes. Description, Process Parameters, Strengths and Weaknesses of Vat Photopolymerization, Material Jetting, Binder Jetting, Material Extrusion, Sheet Lamination, Powder Bed Fusion and Directed Energy Deposition Processes; *Other Processes:* Aerosol Printing and Bio-plotter. Construction of DIY Printers: Motion System, Frame/Chassis, Print Bed, Extruder, Electronics.

Additive Manufacturing Applications: Aerospace: Aerospace Materials and their Requirements, Certification of AM Parts, Aerospace Case Studies. Medical: Medical Scanning Technologies, Planning and Simulation of Complex Surgeries, Medical Case Studies. Automobile: Prototyping, Jigs and Fixtures, Components of Electric Vehicles, Formula 1, Cooling Ducts, Intake Manifolds, Automobile Case Studies. Other Applications of AM: Marine, Railway, Oil and Gas, Construction, Retail Industry, Arts and Architecture, Fashion and Textile, Jewellery, Cion and Tableware, Weapons, Food, Packaging, and Toy Industry.

Design for AM (DfAM): Need for DfAM, AM Production Economics, General Guidelines for DfAM, Design to Minimize Print Time, Design to Minimize Post-processing, Design Guidelines for Part Consolidation, DfAM Guidelines for AM Tooling Design, Design for Improved Functionality, Design for Minimal Material Usage, Lattice Structures in AM, Generative Design and AM, Topology Optimization for AM, Polymer AM Design Guidelines, Metal AM Design Guidelines, Modelling and Optimization of AM Processes, Guidelines for AM Process Selection.

Postprocessing and Testing of AM Parts: Need for Post Processing in AM, **Surface Treatment Methods:** Subtractive Machining Methods, Thermal-based Methods, Abrasive-based Methods, Chemical Methods. Surface Protection, Functionalization, and Decorative Methods. Heat Treatment and Aging. Establish a Relationship between Processing Parameters, Resulting Microstructure, Mechanical Properties, Fatigue, Creep and Corrosion Resistance of AM Parts. Testing of AM Parts: Metrology Measurement Methods, Porosity and Density, Dimensions, Mechanical Measurement Methods, NDT Methods of AM Parts, AM Safety, AM Standards.

Learning Resources:

Text Books:

1. David F. Rogers, J. A. Adams, Mathematical Elements for Computer Graphics, Tata McGrawHill, 2008.
2. Damir Godec, Joamin Gonzalez-Gutierrez, Axel Nordin, Eujin Pei, Julia Urena Alcazar, A Guide to Additive Manufacturing, Springer, 2022.
3. Ian Gibson, David Rosen, Brent Stucker, and Mahyar Khorasani, Additive Manufacturing Technologies, 3rd Edition, Springer, 2021.
4. Diegel, Olaf, Axel Nordin, and Damien Motte, A Practical Guide to Design for Additive Manufacturing, Springer, 2020.
5. Zafar Alam Faiz Iqbal, Dilshad Ahmad Khan, Post-processing Techniques for Additive Manufacturing, CRC Press, 2024.

Reference Books:

1. Michael E.Mortenson, Geometric Modeling, McGrawHill, 2013.
2. Patri K. Venuvinod and Weiyin Ma, Rapid Prototyping: Laser-based and Other Technologies,Springer, 2004.
3. Sanjay Joshi, Richard P. Martukanitz, Abdalla R. Nassar, Pan Michaleris, Additive Manufacturing with Metals: Design, Processes, Materials, Quality Assurance, and Applications, Springer, 2023.
4. L.Lu, J. Y. H. Fuh and Y.S.Wong, Laser-Induced Materials and Processes for Rapid Prototyping, Springer, 2001.
5. Chua Chee Kai, Leong Kah Fai, Rapid Prototyping: 3D Printing and Additive Manufacturing Principles & Applications, 5th Edition. World Scientific, 2019.
6. Gurminder Singh, Ranvijay Kumar, Kamalpreet Sandhu, Eujin Pei, and Sunpreet Singh, Handbook of Post-Processing in Additive Manufacturing: Requirements, Theories, and Methods, CRC Press, 2024.

3-0-0 (3)

ME 26028

Design and Analysis of Experiments

Pre-Requisites: **None**

Course Outcomes:

CO1	Identify objectives and key factors in designing experiments.
CO2	Develop appropriate experimental design to conduct experiments.
CO3	Analyse experimental data and draw valid conclusions.
CO4	Develop empirical models using experimental data to optimize process parameters.
CO5	Design robust products and processes using parameter design approach.

Syllabus:

Fundamentals of Experimentation: Role of experimentation in rapid scientific progress, Historical perspective of experimental approaches, Steps in experimentation, Principles of experimentation.

Simple Comparative Experiments: Basic concepts of probability and statistics, Comparison of two means and two variances, Comparison of multiple (more than two) means & ANOVA.

Experimental Designs: Factorial designs, fractional factorial designs, orthogonal arrays, standard orthogonal arrays & interaction tables, modifying the orthogonal arrays, selection of suitable orthogonal array design, analysis of experimental data.

Response Surface Methodology: Concept, linear model, steepest ascent, second order model, regression.

Taguchi's Parameter Design: Concept of robustness, noise factors, objective function & S/N ratios, inner-array and outer-array design, data analysis.

Learning Resources:

Text Books:

1. Montgomery D. C., Design and Analysis of Experiments, John Wiley & Sons, 2010, 7thEdition.
2. Ross P. J., Taguchi Techniques for Quality Engineering, McGraw-Hill, NY, 2008.
3. Madhav S. Phadke, Quality Engineering using Robust Design, Prentice Hall, 1989

Reference Books:

1. Dukkipati, R V and Pradip K Ray, Product and Process Design for Quality, Economy and Reliability, New Age International, 2010, 1st Edn.

Other Suggested Readings:

1. http://reliawiki.org/index.php/Experiment_Design_and_Analysis_Reference
2. https://ieeexplore.ieee.org/abstract/document/6771276
3. https://link.springer.com/chapter/10.1007/978-1-4684-1472-1_1

ME 36032 **3-0-0 (3)**

AI & ML for Mechanical Systems

Pre-Requisites: **None**

Course Outcomes:

CO1	Understand the core concepts of Mechanical Systems in the context of Industry 4.o
CO2	Apply AI, ML and Deep Learning concepts on Various Mechanical Systems
CO3	Apply the statistical and optimization techniques on Mechanical Systems
CO4	Evaluate the Mechanical System performance using simulation and experimental analysis

Syllabus:

Introduction to Mechanical Systems evolution in the context of Industry 4.0, Key issues: Adaptability, Intelligence, Autonomy, Safety, Sustainability, Interoperability, Flexibility of Mechanical Systems.

Introduction of Statistics; Descriptive statistics: Central tendency measures, Dispersion measures, data distributions, center limit theorem, sampling, sampling methods; Inferential Statistics: Hypothesis testing, confidence level, degree of freedom, P-value, Chi-square test, ANOVA, Correlation V's Regression, Uses of Correlation and regression.

Artificial Intelligence: Brief review of AI history, Problem formulation: Graph structure, Graph implementation, state space representation, search graph and search tree, Search Algorithms: random search, Depth-first, breadth-first search and uniform-cost search. Heuristic: Best first search, A* and AO* algorithm, generalization of search problems. Ontology; Fuzzy; Meta-heuristics.

Machine Learning: Overview of supervised and unsupervised learning; Supervised Learning: Linear Regression, Non-linear Regression Model evaluation methods, Logistic Regression, Neural Networks; Unsupervised Learning: K-means clustering, C-means Clustering. Convolutional Neural Networks (CNN), Pooling, Padding Operations, Interpretability in CNNs, Limitations in CNN. Cases with respect to different mechanical systems.

Introduction to Raspberry Pi; Installation of Raspbian OS on Raspberry Pi; Controlling LED using Raspberry Pi; Integrating IR Sensor with Raspberry Pi; Controlling LED with IR Sensor; Integrating Temperature and amp; Humidity Sensor with Raspberry Pi read Current Environment Values, Collecting the sensor data using Raspberry Pi; Matlab toolboxes - Simulink, Mechanical Systems implementation: From features to software components, Mapping software components to ECUs.

Learning Resources:

Text Books:

1. Rajkumar, Dionisio De Niz, and Mark Klein, Cyber-Physical Systems, Wesley Professional.
2. Rajeev Alur, Principles of Cyber-Physical Systems, MIT Press, 2015.
3. Robert Levine et al., "A Comprehensive guide to AI and Expert Systems", McGraw Hill Inc, 1986.
4. E. A. Lee and S. A. Seshia, "Introduction to Embedded Systems: A Cyber-Physical Systems Approach", 2011.
5. C. Cassandras, S. Lafortune, "Introduction to Discrete Event Systems", Springer,2007.
6. Constance Heitmeyer and Dino Mandrioli, "Formal methods for real-time computing", Wiley publisher, 1996.
7. Montgomery Douglas, 2017. Design of Experiments, John Wiley and Sons, Inc.

ME 36036 **3-0-0 (3)**

Soft Computing Techniques

Pre-Requisites: **None**

Course Outcomes:

CO-1	Classify and differentiate problem solving methods and tools.
CO-2	Apply A*, AO*, Branch and Bound search techniques for problem solving.
CO-3	Formulate an optimization problem to solve using evolutionary computing methods.
CO-4	Design and implement GA, PSO and ACO algorithms for optimization problems in Mechanic Engineering.
CO-5	Apply soft computing techniques for design, control and optimization of Manufacturin systems.

Syllabus:

Problem Solving Methods and Tools: Problem Space, Problem solving, State space, Algorithm's performance and complexity, Search Algorithms, Depth first search method, Breadth first search methods their comparison, A*, AO*, Branch and Bound search techniques, p type, Np complete and Np Hard problems.

Evolutionary Computing Methods: Principles of Evolutionary Processes and genetics, A history of Evolutionary computation and introduction to evolutionary algorithms, Genetic algorithms, Evolutionary strategy, Evolutionary programming, Genetic programming.

Genetic Algorithm and Genetic Programming: Basic concepts, working principle, procedures of GA, flow chart of GA, Genetic representations, (encoding) Initialization and selection, Genetic operators, Mutation, Generational Cycle, applications.

Swarm Optimization: Introduction to Swarm intelligence, Ant colony optimization (ACO), Particle swarm optimization (PSO), Artificial Bee colony algorithm (ABC), Other variants of swarm intelligence algorithms.

Advances in Soft Computing Tools: Fuzzy Logic, Theory and applications, Fuzzy Neural networks, Pattern Recognition, Differential Evolution, Data Mining Concepts, Applications of above algorithms in manufacturing engineering problems.

Deep Neural Networks: Neuron, Nerve structure and synapse, Artificial Neuron and its model, activation functions, Neural network architecture: single layer and multilayer feed forward networks, recurrent networks. Back propagation algorithm, factors affecting back propagation training, applications.

Application of Soft Computing to Mechanical Engineering/Production Engineering Problems: Application to Inventory control, Scheduling problems, Production, Distribution, Routing, Transportation, Assignment problems.

Learning Resources:

Text Books:

1. Tettamanzi Andrea, Tomassini and Marco, Soft Computing Integrating Evolutionary, Neural and Fuzzy Systems, Springer, 2001.
2. Elaine Rich, Artificial Intelligence, McGraw Hill, 2/e, 1990.

3. Kalyanmoy Deb, Multi-objective Optimization using Evolutionary Algorithms, John Wiley and Sons, 2001.

4. Kalyanmoy Deb, Optimization for Engineering Design: Algorithms and Examples, PHI, Ltd, 2012.

References:

1. https://in.mathworks.com/content/dam/mathworks/ebook/gated/machine-learning-ebook - all-chapters.pdf.
2. https://www.iitk.ac.in/kangal/index.shtml

SYLLABI

Honors-4: Computational Mechanics

ME 16001 **3-0-0 (3)**

Advanced Fluid Mechanics

Prerequisites: None

Course Outcomes:

At the end of the course, the student will be able to:

CO-1	Ascertain basic concepts of the fluid mechanics and apply the concepts in the analysis of fluid flow problems
CO-2	Analyze the stress, strain and forces involving in the fluid element and to derive the governing equations
CO-3	Find the exact and approximate solutions of the governing equations for realistic flow situations
CO-4	Analyze the performance of fluid flow in laminar and turbulent flows
CO-5	Differentiate compressible and incompressible flows and solve compressible flow problems

Syllabus:

Introduction: Review of the fundamentals of Fluid mechanics.

Kinematics of Fluids: Lagrangean and Eulerian systems, Velocity potential, Stream function and Vorticity.
General theory of Stress and Rate of Strain: Stress-strain relations.

Fundamental Conservation Equations: Integral and differential forms.

One-dimensional Inviscid Incompressible Flow: Euler's equation and Bernoulli's equation-applications of Bernoulli's equation.

Exact solutions of Navier-Stokes Equations: Couette flow, Hagen-Poiseuille flow, Flow between coaxial and concentric rotating cylinders, Hydrodynamic theory of lubrication, Creeping flows, Unsteady motion of flat plate.

The Laminar Boundary Layer: Prandtl's Boundary Layer Equations, Blasius solution, Momentum-integral equations and its applications, Boundary layer separation and control.

Turbulent Flows: Introduction to Turbulent Flow, Reynolds modification of N-S equations, Semi – empirical theories, Turbulent boundary layer for internal and external flows, Turbulence modelling.

Dimensional Analysis: Flow over a bluff body – Lift and Drag, Dimensional analysis and similitude.

Introduction to Compressible Flow: Isentropic flow, Flow across normal and oblique shocks, Fanno flow, Rayleigh flow, Expansion waves.

Learning Resources:

Text Books:

1. Fox, R.W., Pritchard, P. J. and McDonald, A. T., Introduction to Fluid Mechanics, Wiley, 2018, 8th Edition.
2. White, F. M., Viscous Fluid Flow, Tata McGraw Hill Book Company, 2021, 4th Edition.

Reference Books:

1. Yuan, S. W., Foundations of Fluid Mechanics, Prentice Hall of India, 2000
2. Yahya, S. M., Fundamentals of Compressible Flow with Aircraft and Rocket Propulsion, New Age International Publishers, 2018, 6th Edition.

3. Yahya, S. M., Anderson, J. D. Jr., Modern Compressible Flow –with Historical Perspective, TMH, 2020, 4th edition.

4. Schlichting, H and Gersten, K, Boundary Layer Theory, Springer, 2018, 9th Edition.
5. Muralidhar, K and Biswas, G., Advanced Engineering Fluid Mechanics, Alpha Science International Ltd., 2018, 3rd Edition.

Other Suggested Readings:

1. Advanced Fluid Mechanics by Dr. Suman Chakraborty (IIT Kharagpur), NPTEL Course (Link: https://nptel.ac.in/courses/112/105/112105218/#)
2. Introduction to Turbulence by Prof. Gautam Biswas (IIT Kanpur), NPTEL Course (Link: https://nptel.ac.in/courses/112/104/112104120/)

ME 16003 **3-0-0 (3)**

Computational Methods in Thermal Engineering

Prerequisites: **None**

Course Outcomes:

At the end of the course, the student will be able to:

CO-1	Understand the stepwise procedure to completely solve a fluid dynamics problem using computational methods.
CO-2	Derive the governing equations and understand the behavior of the equations.
CO-3	Analyze the consistency, stability and convergence of various discretisation schemes for parabolic, elliptic and hyperbolic partial differential equations.
CO-4	Analyze variations of SIMPLE schemes for incompressible flows and Variations of Flux Splitting algorithms for compressible flows.
CO-5	Analyze various methods of grid generation techniques and application of finite difference and finite volume methods to various thermal problems.

Syllabus:

Introduction: History and Philosophy of computational fluid dynamics, CFD as a design and research tool, Applications of CFD in engineering, Programming fundamentals, MATLAB programming, Numerical Methods.

Governing equations of fluid dynamics: Models of the flow, The substantial derivative, Physical meaning of the divergence of velocity, The continuity equation, The momentum equation, The energy equation, Navier-Stokes equations for viscous flow, Euler equations for inviscid flow, Physical boundary conditions, Forms of the governing equations suited for CFD, Conservation form of the equations, shock fitting and shock capturing, Time marching and space marching.

Mathematical behaviour of partial differential equations: Classification of quasi-linear partial differential equations, Methods of determining the classification, General behaviour of Hyperbolic, Parabolic and Elliptic equations.

Basic aspects of discretization: Introduction to finite differences, Finite difference equations using Taylor series expansion and polynomials, Explicit and implicit approaches, Uniform and unequally spaced grid points.

Grids with appropriate transformation: General transformation of the equations, Metrics and Jacobians, The transformed governing equations of the CFD, Boundary fitted coordinate systems, Algebraic and elliptic grid generation techniques, Adaptive grids.

Parabolic partial differential equations: Finite difference formulations, Explicit methods – FTCS, Richardson and DuFort-Frankel methods, Implicit methods – Lasonen, Crank-Nicolson and Beta formulation methods, Approximate factorization, Fractional step methods, Consistency analysis, Linearization.

Stability analysis: Discrete Perturbation Stability analysis, von Neumann Stability analysis, Error analysis, Modified equations, Artificial dissipation and dispersion.

Elliptic equations: Finite difference formulation, solution algorithms: Jacobi-iteration method, Gauss-Siedel iteration method, point- and line-successive over-relaxation methods, alternative direction implicit methods.

Hyperbolic equations: Explicit and implicit finite difference formulations, splitting methods, multi-step methods, applications to linear and nonlinear problems, linear damping, flux corrected transport,

monotone and total variation diminishing schemes, TVD formulations, entropy condition, first-order and second-order TVD schemes.

Scalar representation of Navier-Stokes equations: Equations of fluid motion, numerical algorithms: FTCS explicit, FTBS explicit, Dufort-Frankel explicit, McCormack explicit and implicit, BTCS and BTBCS implicit algorithms, SIMPLE algorithm, applications

Grid generation: Algebraic Grid Generation, Elliptic Grid Generation, Hyperbolic Grid Generation, Parabolic Grid Generation.

Finite volume method for unstructured grids: Advantages, Cell Centered and Nodal point Approaches, Solution of Generic Equation with tetrahedral Elements, 2-D Heat conduction with Triangular Elements.

Learning Resources:

Text Books:

1. Anderson, J.D. (Jr), McGraw-Hill., Computational Fluid Dynamics: the Basics with Applications, Book Company, 2017, Indian Edition.
2. Vol. I, II and III, Hoffman, K.A and Chiang, S.T., Computational Fluid Dynamics, Engineering Education System, Kansas, USA, 2000, 4th edition.
3. Suhas V Patankar ., Numerical Heat Transfer and Fluid Flow, CRC Press, 2018, Special Indian Edition.

Reference Books:

1. Chung, T.J., Computational Fluid Dynamics, Cambridge University Press, 2014, 2nd Edition.
2. Anderson, D.A., Tannehill, J.C., and Pletcher , R.H., Computational Fluid Mechanics and Heat Transfer, CRC Press, 2020, 4th Edition.

Other Suggested Readings:

1. Introduction to CFD by Prof. M. Ramakrishna (IIT Madras), NPTEL Course (Link: https://nptel.ac.in/courses/101/106/101106045/)

ME 26003 **3-0-0 (3)**

Advanced CAM and Intelligent Manufacturing Systems

Pre-Requisites: None

Course Outcomes:

CO-1	Classify and distinguish NC, CNC and DNC systems
CO-2	Assess the performance of manufacturing systems
CO-3	Develop a systematic approach for design and implementation of manufacturing systems
CO-4	Suggest new procedures to improve the productivity of existing manufacturing systems
CO-5	Utilise online collaboration tools to work in complex teams

Syllabus:

CNC Technology:

Introduction, Classification, Advantage, Disadvantages and applications of NC/CNC/DNC and Machine Tool, product cycle and automation in CAD/CAM, Need of CAD/CAM, Computer Aided Process Planning (CAPP), Basic concepts of process planning, Constructional features of CNC machine tools, Design at ion of axis in CNC systems, NC coordinate system, positional control, system devices; drives, ball screws, transducers, feedback devices

Computer Integrated Manufacturing Systems Structure and functional areas of CIM system – CAD, CAPP, CAM**,** CAQC, ASRS. Advantages of CIM. Manufacturing Communication Systems – MAP/TOP, OSI Model, Data Redundancy, Top- down and Bottom-up Approach, Volume of Information. Intelligent Manufacturing System Components, System Architecture and Data Flow, System Operation.

Knowledge Based Systems – Basic Components of Knowledge Based Systems, Knowledge Representation, Comparison of Knowledge Representation Schemes, Interference Engine, Knowledge Acquisition.

Machine Learning – Concept of Artificial Intelligence, Conceptual Learning, Artificial Neural Networks – Biological Neuron, Artificial Neuron, Types of Neural Networks, Applications in Manufacturing.

Automated Process Planning – Variant Approach, Generative Approach, Expert Systems for Process Planning, Feature Recognition, Phases of Process planning. Knowledge Based System for Equipment Selection (KBSES) – Manufacturing system design. Equipment Selection Problem, Modeling the Manufacturing Equipment Selection Problem, Problem Solving approach in KBSES, Structure of the KRSES.

Group Technology: Models and Algorithms Visual Method, Coding Method, Cluster Analysis Method, Matrix Formation – Similarity Coefficient Method, Sorting-based Algorithms, Bond Energy Algorithm, Cost Based method, Cluster Identification Method, Extended CI Method. Knowledge Based Group Technology – Group Technology in Automated Manufacturing System. Structure of Knowledge based system for group

technology (KBST) — Data Base, Knowledge Base, Clustering Algorithm.

Learning Resources:

Text Books:

1. Andrew Kusiak, Intelligent Manufacturing Systems, Prentice Hall.
2. Yagna Narayana, Artificial Neural Networks, PHI, 2006
3. Groover M.P, Automation, Production Systems and CIM, PHI, 2007
4. Simon Haykin, Neural networks: A comprehensive foundation, PHI.
5. B. Vegnanarayana, Artificial neural networks, PHI
6. Li Min Fu, Neural networks in Computer intelligence, TMH, 2003
7. James A Freeman, David M S kapura, Neural networks, Pearson education/2004
8. Jacek M. Zurada, Introduction to Artificial Neural Systems, JAICO Publishing House Ed. 2006.

ME 46021 **3-0-0 (3)**

Computer-Aided Geometric Design

Pre-Requisites: **None**

Course Outcomes:

CO-1	Apply geometric transformations and projection methods in CAD
CO-2	Develop geometric models to represent curves
CO-3	Design surface and solid models for engineering design
CO-4	Apply mesh generation techniques for engineering analysis

Syllabus:

Introduction: Introduction to CAE, CAD. Role of CAD in Mechanical Engineering, Design process, software tools for CAD, Geometric modelling.

Transformations in Geometric Modeling: Introduction, Translation, Scaling, Reflection, Rotation in 2D and 3D. Homogeneous representation of transformation, Concatenation of transformations. Computer-Aided assembly of rigid bodies, Applications of transformations in design and analysis of mechanisms, etc. Implementation of the transformations using computer codes.

Projections: Projective geometry, transformation matrices for Perspective, Axonometric projections, Orthographic and Oblique projections. Implementation of the projection formulations using computer codes.

Introduction to Geometric Modeling for Design: Introduction to CAGD, CAD input devices, CAD output devices, CAD Software, Display Visualization Aids, and Requirements of Modelling.

Curves in Geometric Modeling for Design: Differential geometry of curves, Analytic Curves, PC curve, Ferguson's Cubic Curve, Composite Ferguson, Curve Trimming and Blending. Bezier segments, de Casteljau's algorithm, Bernstein polynomials, Bezier-subdivision, Degree elevation, Composite Bezier. B-spline basis functions, Properties of basic functions, Knot Vector generation, NURBS, Conversion of one form of curve to other. Implementation of the all the curve models using computer codes in an interactive manner.

Surfaces in Geometric Modeling for Design: Differential geometry of surfaces, Parametric representation, Curvatures, Developable surfaces. Surfaces entities (planar, surfac of revolution, lofted etc). Free-for surface models (Hermite, Bezier, B-spline surface). Boundary interpolating surfaces (Coon's). Implementation of the all the surface models using computer codes.

Solids in Geometric Modeling for Design: Solid entities, Boolean operations, Topological aspects, Invariants. Write-frame _odelling, B-rep of Solid Modelling, CSG approach of solid modelling. Popular _odelling methods in CAD softwares. Data Exchange Formats and CAD Applications:

Meshing Methods for Engineering Analysis: FEM, Meshing, Quality of meshing, Mesh generation methods

Learning Resources:

Text Books:

1. Michael E. Mortenson, Geometric Modeling, Tata McGraw Hill, 2013.
2. Saxena and B. Sahay, Computer-Aided Engineering Design, Anamaya Publishers, New Delhi, 2005.

Reference Books:

1. Rogers, David F.Morgan, An introduction to NURBS: with historical perspective, Kaufmann Publishers, USA, 2001.
2. David F. Rogers, J. A. Adams, Mathematical Elements for Computer Graphics, TMH, 2008.
3. Kunwoo Lee, Principles of CAD/CAM/CAE systems, Addison-Wesley, 1999.

ME 46004 **3-0-0 (3)**

Finite Element Analysis for Design

Pre-Requisites: **None**

Course Outcomes:

CO-1	Make use of the concept of finite element method for solving machine design problems
CO-2	Solve problems in 1-D structural systems involving bars, trusses, beams and frames.
CO-3	Develop 2-D and 3-D FE formulations involving triangular, quadrilateral elements and higher order elements.
CO-4	Apply the knowledge of FEM for stress analysis, model analysis, heat transfer analysis and flow analysis.
CO-5	Develop algorithms and FE code for solving design problems and adapt commercial packages for complex problems.

Syllabus:

Introduction: Historical Perspective of FEM and applicability to mechanical engineering design problems.

Mathematical Models and Approximations: Review of elasticity. Mathematical models for structural problems: Equilibrium of continuum-Differential formulation, Energy Approach- Integral formulation: Principle of Virtual work - Variational formulation. Overview of approximate methods for the solution of the mathematical models, Residual methods and weighted residual methods, Ritz, Rayleigh-Ritz and Gelarkin's methods. Philosophy of solving continuum problems using Finite Element Method.

Finite Element Formulation: Generalized FE formulation based on weightedresidual method and through minimization of potential, displacement based formulation,Concept of discretization, Interpolation, Formulation of Finite element characteristic matrices and vectors, Compatibility conditions, Assembly and boundary considerations.

Finite Element Analysis for One Dimensional Structural problems: Structuralproblems with one dimensional geometry. Bar element: formulation of stiffness matrix,consistent and lumped load vectors. Boundary conditions and their incorporation:Elimination method, Penalty Method, Introduction to higher order elements and their advantages and disadvantages. Formulation for Truss elements, Case studies involving hand calculations with an emphasis on assembly, boundary conditions,contact conditions and multipoint constraints.

Beams and Frames: Review of bending of beams, higher order continuity (C^0 and C^1 Continuity), interpolation for beam elements and formulation of FE characteristics, Plane and space frames and examples problems involving hand calculations. Algorithmic approach for developing computer codes involving 1-D elements.

Two dimensional Problems: Interpolation in two dimensions, natural coordinates, Isoparametric representation, Concept of Jacobian. Finite element formulation for plane stress plane strain and axi-symmetric problems; Triangular and Quadrilateral elements, higher order elements, sub-parametric, Isoparametric and superparametric elements. Formulation of plate bending elements using linear and higher order bending theories, Shell elements, General considerations in finite element analysis of design problems, Choosing an appropriate element and the solution strategies. Introduction to pre and post processing of the results and analysis.

Three Dimensional Problems: Finite element formulation for 3-D problems, mesh preparation, tetrahedral and hexahedral elements, case studies.

Dynamic Analysis: FE formulation in dynamic problems in structures using Lagrangian Method, Consistent and lumped mass models, Formulation of dynamic equations of motion, Modelling of structural damping and formulation of damping matrices, Model analysis, Mode superposition methods and reduction techniques.

FEM in Heat Transfer and Fluid Mechanics problems: Finite element solution for one dimensional heat conduction with convective boundaries. Formulation of element characteristics and simple numerical problems. Formulation for 2-D and 3-D heat conduction problems with convective boundaries. Introduction to thermo-elastic contact problems. Finite element applications in potential flows; Formulation based on Potential function and stream function. Case studies.

Algorithmic Approach for problem solving: Algorithmic approach for Finite element formulation of element characteristics, Assembly and incorporation of boundary conditions. Guidelines for code development. Introduction to commercial Finite Element software packages like ANSYS.

Learning Resources:

Text Books:

1. Singiresu S.Rao, Finite element Method in Engineering, Elsevier, 2012, 5th edition,
2. Seshu P, Textbook of Finite Element Analysis, PHI. 2004.
3. U. S. Dixit, Finite Element Methods for Engineers, Cengage Learning, 2009

Reference Books:

1. Reddy, J.N., Finite Element Method in Engineering, Tata McGraw Hill, 2017
2. Zeincowicz, The Finite Element Method, 4 Vol set, Elsevier, 2007, 4th Edition.

ME 16054 **3-0-0 (3)**

Design and Optimization of Thermal Systems

Pre-Requisites: **None**

Course Outcomes:

CO-1	Perform economic analysis of a thermal system.
CO-2	Design turbomachines and heat exchangers
CO-3	Use numerical techniques to solve thermal system models
CO-4	Apply optimization procedures to design thermal systems

Syllabus:

Introduction: Introduction to design and specifically system design. Morphology of design with a flow chart, brief discussion on market analysis, profit, time value of money, an example of discounted cash flow technique. Concept of workable design, practical example on workable system and optimal design.

Design of Turbomachines: Principles of Design of turbo machines, Design of axial flow turbine stage, Design of axial flow compressor stage, Design of centrifugal compressor.

Design of Heat Exchanger : Study of design aspects, fluid flow and heat transfer characteristics, Material requirement of heat exchange equipment, Liquid - to - liquid and Liquid - to - gas heat exchange systems, Familiarity with use of design related industrial standards and codes, Design of Heat exchanger.

Design of Auxiliary systems: Lubrication, fuel, seal and gas conditioning

System Simulation: Classification. Successive substitution method, Newton Raphson method, Gauss Seidel method, Rudiments of finite difference method for partial differential equations.

Optimization: Introduction. Formulation of optimization problems, calculus technique, search methods, method of steepest ascent/ steepest descent, conjugate gradient method, geometric programming, dynamic programming, linear programming, new generation optimization techniques – genetic algorithm and simulated annealing.

Learning Resources:

Text Books:

1. C. Balaji, Essentials of Thermal System Design and Optimization, Ane Books, New Delhi in India and CRC Press in the rest of the world, 2011.
2. Y. Jaluria, Design and optimization of thermal systems, McGraw Hill, 1998.

Reference Books:

1. L.C. Burmeister, Elements of thermal fluid system design, Prentice Hall, 1998.
2. W.F. Stoecker, Design of thermal systems, McGraw Hill, 1989

Other Suggested Readings:

1. Design and Optimization of Energy systems by Prof. C. Balaji (IIT Madras), NPTEL Course (Link: https://nptel.ac.in/courses/112/106/112106064/)

ME 46028 **3-0-0 (3)**

Optimization Methods for Engineering Design

Pre-Requisites: **None**

Course Outcomes:

CO-1	Formulate a design task as an optimization problem.
CO-2	Solve unconstrained optimization problems using corresponding methods.
CO-3	Solve unconstrained optimization problems using corresponding methods.
CO-4	Solve the nonlinear optimization problems with evolutionary methods

Syllabus:

Introduction to Optimization in Design: Problem formulation, Optimization problems in Mechanical Engineering, Classification of methods for optimization

Single-variable Optimization: Optimal criteria, Derivative-free methods (bracketing, region elimination), Derivative based methods, root-finding methods.

Multiple-variable Unconstrained Optimization: Optimal criteria, Direct search methods (Box's, Simplex, Hooke-Jeeves, Conjugate methods), Gradient-based methods (Steepest Descent, Newton's, Marquardt's, DFP method). Formulation and Case studies.

Constrained Optimization: KKT conditions, Penalty method, Sensitivity analysis, Direct search and gradient based methods for constrained optimization. Formulation and Case studies.

Evolutionary Optimization algorithms: Philosophy**,** Genetic algorithms and simulated annealing.

Multi-objective Optimization: Terminology and concepts, the concepts of Pareto optimality and Pareto optimal set, formulation of multi-objective optimization problem, NSGA.

Case studies and Computer Implementation: Representative case studies for important methods and development of computer code for the same to solve problems.

Learning Resources:

Text Books:

1. Jasbir Arora, Introduction to Optimum Design, Academic Press, 2004.

Reference Books:

1. Kalyanmoy Deb, Optimization For Engineering Design: Algorithms and Examples, PHI, 2004.
2. Kalyanmoy Deb, Multi-Objective Optimization using Evolutionary Algorithms, Wiley, 2001

ME 36032 **3-0-0 (3)**

AI & ML for Mechanical Systems

Pre-Requisites: **None**

Course Outcomes:

CO1	Understand the core concepts of Mechanical Systems in the context of Industry 4.o
CO2	Apply AI, ML and Deep Learning concepts on Various Mechanical Systems
CO3	Apply the statistical and optimization techniques on Mechanical Systems
CO4	Evaluate the Mechanical System performance using simulation and experimental analysis

Syllabus:

Introduction to Mechanical Systems evolution in the context of Industry 4.0, Key issues: Adaptability, Intelligence, Autonomy, Safety, Sustainability, Interoperability, Flexibility of Mechanical Systems.

Introduction of Statistics; Descriptive statistics: Central tendency measures, Dispersion measures, data distributions, center limit theorem, sampling, sampling methods; Inferential Statistics: Hypothesis testing, confidence level, degree of freedom, P-value, Chi-square test, ANOVA, Correlation V's Regression, Uses of Correlation and regression.

Artificial Intelligence: Brief review of AI history, Problem formulation: Graph structure, Graph implementation, state space representation, search graph and search tree, Search Algorithms: random search, Depth-first, breadth-first search and uniform-cost search. Heuristic: Best first search, A* and AO* algorithm, generalization of search problems. Ontology; Fuzzy; Meta-heuristics.

Machine Learning: Overview of supervised and unsupervised learning; Supervised Learning: Linear Regression, Non-linear Regression Model evaluation methods, Logistic Regression, Neural Networks; Unsupervised Learning: K-means clustering, C-means Clustering. Convolutional Neural Networks (CNN), Pooling, Padding Operations, Interpretability in CNNs, Limitations in CNN. Cases with respect to different mechanical systems.

Introduction to Raspberry Pi; Installation of Raspbian OS on Raspberry Pi; Controlling LED using Raspberry Pi; Integrating IR Sensor with Raspberry Pi; Controlling LED with IR Sensor; Integrating Temperature and amp; Humidity Sensor with Raspberry Pi read Current Environment Values, Collecting the sensor data using Raspberry Pi; Matlab toolboxes - Simulink, Mechanical Systems implementation: From features to software components, Mapping software components to ECUs.

Learning Resources:

Text Books:

1. Rajkumar, Dionisio De Niz, and Mark Klein, Cyber-Physical Systems, Wesley Professional.
2. Rajeev Alur, Principles of Cyber-Physical Systems, MIT Press, 2015.
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