Academic Program: UG

Academic Year 2023-24

Syllabus

V & VI Semester B.E.

Mechanical Engineering

SHRI DHARMASTHALA MANJUNATHESHWARA COLLEGE OF ENGINEERING & TECHNOLOGY,

DHARWAD – 580 002

(An Autonomous Institution approved by AICTE & Affiliated to VTU, Belagavi)

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SDM College of Engineering & Technology, Dharwad

It is certified that the scheme and syllabus for V & VI semester of UG program in Mechanical Engineering is recommended by Board of Studies of Mechanical Engineering Department and approved by the Academic Council, SDM College of Engineering &Technology, Dharwad. This scheme and syllabus will be in force from the academic year 2023-24 till further revision.

Principal Chairman BoS & HoD

SDM College of Engineering & Technology, Dharwad

Department of Mechanical Engineering

College

Vision:

To develop competent professionals with human values.

Mission:

1. To have contextually relevant Curricula.
2. To promote effective Teaching Learning Practices supported by Modern Educational Tools and Techniques.
3. To enhance Research Culture.
4. To involve Industrial Expertise for connecting classroom content to real life situations.
5. To inculcate Ethics and impart soft-skills leading to overall Personality Development.

SDMCET- Quality Policy

- In its quest to be a role model institution, committed to meet or exceed the utmost interest of all the stake holders.

SDMCET- Core Values

- Competency
- Commitment
- Equity
- Team work and
- Trust

Department

Vision:

To establish a synergetic Mechanical Engineering program anchored in fundamentals and relevant state of the art technologies, thereby enabling the students to achieve all round development for careers in industry and for higher learning, being responsible to society and environment.

Mission:

1. To establish a curricula & syllabi consisting of robust core courses with emphasis on imparting fundamental principles of mechanical engineering coupled with adaptive and relevant electives catering to the cutting edge technologies.
2. To promote interactive teaching practices using modern educational tools & techniques to attain synergy in teaching, research and industrial practices.
3. To imbibe industrial expertise for connecting class room learning to real life situation.
4. To impart soft skills and professional ethics enabling students to achieve an all-round personality development, making them responsive to societal needs and environmental concerns.

Programme Educational Objectives (PEOs):

1. Graduates will be successful in industry, research and higher learning.
2. Graduates will formulate, analyze and solve engineering problems.
3. Graduates will work in teams to address industrial and socially relevant problems / projects.
4. Graduates exhibit awareness and commitment to lifelong learning & practice professional ethics.

Program Outcomes (POs)

Engineering Graduates will be able to:

1. **Engineering knowledge:** Apply the knowledge of mathematics, science, engineering fundamentals, and an engineering specialization to the solution of complex engineering problems.

2. **Problem analysis:** Identify, formulate, review research literature, and analyze complex engineering problems reaching substantiated conclusions using first principles of mathematics, natural sciences, and engineering sciences.

3. **Design/development of solutions:** Design solutions for complex 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.

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.

5. **Modern tool usage:** Create, select, and apply appropriate techniques, resources, and modern engineering and IT tools including prediction and modeling to complex engineering activities with an understanding of the limitations.

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 the professional engineering practice.

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.
8. **Ethics:** Apply ethical principles and commit to professional ethics and responsibilities and norms of the engineering practice.

9. **Individual and team work:** Function effectively as an individual, and as a member or leader in diverse teams, and in multidisciplinary settings.
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.
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.
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 (PSOs)

13. **Industrial interactions:** Enhance knowledge of mechanical engineering with industrial practices and standards by exposure to industries.
14. **Role of economics and costing:** Learn the concepts of economics and costing to provide effective solutions to mechanical engineering problems.

Scheme for V Semester

Course Code	Course Category	Course Title	Teaching		Examination				
			L-T-P (Hrs/Week)	Credits	CIE	Theory (SEE)		Practical (SEE)	
					Max. Marks	*Max. Marks	Duration in Hrs.	Max. Marks	Duration In Hrs.
21UHUC570	HU	Management, Entrepreneurship and IPR	3 - 0 - 0	3	50	100	3	-	-
21UMEC500	PC	Theory of Machines	2 - 2 - 0	3	50	100	3	-	-
21UMEC501	PC	Thermo-Fluids Engineering	2 - 2 - 0	3	50	100	3	-	-
21UMEC502	PC	Introduction to Scientific Programming (Computer Language to augment placement)	2 - 0 - 2	3	50	100	3	--	--
21UMEO52X	PE	Program Elective - 1	3 - 0 - 0	3	50	100	3	--	--
21UMEL503	PC	Thermal Engineering Laboratory - II	0 - 0 - 2	1	50	--	--	50	2
21UMEL504	PC	Machine shop Practice	0- 0 -2	1	50	--	--	50	2
21UAEE575	AE	Geometric Dimensioning &Tolerancing	2 - 0 - 0	2	50	50	2	--	--
21UMEL505	PC	Minor Project-1	0-0-2	1	50	--	--	--	--
21UMEL506	PC	Internship-I	Minimum 2 weeks	1	50	--	--	--	--
		Total	**14- 4 -8**	**21**	**500**	**550**		**100**	

BS- Basic Science, **PC**- Program Core
CIE: Continuous Internal Evaluation **SEE**: Semester End Examination
L: Lecture **T**: Tutorials **P**: Practical
*SEE for theory courses is conducted for 100 marks and reduced to 50 marks

Electives

Course code	Elective Courses (PE – 1)
21UMEE521	Mechatronics
21UMEE522	Total Quality Management
21UMEE523	Sustainable Building Technology
21UMEE524	Design Thinking
21UMEE525	Fundamentals of Automobile Design

Scheme for VI Semester

Course Code	Course Category	Course Title	Teaching		Examination				
			L-T-P (Hrs/Week)	Credits	CIE	Theory (SEE)		Practical (SEE)	
					Max. Marks	*Max. Marks	Duration in Hrs.	Max. Marks	Duration In Hrs.
21UMEC600	PC	Heat Transfer	2 - 2 - 0	3	50	100	3	-	-
21UMEC601	PC	Finite Element Methods	2 - 2 - 0	3	50	100	3	-	-
21UMEC602	PC	Fluid Power Control	2 - 0 - 2	3	50	100	3	-	-
21UMEE62X	PE	Program Elective - 2	3 - 0 - 0	3	50	100	3	-	-
21UMEE63X	PE	Program Elective - 3	3 - 0 - 0	3	50	100	3	-	-
21UMEO64X	OE	Open Elective - 1	3 - 0 - 0	3	50	100	3	--	--
21UMEL603	PC	Thermal Engineering Laboratory - III	0 - 0 - 2	1	50	--	--	50	2
21UMEL604	PC	Computer-Aided Engineering Analysis Laboratory	0 - 0 - 2	1	50	--	--	50	2
21UMEL605	PC	Minor Project-2	0- 0 -3	1	50	--	--	50	2
21UHUL606	HU	Soft skills and Aptitude	0-0-2	1	50	--	--	--	--
		Total	15- 4 -11	22	500	600		150	

BS- Basic Science, **PC**- Program Core
CIE: Continuous Internal Evaluation **SEE**: Semester End Examination
L: Lecture **T**: Tutorials **P**: Practical
*SEE for theory courses is conducted for 100 marks and reduced to 50 marks

Electives

Course code	Elective Courses (PE-2)	Course code	Elective Courses (PE– 3)	Course code	Elective Courses (OE–1)
21UMEE621	CAD/CAM (Computer aided design / Computer aided manufacturing)	21UMEE631	Introduction to Composite Materials	21UMEO641	Smart Materials and Structures
21UMEE622	Advanced Automobile Design	21UMEE632	Non -Traditional Machining	21UMEO642	Introduction to Aircraft Industry & Aircraft Systems
21UMEE623	Refrigeration & Air conditioning	21UMEE633	Cryogenics	21UMEO643	Design of Renewable Energy Systems
21UMEE624	Advanced Fluid Dynamics	21UMEE634	Alternate Fuels	21UMEO644	Optimization Techniques in Engineering
21UMEE625	Tool Design Engineering.	21UMEE635	Tribology & Bearing Design		
21UMEE626	Industry 4.0 & Artificial Intelligence	21UMEE636	Theory of Elasticity		
21UMEE627	Turbo Machines	21UMEE637	Scientific Computing - I		

V semester

21UHUC570 Management, Economics & Intellectual Property Rights (3-0-0) 3

Contact Hours: 39

Course Learning Objectives (CLOs): The objectives of this course are to make the student to learn:

1. Patent, copyright and trade secret protection.
2. Role and importance of intellectual property rights in contemporary business environment.
3. Historical development of software patents.
4. Consequences of software piracy on software developers and the role of relevant enforcement organizations.
5. Role of entrepreneurship in modern economy and entrepreneurial opportunities.

Course outcomes (COs):

Description of the Course Outcome: At the end of the course the student will be able to:		**Mapping to POs(1-12)/ PSOs (13,14)**		
		Substantial Level (3)	**Moderate Level (2)**	**Slight Level (1)**
CO-1	Enumerate developments of management thought and functions of manager	-	1	-
CO-2	Demonstrate the ability to recognize a business opportunity and launch entrepreneurial career.	-	2	11
CO-3	Estimate direct, indirect costs and expenses of product and organization.	1	11,14	8
CO-4	Explain the rules and regulations of Government agencies supporting Industries and project management concepts	-	6	-
CO-5	Identify problems of present business environment and carry out the feasibility studies.	-	8	10,11,13
CO-6	Explain different forms of Intellectual Properties rights.	8	-	-

POs/PSOs	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Mapping Level	2	2	-	-	-	2	-	2	-	1	1.3	-	1	2

Pre requisites: Nil

Course Contents:

Unit - I

Engineering and Management: Historical Development of Engineering, Management, Engineering, Management and Engineering & Management a synthesis.

Planning; Forecasting and Decision Making: Nature of Planning, the foundation of planning, some planning concepts, forecasting, nature of decision making, management science, tools for decision-making.

Organizing and staffing: nature of organizing, traditional organizational theory, technology and modern organization structures, staffing technical organization, authority and power; delegation, meeting & committees. **9 Hrs**

Unit - II

Motivation: Motivation, Theories of Motivation leadership, motivating and leading technical professionals. Motivating factors for Engineers. Leadership, Types and styles of leadership,

Controlling: process of control, financial controls and non-financial controls**.** Process of control and steps involved in controlling**.** Various financial and non-financial ratios.

Foundations of Entrepreneurship: Meaning of entrepreneur, functions of entrepreneur, types of entrepreneur, concept of entrepreneurship, role of entrepreneurs in economic development, barriers of entrepreneurship.

Small Scale Industry: Definition, characteristics, objects, role of SSI in economic development, advantages of SSI, steps to start a SSI, impact of liberalization, privatization, and globalization on SSI, definition of ancillary and tiny industry. **11 Hrs**

Unit - III

Government and Institutional Support: Nature of support of government, Central organizations NSTEDB, NPC, NISIET, NIESBUD. objectives and functions of SISI, SIDBI, DIC, single window agency, KIADB, KSSIDC, KSFC.

Elements of Costs: Calculation of Material costs, Calculation of Direct Labour cost, Labour cost, Factory expenses. Administrative Expenses, selling and Distribution expenses. Fixed and Variable overheads, Components of cost; Selling price; Allocation of on-cost-Percentage on Prime cost, Direct Labour

cost, Direct material cost, Man hour rate, Machine hour rate, Combination of Man hour and Machine hour rate, Unit rate method; Numerical.

Indirect Expenses: Factory, Administrative, sales and distribution expenses. Calculation of various overheads- Depreciation, Obsolescence: Methods of calculating Depreciation; Interest on Capital; Idleness of machines and workers; Repairs and Maintenance. Estimation of Material cost, Procedure and numericals. **15 Hrs**

Unit - IV

Preparation of Project: Meaning of project identification, project report, contents and formulation, identification of business opportunities, feasibility studies, types and purpose.

Introduction to IPR: Meaning and forms of intellectual property right, competing rationale for protection, international conventions, world court.

Copyright: Meaning of copyright, content of copy right, ownership and rights, period of copyright, assignment and relinquishment of copyright, license, infringement of copy right, fair use, offenses and penalties. **9 Hrs**

Unit - V

Patents: Concept of patent, patentable inventions, procedure for obtaining patent, rights and obligations of patent holders, infringements and remedies, offenses and penalties.

Industrial Designs: Definition of design, procedure for registration, rights conferred by registration, infringements, Value of creating Design.

Trademarks – Trademarks and trade names, service marks, Trademarks act 1999, Objectives. Functions and essential features of trademark. Concept, significance, Functions, Features. **8 Hrs**

Reference Books:

1) Daniel L. Babcock, “Managing Engineering and Technology”, 4th edition, PHI.
2) N V R Naidu, “Management and Entrepreneurship”.
3) Thomas W. Zimmers, “Essentials of Entrepreneurship & small business management”, 5th edition, PHI, 2011.
4) Peter Drucker, “The Practice of Management”.
5) Khan & Jain, “Cost Accounting”, TMH, 2013.
6) T. R. Banga and S.C. Sharma, “Mechanical Estimation and Costing”, Khanna Publishers.
7) N.K. Acharya, “Text book on Intellectual Property Rights”, 4th edition, Asia Law House.

21UMEC500	Theory of Machines	(2-2-0) 3

Contact Hours: 39

Course Learning Objectives (CLOs): The objectives of this course are to make the student to learn:

1. Kinematics, linkages for motion constrainment, their applications and kinematic analysis.
2. Cams/followers/follower motion pattern and cam profile synthesis.
3. Gears/gear trains, their terminology, and application of gears/gear trains
4. Force analysis in gear trains and planar mechanisms.
5. Balancing for rotating and reciprocating machines.
6. Gyroscopic effects in automobiles and aircrafts.

Course Outcomes (COs): At the end of the course students will be able to

Description of the Course Outcome: At the end of the course the student will be able to:		**Mapping to POs(1-12)/ PSOs (13,14)**		
		Substantial Level (3)	**Moderate Level (2)**	**Slight Level (1)**
CO-1	Explain working of mechanisms, inversions of kinematic chains with or without relevant sketches and derivations	1	-	-
CO-2	Determine the velocity, accelerations, forces of various members of the mechanisms by graphical or analytical method.	1	2	-
CO-3	Draw cam profiles with relevant calculations	1	-	3
CO-4	Evaluate the various gear parameters with or without derivations, speeds / forces / torques on gears found in gear trains.	1	2	-
CO-5	Calculate the necessary balancing masses for rotary/ reciprocating systems / assess the imbalance.	1	-	-
CO-6	Analyze the effects of gyroscopic couples / forces on vehicles/mechanical systems.	1	2	-

POs/PSOs	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Mapping Level	3	2	1	-	-	-	--	-	-	-	-	-	-	-

Prerequisites: Nil

Course Contents:

Unit - I

Introduction: Mechanisms and machines, Kinematic pairs-types, degree of freedom, Kinematic chains and their classification, Kinematic inversions, QRMs, Intermittent motion mechanisms, straight line motion mechanisms and Steering mechanisms used in automobiles. **7L+2T Hrs**

Unit - II

Velocity and Acceleration analysis of planar mechanisms: Velocity and acceleration analysis of four bar mechanism and slider crank mechanisms by graphical/ analytical methods. Corioli's component of acceleration.

Force analysis of planar mechanisms: Static force analysis of four bar mechanism and slider crank mechanism, Introduction to Inertia force analysis. **7L+3THrs**

Unit - III

Gears: Spur Gears – Terminology, Law of gearing, velocity of sliding, contact ratio, path of contact, arc of contact, interference in gears, minimum number of teeth to avoid interference, comparison between involute and cycloidal profile, helical and bevel gear terminology and applications. Force analysis in spur gear trains.

Gear trains: Types of gear trains, epicyclic gear trains, speed and torques in epicyclic gear trains. **8L+4T Hrs**

Unit - IV

Balancing- Balancing for rotating and reciprocating machines by graphical or analytical method.

Gyroscope: Gyroscopic forces and couples in aero planes, four wheel and two wheel vehicles. **9L+3T Hrs**

Unit - V

Cams: Types of cams and followers, follower motion analysis, Layout of cam profiles for different follower motions. **7L+2T Hrs**

Reference Books:

1) S S Rattan, “Theory of Machines”, TATA McGraw Hill publishing company Ltd, New Delhi, 3rd edition,2009.
2) Shigley, J.V and Uicker JJ, “Theory of Machines and Mechanisms”, 2nd edition, McGraw Hill, 1995.
3) John J Uicker, Gordon R Pennock, Joseph E Shigley, “Theory of Machines and Mechanisms”, 3rd edition, Oxford publisher, 2009.
4) Dr. R K Bansal and Dr. J S Brar, “Theory of Machines”, 5th edition, Laxmi publications, 2015.

21UMEC501	Thermo-Fluids Engineering	(2-2-0) 3

Contact Hours: 39

Course Learning Objectives (CLOs): The objectives of this course are to make the student to learn, basic laws of thermodynamics related to IC Engines, and turbomachines.

Course outcomes (COs):

Description of the Course Outcome: At the end of the course the student will be able to:		**Mapping to POs(1-12)/ PSOs (13,14)**		
		Substantial Level (3)	**Moderate Level (2)**	**Slight Level (1)**
CO-1	Explain the testing of IC engines and air compressors		1	2
CO-2	Calculate the performance parameters of refrigeration and AC systems		1,2	
CO-3	Explain and draw velocity triangles of turbo machines and compare Turbomachines with positive displacement machines.		1.2	
CO-4	Evaluate performance parameters of hydraulic turbo machines	1, 2		
CO-5	Evaluate performance parameters of steam turbine		1, 2	

POs/PSOs	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**
Mapping Level	1.4	1.5	-	-	-	-	-	-	-	-	-	-	-	-

Prerequisites: Nil

Course Contents:

Unit - I

Performance Testing of IC Engines: Two-stroke and Four-stroke I.C. engines - Measurement of speed, air flow, fuel consumption, Measurement of Brake

Power and Indicated Power, Performance curves, Heat Balance sheet and Multi cylinder Engines testing, Morse test.

Air Compressors: Operation of a single stage reciprocating compressors: work input through p-v diagram, effect of clearance and volumetric efficiency, adiabatic, isothermal and mechanical efficiencies. Multi-stage compressor, saving in work, optimum intermediate pressure, inter-cooling, minimum work for compression. **6L+2T Hrs**

Unit - II

Refrigeration: Vapor compression refrigeration system; description, analysis, refrigerating effect, capacity, power required, units of refrigeration, COP, reversed Carnot cycle, vapor absorption refrigeration system and Air refrigeration system. Use of refrigeration tables and p-h chart. Classification of Refrigerants. Desirable properties of refrigerants.

Psychrometrics: Atmospheric air and Psychrometric properties: DBT, WBT, DPT, partial pressure, specific and relative humidity and relation between the enthalpy and adiabatic saturation temperatures. Construction and use of psychrometric chart. Basic psychrometric processes in air-conditioning **6L+2T Hrs**

Unit - III

Introduction to Turbo machines: Classification, comparison between turbo machines and positive displacement Euler's equation for a Turbo machine Impulse & Reaction machine- Axial flow and radial flow machines utilization factor, degree of reaction & efficiencies of Turbo machines, **6L + 2T Hrs**

Unit - IV

Hydraulic Turbines: Classification of hydraulic turbines- Pelton wheel - Francis turbine- Kaplan turbine. Draft tubes. Cavitation, characteristic curves

Centrifugal Pumps: Main Parts of centrifugal pump, basic terms and definitions, work done, minimum speed for starting centrifugal pump, Classifications- Performance characteristics of centrifugal pumps. Multistage pumps characteristic curves. **8 Hrs**

Unit - V

Centrifugal Blowers & Compressors: Centrifugal blower - types- size & speed- vane shape & efficiency- vane shape & stresses- vane shape & characteristics- actual performances characteristics- slip.

Steam and gas Turbines: Impulse turbines, Staging - expression for work done in a 2 stage velocity compounded turbine- effect of blade & nozzle losses- Reaction staging- reheat factor- performance characteristics, problems using Mollier's chart & introduction to gas turbines. **7 Hrs**

Reference Books:

1) Energy Conversion Volume-III Turbo-machinery by V Kadambi & Manohar Prasad Tata Mc Graw Hill 4th edition
2) Yunus Cengel "Applied thermodynamics (SI units)" McGraw Hill, 2014
3) R.K.Bansal "Fluid Mechanics and Hydraulics" Metropolitan Book Co. Pvt. Ltd., New Delhi, 1995.
4) D,G,Sheford "turbomachinery " MacMillan Company

21UMEC502 Introduction to Scientific Programming (2-0-2) 3

Contact Hours: 39

Course Learning Objectives (CLOs): The objectives of this course are to make the student to learn:

1. To improve their ability in solving mathematical problems using Python software
2. To develop skills in handling errors, functions and loops in program, enhance problems solving capability.
3. To emphasize signification of plotting graphs and interpreting the data's in Python software.
4. To gain knowledge in scientific methods and familiarize with application of differential equation and integration to solve engineering problems.

Course Outcomes (COs):

Description of the Course Outcome: At the end of the course the student will be able to:		**Mapping to POs(1,12) / PSO (13,14)**		
		Substantial Level (3)	**Moderate Level (2)**	**Slight Level (1)**
CO-1	Develop program by analyzing problem and handling errors in Python software.	5	1,2	3
CO-2	Use data structures in programming approach.	5	1,2	3
CO-3	Apply function features to develop realistic programs.	5	1,2	3
CO-4	Develop Python Programs using NumPy array and matplotlib for solving problems	5	1,2	3
CO-5	Use various package's and libraries SciPy, ODEINT to solve a mathematical problem.	5	1,2	3

POs/PSOs	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Mapping Level	2	2	1	-	3	-	-	-	-	-	-	-	-	-

Prerequisites: Nil

Course Contents:

Unit - I

Introducing Python: Working with the Python Interactive, Python Installation, Interpreter, Python Shell, Simple Python Scripts, Python Syntax Variables Values , Assigning Variables , Reserved Words ,Python Keywords , Variable Assignment and Variable Naming, User Input and output, Comments.

Introduction Numerical Data: Operators, Order of Operations, Arithmetic Operators, Comparison Operators Logical Operators Membership Operators,

Introduction Control Statements: Program Flow, Control Statement, if Statement, working with the if Statement and else, Loops, The while Statement, The for Loop, Nesting Loops, The break Statement, The continue Statement. The pass Statement, The range Function, **8 Hrs**

Unit - II

Strings: String Operations, Indexing, Slicing, String Methods, Working with Strings Escape Sequences, Manipulating Strings, Booleans,

Functions: Introduction function, Built-In Functions, User-Defined Functions. Calling a Function. Global and Local Variable, Return Using main() Function, Arguments, Required Arguments, Keyword Arguments, Default Arguments, Variable Number of Arguments, Creating a Lamda Function, **7 Hrs**

Unit - III

Introduction to data types: Lists, List Operations, Working with Lists, List Syntax, List Methods, Tuple Syntax, Using Indexing, Slicing, Tuple Methods, Dictionaries and Sets Introduction: Working with Dictionaries, Adding Data to a Dictionary, The Basics of Sets.

Matplotlib: Introduction, Matplotlib basics, multiple plots, Line chart, bar chart, pie chart, scattered plot, working with the legend, Contour plots, 3D plots. **8 Hrs**

Unit - IV

Array Computing and Curve Plotting: Basic array methods, NumPy array, Numerical Operations on Numpy Arrays, Reading and writing an array to a file, Polynomials, Linear algebra, Matrices, computation with matrix, dot product, cross product, inverse matrix, quadratic equation. **8 Hrs**

Unit - V

Differential Equations and Integration: The Simplest Case, ordinary differential equation and partial differential equation, Integration and double integration, initial value problems, optimization (LPP Problems). **8 Hrs**

Activity Beyond Syllabus: working with simple real-time application in Python software.

Text Books:

1) Allen B. Downey, “Think Python”, 2nd Edition, O’Reilly Publication, 2015.
2) Christian Hill, “Learning Scientific Programming with Python”, Cambridge University Press, 2015.

Reference Books:

1) Charles Dierbach, "Introduction to Computer Science Using Python", 1st Edition, Wiley India Pvt Ltd, 2015.
2) T.R. Padmanabhan, “Programming with Python”, Springer, 2016.
3) Hans Petter Langtangen, “A Primer on Scientific Programming with Python”, Springer; 3rd Edition, 2012.

21UMEL503	Thermal Engineering Laboratory-II	(0-0-2) 1

Contact Hours: 26

Course Learning Objectives (CLOs): The objectives of this Laboratory are to make the student to learn:

1. Different types Heat engines and their performance parameters
2. Power absorbing turbomachines and their performance
3. Reciprocating pump and compressor
4. water turbines and their performances

Course outcomes (COs):

Description of the Course Outcome: At the end of the course the student will be able to:		**Mapping to POs(1-12)/ PSOs (13,14)**		
		Substantial Level (3)	**Moderate Level (2)**	**Slight Level (1)**
CO-1	Determine performance test on IC engine and determine heat balance sheet	1	2	4,9
CO-2	Experiment on Water turbine and draw characteristic curves	1,2	4	9
CO-3	Calculate performance parameters of power absorbing turbo machines and PDM	1,2	4	9
CO-4	Carry out test on vapor compression refrigeration system and determine COP	1,2	4	9
CO-5	Determine performance parameters of computerized IC engine and an Electric vehicle through demonstration	-	1,2	4,5,9

POs/PSOs	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**
Mapping Level	2.8	2.6	-	1.6	1	-	-	-	1	-	-	-	-	-

Pre-requisites: Basic principles of Engineering Thermodynamics and Fluid Mechanics.

1. Performance test on single cylinder four stroke diesel engine and draw Heat balance sheet.
2. Performance test on single cylinder VCR petrol engine and draw Heat balance sheet.
3. Performance test on multi cylinder diesel engine, draw Heat balance sheet and perform Morse test.
4. Demonstration of EV two wheeler and study its performance
5. Performance test on Vapour compression refrigeration & Air conditioning-test rig.
6. Performance test on single stage Reciprocating compressor.
7. Demonstration on Computerised IC Engine test rig for its performance.
8. Performance test on single and multi-stage centrifugal pump.
9. Performance test on Reciprocating Pump.
10. Performance test on Pelton turbine and draw main and operating characteristics.
11. Performance test on Kaplan turbine and draw main and operating characteristics.
12. Performance test on Francis turbine and draw main and operating characteristics.
13. Performance test on centrifugal blower and draw operating characteristics for different vane shapes.

21UMEC504	Machine Shop Practice	(0-0-2) 1

Contact Hours: 26

Course Learning Objectives (CLOs): The objectives of this course are to make the student to learn:

1. Fundamentals of machining, machine tools & their elements
2. Sequence of operation
3. Metal cutting practice
4. Safety while operating machine.
5. CNC Machining operation, writing NC programming.

Course outcomes (COs): Upon the completion of the course, the student should be able to

Description of the Course Outcome: At the end of the course the student will be able to:		**Mapping to POs(1-12)/ PSOs (13,14)**		
		Substantial Level (3)	**Moderate Level (2)**	**Slight Level (1)**
CO-1	Measure and mark dimensions using suitable instruments.	1	9	3
CO-2	Perform basic turning operations on Lathe	1	9	-
CO-3	Carry out the basic machining operations on milling and shaping machines.	1	-	4
CO-4	Write NC programs to perform machining operation on CNC milling machine.	1	5	3

POs/PSOs	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**
Mapping Level	3	-	1	1	2	-	-	-	2	-	-	-	-	-

Prerequisites: Nil

Course Contents:

1. **Lathe:** Plain Turning, Taper Turning. Step Turning, Thread Cutting. Facing, Knurling, Eccentric Turning. (Demo)
2. **Milling machine:** square milling and gear teeth using horizontal or vertical milling machines.
3. **Shaping machine:** Cutting of V-groove /key way groove.
4. **CNC machine**: setup of the machine and exercises comprising of plain milling, Step milling and drilling.

21UAEE575	Geometric Dimensioning and Tolerancing (Ability Enhancement Course)	(2-0-0) 2

Contact Hours: 26

Course Objectives: The objectives of this course are to make the student to learn:

1. The method of interpreting the GD&T symbols
2. The basic principles of Tolerancing
3. The method of using the basic rectangular datum reference frames
4. The procedure for indicating Form and Profile tolerances with required material conditions

Description of the Course Outcome: At the end of the course the student will be able to:		**Mapping to POs(1-12)/ PSOs (13,14)**		
		Substantial Level (3)	**Moderate Level (2)**	**Slight Level (1)**
CO-1	Interpret Geometric Dimensioning Tolerance symbols, terms applied on a given drawing of parts.		1	2
CO-2	Identify basic principles of Tolerancing and GD&T rules	-	1	2
CO-3	Set up and use basic rectangular datum reference frames	-	1	2
CO-4	Interpret 'Form and Profile tolerances' with applied material conditions	-	1	2
CO-5	Analyse/calculate the part feature tolerances for control of form accuracies	-	1	2

POs/PSOs	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**
Mapping Level	2	1	-	-	-	-	-	-	-	-	-	-	-	-

Prerequisites: Nil

Course Contents:

UNIT-I

Introduction: Scope, Definitions, Engineering Drawing, Units of Measure, Types of Dimensioning,and tolerances, Dimensioning standards, Fundamental dimensioning rules, Coordinate tolerancing system, Shortcomings of coordinate system,The geometric dimensioning and tolerancing system, benefits of GD&T.

GD&T symbols and terms: Definitions, material condition(MMC&LMC), modifiers, Radius and controlled radius, Introduction to geometric tolerances, Feature Control Frame Symbols, Feature Control Placement,Illustrative problems. **5 Hrs**

UNIT-II

Principles of Tolerancing: Rules of GD&T, Concept of GD&T, Introduction to basic dimensions, Introduction to virtual conditions, Inner & outer boundary, Introduction to bonus tolerance, Illustrative problems. **5 Hrs**

UNIT-III

Datums: Implied datums, planar datums, datum targets, FOSdatum features, FOS datum feature application(RFS), FOS datum feature referred at MMC, FOS datum feature applications(MMC) Illustrative problems. **5 Hrs**

UNIT-IV

Form Tolerances: Form Control- Flatness control, straightness control as a surface element control straightness control as an axis or central plane control, circularity control, cylindricity control, Runout tolerances-Types of Runout tolerances, Illustrative problems.Orientation control**-** Perpendicularity control, angularity control and parallesim control. Illustrative problems. **6 Hrs**

UNIT-V

Profile Tolerances: Profile of a surface, profile of a line, Tolerance Zone Boundaries, Applications, Part calculations. Illustrative problems. **5 Hrs**

Reference Books:

1) P.S. Gill, 'Geometric Dimensioning and Tolerancing' , S. K. Kataria& Sons, 2009
2) Alex Krulikowski, 'Fundamentals of Geometric Dimensioning and Tolerancing', Diamler Pubilshers, 2nd edition.
3) James D. Meadows, 'Geometric Dimensioning and Tolerancing: Applications and Techniques for Use in Design, Manufacturing, and Inspection', CRC Press, 1995
4) 2.Ashok Kumar, ' Simplified GD & T': Based on ASME-Y 14.5-2009, 2nd Edition, AzukoPublishing 2009
5) 3.Gene Cogorno, 'Geometric Dimensioning and Tolerancing for Mechanical Design, A Self teaching guide, Tata McGraw Hill Publisher, 2006

21UMEL505	Minor Project - I	(0-0-2) 1

Contact Hours: 26

Course Learning Objectives (CLOs):

The course is included to provide an exposure, focusing more on the domain related problem definitions, building prototypes which can lead to take up the project in the higher semester(s). The work based on using the concepts studied in the core/elective courses studied shall be used to formulate the problem. They are also required to learn to find related material, use appropriate tool to obtain the solution and prepare a report based on the work carried out.

Course Outcomes (COs):

Description of the Course Outcome: At the end of the course the student will be able to:		**Mapping to POs(1-12)/ PSOs (13,14)**		
		Substantial Level (3)	**Moderate Level (2)**	**Slight Level (1)**
CO-1	Identify the domain related problem and formulate a problem statement	6	-	9
CO-2	Propose the technical approach towards the solution.	11	4	9
CO-3	Develop physical model or software solution.	4	1, 2, 3, 5, 11	9,10, 12,13
CO-4	Prepare the report in a specified format.	8, 10	-	9, 14

POs/PSOs	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**
Mapping Level	2	2	2	2.5	2	3	-	3	1	2	2.5	1	1	1

Prerequisites: Nil

Minor project – 1 is undertaken to focus on the domain related problem definitions, building prototypes which can lead to take up the project in the higher semester. The work based on the core courses studied shall be used to formulate the problem. The team consisting of 10-12 students shall be asked to identify the problems related to community and try to propose the solution. A faculty members handling one of the courses for that semester shall guide the students. A committee consisting of minimum 3 faculty members shall evaluate at the end for CIE. There is no SEE for minor project-1.

21UMEL506	Internship - I	1 Credit

Contact Hours: 26

The students are required to undergo internship in any of the relevant department including centre of excellences & incubation centres in the college for a period of minimum two weeks in vacation between IV and V semesters to get an exposure to the Engineering establishment and activities of the other departments. The students are required to prepare a report on the internship-I undergone.

21UMEE521	Mechatronics	(3-0-0) 3

Contact Hours: 39

Course Learning Objectives (CLOs): The objectives of this course are to make the student to learn:

1. Recognize various elements of mechatronics system.
2. Synergic integration of mechanical, electrical, electronic systems.
3. Illustrate various components of Mechatronics systems.
4. Assess various control systems used in automation.
5. Develop mechanical, hydraulic, pneumatic and electrical control systems.

Course Outcomes (COs):

Description of the Course Outcome: At the end of the course the student will be able to:		**Mapping to POs(1-12)/ PSOs (13,14)**		
		Substantial Level (3)	**Moderate Level (2)**	**Slight Level (1)**
CO-1	Explain basic elements of mechatronic systems and sensors.	1	-	-
CO-2	Explain microcontrollers and microprocessors used in automation systems.	-	1	-
CO-3	Construct the ladder diagrams for PLC applications.	-	3	-
CO-4	Describe various mechanical and electrical actuation systems.	2	-	-
CO-5	Develop solutions for automation applications using fluid power systems.	2	-	3,13

POs/PSOs	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**
Mapping Level	2.5	3	1.5	-	-	-	-	-	-	-	-	-	1	-

Prerequisites: Nil

Course Contents:

Unit - I

Introduction: Definition, Multidisciplinary Scenario, Evolution of Mechatronics, Mechatronics systems-Measurement systems, examples of microprocessor based controllers- Principle of working of automatic washing machine, autofocus camera, engine management system. Definition and

classification of sensors and transducers, principle of working and applications of capacitive sensors, inductive sensors, light sensors, ultrasonic sensors, proximity switches and Hall Effect sensors. **8 Hrs**

Unit - II

Microprocessor & Microcontrollers: Introduction, Microprocessor systems, Basic elements of control systems, Microcontrollers, Difference between Microprocessor and Microcontrollers.

Microprocessor Architecture: Microprocessor architecture and terminology-CPU, memory and address, I/O and Peripheral devices, ALU, Instruction and Program, Assembler, Data, Registers, Program Counter, Flags, Fetch cycle, write cycle, state, bus interrupts. Intel's 8085A Microprocessor. **8 Hrs**

Unit – III

Programmable logic controller: Introduction to PLC's, basic structure, Principle of operation, Programming and concept of ladder diagram, concept of latching & selection of a PLC.

Integration: Introduction & background, Advanced actuators, Pneumatic actuators, Industrial Robot, different parts of a Robot-Controller, Drive, Arm, End Effectors, Sensor & Functional requirements of robot. **8 Hrs**

Unit - IV

Mechanical actuation systems: Mechanical systems, types of motion, Cams, Gear trains, Ratchet & Pawl, belt and chain drives, mechanical aspects of motor selection.

Electrical actuation systems: Electrical systems, Mechanical switches, Solenoids, Relays, DC/AC Motors, Principle of Stepper Motors &servomotors. **7 Hrs**

Unit - V

Pneumatic and hydraulic actuation systems: Actuating systems, Pneumatic and hydraulic systems, Classifications of Valves, Pressure relief valves, Pressure regulating/reducing valves, Cylinders and rotary actuators

DCV & FCV: Principle & construction details, types of sliding spool valve, solenoid operated, Symbols of hydraulic elements, components of hydraulic system, functions of various units of hydraulic system. Design of simple hydraulic circuits for various applications. **8 Hrs**

Reference Books:

1) W.Bolton, “Mechatronics Electronic Control Systems in Mechanical and Electrical Engineering”, Pearson Education 1st Edition, 2005.

2) Nitaigour Premchand Mahalik, “Mechatronics-Principles”, Concepts and Applications, Tata McGraw Hill, 1st Edition, 2003.

3) Mechatronics by HMT Ltd. – Tata McGraw Hill, 1st Edition, 2000.

4) Anthony Esposito, “Fluid Power”, Pearson Education, 6th Edition, 2011.

21UMEE522	Total Quality Management	(3-0-0) 3

Contact Hours: 39

Course Learning Objectives (CLOs): The objectives of this course are to make the student to learn:

1. Theoretical concepts of Total Quality Management.
2. Importance of application of Total Quality management philosophy and concepts.
3. Analytical skills associated with the usage of tools and techniques of Total Quality Management.
4. Principles of experimental design.

Course outcomes (COs):

Description of the Course Outcome: At the end of the course the student will be able to:		**Mapping to POs(1-12)/ PSOs (13,14)**		
		Substantial Level (3)	**Moderate Level (2)**	**Slight Level (1)**
CO-1	List the basic tools of quality control and experimental design	-	1,2	-
CO-2	Describe scientific techniques and tools of total quality management	1,2	-	-
CO-3	Demonstrate practical knowledge through case studies.	-	2	-
CO-4	Solve engineering problems using experimental design and modern engineering tools	4, 5	1,2	-
CO-5	Interpret control charts to facilitate quality control	1,2	4	-
CO-6	Differentiate between Taguchi and Deming's philosophy of quality engineering	-	1	2

POs/PSOs	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**
Mapping Level	2.4	2.6	-	2.5	3	-	-	-	-	-	-	-	-	-

Prerequisites: Nil.

Course Contents:

Unit - I

Overview of Total Quality Management: Introduction – Definition, Basic Approach, Contribution of Gurus – Total Quality Management, TQM frame work, Historical Review, Benefits of TQM.

Deming's Philosophy: Customers' satisfaction, Customers' perception, using Customers complaints, Feedback, Employee involvement, Suggestion system, Continuous Process Improvement- Juran's Trilogy PDSA Cycle, Imai's Kaizen. **8 Hrs**

Unit - II

Tool & Techniques of TQM: Bench marking, Definition, Process of bench marking, Quality Management Systems, Reengineering, six sigma, ISO–9000 series of standards, **8 Hrs**

Unit - III

Introduction to QFD & QFD process, FMEA (Failure Mode and effect Analysis), Design FMEA and Process FMEA studies, Cases. **7 Hrs**

Unit - IV

Basic tools of quality control, Control charts for variables, Construction, interpretation, Analysis using x–R control charts, Process capability estimation, Process capability indices, process improvement through problem analysis (Intensive coverage with numerical problems), Control charts for attributes, cases. **8 Hrs**

Unit - V

Experimental Design: One factor designs, two factor designs, Orthogonal design, Full factorial and factional factorial design, Taguchi's Philsophy of quality engineering, Loss function, Orthogonal array, Signal to noise ratio, Parameter design, Tolerance design (Basic Conceptual Treatment only), Cases. **8 Hrs**

Reference Books:

1) Dale H Besterfield, Carol Besterfield, Glen H Besterfield, Mary Besterfield, "Total Quality Management", 3rd Edition, Pearson Education, 2008.
2) Douglas C. Montgomery, "Statistical Quality Control", John Wiley & Sons; 7th Edition edition, 2012.
3) K. Shridhara Bhat, "Total Quality Management Texts cases", Himalaya Publishing House, 2010.
4) P. L. Jain, "Quality Control and Total Quality Management", Tata McGraw hill Publishing Co. Ltd., New Delhi, 2001.
5) Shoji Shiba, Alan Graham & David Walden, "A New Amercian TQM – Four Practical Revolutions in Management", Productivity Press, Portland (USA) 2000.

21UMEE523	Sustainable Building Technology	(3-0-0) 3

Contact Hours: 39

Course Learning Objectives (CLOs): The objectives of this course are to make the student to learn:

1. Need for energy conservation in building sector and basic
2. Space conditioning needs and evaluation in building
3. Energy efficiency in lighting and material of the building
4. Zero energy and rating systems related to building

Course Outcomes (COs):

Description of the Course Outcome: At the end of the course the student will be able to:		**Mapping to POs(1-12)/ PSOs (13,14)**		
		Substantial Level (3)	**Moderate Level (2)**	**Slight Level (1)**
CO-1	Review the energy use trends in Building sector and need for energy conservation in building	-	1,2	-
CO-2	Evaluate space condition and lighting loads in building	-	1,2	-
CO-3	Calculate the embodied energy of building material, U and R values for green building	-	1,2	-
CO-4	Apply the guidelines of green rating systems on a building	-	-	1,7

POs/PSOs	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**
Mapping Level	1.8	2	-	-	-	-	1	-	-	-	-	-	-	-

Prerequisites: Nil

Course Contents:

Unit - I

Introduction: Energy use patterns in world and Indian sectors. Energy scenario in India and Indian building sector. Need for energy management in building sector. Basic terms used in buildings, energy efficiency measures in building.

Heating ventilation and air conditioning: Introduction, principles of HVAC, human comfort, Indoor air quality and air change rates in building ventilation requirement, Energy efficient HVAC systems. **8 Hrs**

Unit - II

Air-conditioning: Psychrometry, working of winter and summer air condition systems, classification of air condition system, c.o.p of air condition systems, evaluation of cooling load and heating load for space condition. **8 Hrs**

Unit - III

Energy efficiency in lighting: basic terms in lighting, design of lighting for building, lighting requirements in built in spaces. Design of electric and day lighting devices, roof top PV systems **8 Hrs**

Unit - IV

Energy efficient building materials, Embodied energy, Operational energy in Building and Life cycle energy. Energy efficient materials for window, wall and roof, sol-air temperature, U value and R value, solar heat gain coefficient **8 Hrs**

Unit - V

Green building rating systems: energy and built in environment. Waste management in building, brief study of ECBC, IGBC LEED and GRIHA rating. **7 Hrs**

Reference Books:

1) Arora and Domkundwar, “A course on Refrigeration and air conditioning”, Dhanpatrai and sons, 2018.
2) Jan F Kreider, Peter S Cutriss, “Heating and cooling of building, principals and practice of energy efficient design”, CRC Press, 2018.
3) ASHRAE (American Society of Heating and Ventilation Engineers) Standard 62.2P Ventilation and acceptable indoor air quality in low rise residential building, 2002.
4) B.L.Thereja, “Text book of Electrical Technology”, Vol.3, S.Chand 2018.
5) Venkatarama Reddy, B. V., and. Jagadish, K., S. “Embodied energy of common and alternative building materials and technologies”. Energy and Buildings, 2003.
6) Ministry of Power, Energy Conservation Building Code 2018, Revised Version, Bureau of Energy Efficiency, 2018, TERI-GRIHA’s Green Design practices (www.teriin.org/bcsd/griha/griha.html)

21UMEE524	Design Thinking	(3-0-0) 3

Contact Hours: 39

Course Learning Objectives (CLOs): The objectives of this course are to make the student to learn:

1. Discipline—design thinking—that enhances innovation activities.
2. Individual and collaborative capabilities to identify problems/issues/needs.
3. Translate broadly defined opportunities into actionable innovation possibilities.

Course outcomes (COs):

Description of the Course Outcome: At the end of the course the student will be able to:		**Mapping to POs(1-12)/ PSOs (13,14)**		
		Substantial Level (3)	**Moderate Level (2)**	**Slight Level (1)**
CO-1	Define design thinking mindset	1	-	-
CO-2	Build empathy for target audiences from different cultures.	-	2	-
CO-3	Utilize the design thinking resources	3	-	-
CO-4	Develop a strong understanding of the design process and its application in business settings.	1,2	-	4
CO-5	Apply design thinking tools and methods for product development	1	2	-

POs/PSOs	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**
Mapping Level	3	2.3	3	1	-	-	-	-	-	-	-	-	-	-

Prerequisites: Nil.

Course Contents:

Unit - I

Design Thinking Background: Definition of Design Thinking, Business uses of Design Thinking, Variety within the Design Thinking Discipline, Design Thinking Mindset.

Self-study: Morphology of design, design methods - morphological analysis, AIDA, brainstorming, lateral thinking and puzzles on lateral thinking, creativity, design optimization. **7 Hrs**

Unit – II

Design Thinking Approach: Fundamental Concepts, Empathy, Ethnography, Divergent Thinking, Convergent Thinking, Visual Thinking, Assumption Testing, Prototyping, Time for Learning and Validation.

Design Thinking Resources: People, Place, Materials, Organizational Fit.

8 Hrs

Unit – III

Design Thinking Processes: Numerous Approaches, Double Diamond Process, 5 Staged. School Process, Designing for Growth Process, Role of Project Management. **8 Hrs**

Unit – IV

Design Thinking in Practice: Process Stages of Designing for Growth, What Is, What If, What Wows, What Works.

Design Thinking Application: Design Thinking Applied to Product Development. **8 Hrs**

Unit – V

Design Thinking Tools and Methods: Purposeful Use of Tools and Alignment with Process, What Is: Visualization, What Is: Journey Mapping, What Is: Value Chain Analysis, What Is: Mind Mapping, What If: Brainstorming, What If: Concept Development, What Wows: Assumption Testing, What Wows: Rapid Prototyping, What Works: Customer Co-Creation, What Works: Learning Launch**.** **8 Hrs**

Reference Books:

1) A4Q - Alliance for Qualification Design Thinking booklet, 2018.
2) Jeanne Liedtka and Tim Ogilvie, “Designing for growth - A design thinking tool kit for managers”, 2011.
3) Michael Lewrick, Patrick Link, Larry Leifer, “The design thinking play book: Mindful digital transformation of teams, products, services, businesses and ecosystems”, 2018.
4) Leo Frishberg and Charles Lambdin, “Presumptive design: Design provocations for innovation”, 2016.
5) Jamshid Gharajedaghi, “Systems thinking: Managing chaos and complexity: A platform for designing business architecture, Chapter Seven: Design Thinking”, 2011.

21UMEE525	Fundamentals of Automobile Design	(3-0-0) 3

Contact Hours: 39

Course Learning Objectives (CLOs): The objective of this course is to make the student aware of:

1. Theoretical concepts of automotive industry.
2. Design and development automotive systems.
3. Die and Fixtures Design.
4. Explain Industrial Design and its importance

Course Outcomes (COs):

Description of the Course Outcome: At the end of the course the student will be able to:		**Mapping to POs(1-12)/ PSOs (13,14)**		
		Substantial Level (3)	**Moderate Level (2)**	**Slight Level (1)**
CO-1	Identify the importance of design and styling for Automotive Product Development	1	-	-
CO-2	Apply fundamental concepts on the bonnet design	-	2	-
CO-3	Investigate the concept of FEA and NVH in the process of model creation and analysis.	3	-	-
CO-4	Investigate the Die and fixture design process	3	-	-
CO-5	Discuss on different methods of sheet metals process and its use in automobile.	-	2	-
CO-6	Describe various methods of operations performed on sheet metals fixtures	-	2	-

POs/PSOs	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**
Mapping Level	2	3	3	-	-	-	-	-	-	-	-	-	-	-

Prerequisites: Nil

Course Contents:

Unit - I

Automotive design and development cycle: Introduction to styling, Design, Design Examples, Industrial Design, applications. Typical Product Life Cycle, Automotive Design Process (Design Process for production release), Design Studio Process or Product Conceptualization process, case study, Computer Aided Styling (CAS) Surfaces or Digital Clay Models, Class A Surfaces, Role of Class A Surface Engineer, Requirements for Class A Surface, Case Studies for Class A Surfaces, Step by Step Process for Bonnet Class A Surface Creation. Good Design & its examples.

Practical sessions:
Session1: Exercise to obtain the outer surface (CAS) of a bonnet based on car style
Session2: Writing the Requirement Specification of car bonnet (idea is to provide this as input to source a supplier)
Session3: Basic introduction to CAD & suitable software (Siemens NX, Catia)
4L+3P Hrs

Unit - II

Introduction to styling: Function of a bonnet, Inputs for the bonnet, Design procedure- Develop Hood Package Layout, Develop Typical Sections, Define Block Surfaces in 3D, Define Dynamic Clearance Surfaces in 3D, Define Hood Structural Members, Computer Aided Engineering(CAE) 1(Durability, crash), Panel Detail Design, Define Body Assembly Process, CAE 2(Durability, crash, Individual pane l level). Design Updating and Detailing Prototypes, Design Updating and Production Release.
Practical sessions:
Session 1: CAD design of a bonnet - 1
Session 2: CAD design of a bonnet – 2
Session 3: Application of CAE simulation on bonnet CAD (air flow, water flow, etc)
4L+3P Hrs

Unit - III

Introduction to CAD, CAM & CAE: Finite Element Analysis(FEA),Noise Vibration and Harshness(NVH), Dura, Crash, Occupant Safety, CFD Implicit vs. Explicit Solvers, Degrees of Freedom, Stiffness matrix, Pre -Post and Solver; Types of Solvers, Animations, Durability: Oil Canning on Hood, Scope of Work, NVH: Constrained Modal Analysis on Hood, Scope of Work, Loading, Boundary Conditions, Results & Conclusion, Crash: Vehicle Crashworthiness, Energy Management Biomechanics, Head Impact Analysis on Hood, Importance of Failure Criteria, Von Mises Stress.

Practical sessions
Session 1: Application of CAE simulation on bonnet CAD (strength & stiffness, debt resistance)
Session 2: Fixture design
Session 3: Assembly& disassembly considerations for components (after sales, service)
4L+3PHrs

Unit - IV

Sheet metal design and manufacturing: Introduction to Sheet metal design and manufacturing cycle, Simultaneous Engineering (SE) feasibility study, Auto body and its parts Important constituents of an automobile, different types of Sheet metal processes, Types of draw dies, Draw Model development, Considerations while developing draw model, Forming simulations, Material properties Forming Limit Curve (FLD), Pre- processing, Post Processing, Sheet Metal Formability – Simulation.

Practical sessions:

Session 1: Design for manufacture of plastic parts (mould flow, draft angle etc)

Session2: Bench marking a bonnet by studying competitor data (2 or 3 examples) **8L+2PHrs**

Unit - V

Die design: Requirements, Sheet metal parts and their operation like Cutting, Non-cutting etc., Presses, and Various elements used in die design. Function of each element, Different types of dies, working of dies .Real life 3D experience of Die design.

Fixture design: Requirements, definition, operation and elements of fixture design, Different types of welding processes used for fixture, Body Coordinates 3- 2-1 principle, need for Fixture, Design Considerations. Specification of product using GD&T in the Fixture design. Fixture Elements. typical operations in Sheet metal Fixture using Manual/Pneumatic/Hydraulic fixture, typical Unit Design for Sheet metal parts (Rest/Clamp/location/Slide/Dump units/base), types of Fixture (Spot welding/Arc welding/Inspection Fixture/Gauges)

Practical sessions:

Session 1: Example Design Failure mode and Effect Analysis (DFMEA) practical 1 - how to analyze risk & define counter measures.

Session 2: Example DFMEA practical 2 - how to analyse risk & define counter measures. **6L+2P Hrs**

Reference Books:

1) Banabic, D. (n.d.). “Sheet Metal Forming Processes”, Constitutive Modelling and Numerical Simulation.
2) Klocke, F. (n.d.). “Manufacturing Processes 4 Forming”, Retrieved from http://www.springer.com/series/7858.
3) Mikell P. Groover “Fundamentals Of Modern Manufacturing”, Materials, Processes, and Systems Fourth Edition,
4) H-Point The Fundamentals of Car Design & Packaging, copy write 2008 by Design Studio press.
5) Delmar, Cengage Learning, “Jig and Fixture Design”, Fifth Edition Edward G. Hoff man, 2004.
6) Mohammed A. Omar, “The Automotive Body Manufacturing Systems And Processes”, John Wiley & Sons Ltd, Edition first published 2011,

VI Semester

21UMEC600	Heat Transfer	(2-2-0) 3

Contact Hours: 39

Course Learning Objectives (CLOs): The objectives of this course are to make the student to learn:

1. Principles of heat transfer.
2. Steady and transient heat transfer, obtain the differential equation of heat conduction in various coordinate system.
3. Physical mechanism of convection and visualize the development of velocity and thermal boundary layers during flow over a surface.
4. Radiation heat transfer mechanism .

Course Outcomes (COs):

Description of the Course Outcome: At the end of the course the student will be able to:		**Mapping to POs(1-12)/ PSOs (13,14)**		
		Substantial Level (3)	**Moderate Level (2)**	**Slight Level (1)**
CO-1	Solve steady state heat transfer problems in conduction.		1,2	-
CO-2	Determine heat transfer and temperature profiles in transient system		1,2	-
CO-3	solve convection heat transfer problems using correlations	-	1,2	-
CO-4	Explain the mechanisms of boiling and condensation. And determine performance of extended surfaces	-	1,2	-
CO-5	Evaluate radiation and Heat exchanger related problems	-	1,2	-

POs/PSOs	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**
Mapping Level	2	2	-	-	-	-	-	-	-	-	-	-	-	-

Prerequisites: Nil

Course Contents:

Unit - I

Introductory Concepts and definition: Review of basics of Modes of Heat Transfer. Conduction-Basic Equations: General form of one-dimensional heat conduction equation. Boundary conditions of first, second and third kinds;

One dimensional Steady state conduction with and without heat generation: Steady state conduction in slab, cylinder and sphere with engineering applications. **7L+1T Hrs**

Unit - II

Steady state conduction: Overall heat transfer coefficient for a composite medium; thermal contact resistance; critical thickness of insulation.

One dimensional Transient conduction: Conduction in solids with negligible internal temperature gradients (lumped system analysis) Use of transient temperature charts (Heisler's charts) for Transient conduction in slab, long cylinder and sphere; concept of semi-infinite solids. **6L+2T Hrs**

Unit - III

Concepts and Basic Relations in Boundary layers: Flow over a flat plate - Velocity boundary layer, Thermal boundary layer; Prandtl number; general expression for local heat transfer coefficient; Average heat transfer coefficient.

Forced Convection: Physical significance of Dimensionless numbers. Use of various Correlations for hydro dynamically and thermally developed flows; Use of correlations for flow over a flat plate, cylinder, sphere.

Free or Natural Convection: Physical significance of dimensionless numbers. Use of correlations for free convection from or to vertical, horizontal cylinder/plate. **7L+2T Hrs**

Unit - IV

Boiling and Condensation; Film, dropwise condensation theory, Pool boiling regimes

Extended surfaces: Steady state conduction in fins of uniform cross section long fin, fin with insulated tip and fin with convection at the tip; fin efficiency & effectiveness. **5L+1T Hrs**

Unit - V

Heat Exchangers: Classification of heat exchangers; Overall heat transfer coefficient, Fouling, Scaling factors; LMTD and NTU methods of analysis of heat exchangers.

Radiation Heat transfer: Concept of thermal radiation resistance, Radiation network, view factor, Radiation heat exchange between two parallel infinite black surfaces, between two parallel infinite gray surfaces; Effect of radiation shield; **6L+2T Hrs**

Reference Books:

1) MN. Ozisik, “Heat Transfer A basic approach”, McGraw Hill International, 1988.
2) R. C. Sachdeva, “Fundamentals of Engineering Heat and Mass transfer”, Wieley Eastern Ltd., 1995.
3) Incropera, DeWitt,Bergmann, Lavine “Fundamentals of Heat and Mass Transfer” Sixthe edition, 2011 (reprint), Wiley India Pvt. Ltd.,
4) Yunus A Cengel, “Heat Transfer A Practical approach”, TATA McGraw Hill 2002
5) Mahesh M. Rathore, “Engineering Heat and Mass transfer”, Laxmi Publications, 2nd edition, 2006.
6) Heat Transfer data handbook by C P Kothandaraman, S Subramanyan, 8th edition, New Age International Publisher Delhi.

21UMEC601	Finite Element Methods	(2-2-0) 3

Contact Hours: 39

Course Learning Objectives (CLOs): The objectives of this course are to make the student to learn:

1. Numerical methods used to solve engineering problems.
2. Skills associated with the principles of FEM.
3. Skills in applying the basic matrix operation to form a global matrix equation and enforce the concept of steps in obtaining solutions for a truss Structures.
4. Interpolation functions to solve beam problems.
5. Skills in applying FEM solution to structural and thermal problems.

Course outcomes (COs):

Description of the Course Outcome: At the end of the course the student will be able to:		**Mapping to POs(1-12)/ PSOs (13,14)**		
		Substantial Level (3)	**Moderate Level (2)**	**Slight Level (1)**
CO-1	Solve problems on matrix algebra and numerical integration.	-	1,2	-
CO-2	Explain basic concepts of theory of elasticity and FEM.	1,2	-	-
CO-3	Solve basic problems in solid mechanics using variational and other principles	1,2	-	-
CO-4	Develop finite element formulation for 1D bars and trusses.	1,2	-	3
CO-5	Develop finite element formulation for higher order elements and 1D heat transfer problems.	-	1,2	3

POs/PSOs	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**
Mapping Level	2.6	2.6	1	-	-	-	-	-	-	-	-	-	-	-

Prerequisites: Nil

Course Contents:

Unit - I

Introduction: Need for use of FEM, Advantages, disadvantages and applications of FEM; Matrix Algebra - (Terminology and operations), Gaussian elimination method. **7L+2T Hrs**

Unit – II

Numerical Integration- Gauss quadrature, one point and two point formula, 1D and 2D integrals.

Basics of Theory of Elasticity: Definitions of stress and strain, strain-displacement relations, stress-strain relations in 2D Cartesian and polar co-ordinates. **7L+2T Hrs**

Unit - III

Continuum methods: Principal of minimum potential energy; Rayleigh – Ritz method applied to simple problems on axially loaded members, cantilever and simply supported beam; Galerkin method and its application to simple axially loaded problems. **7L+3T Hrs**

Unit - IV

Finite Element Method: Direct approach to discrete systems (Derivation of stiffness matrix by direct method for 2 node bar& 2D truss), transformation law, Displacement method; Different co-ordinate systems, Shape functions, Formulation of 2 node bar element, stress recovery, Boundary conditions (Single point Constraints only), Elimination of handling boundary conditions. **9L+3T Hrs**

Unit – V

Finite Element Method (Continued): Direct approach to discrete systems Derivation of stiffness matrix by direct method for beam element, shape functions and determining [B] for CST element.

One-dimension steady state heat conduction: formulation of 2 node, 1-D element, using Galerkin method. **9L+3T Hrs**

Reference Books:

1) Rao S.S., “The finite Element Method in Engineering”, 5th edition, Butterworth-Heinemann, 2013.
2) T. R. Chandrupatla and A. D. Belegundu, “Introduction to finite Elements in Engineering”, 2nd edition, Prentice Hall of India, New Delhi, 2001.
3) R. D. Cook et al, “Concepts and Applications of Finite Element Analysis” 4th edition, Joln Wiley & Sons, inc, 2005.

21UMEC602	Fluid Power Control	(3-0-0) 3

Contact Hours: 39

Course Learning Objectives (CLOs): The objectives of this course are to make the student to learn:

1. Types of Hydraulic power actuators, motors and concepts of circuit design.
2. Maintenance of fluid power systems.
3. Various actuators, valves, control signal processing elements and multi cylinder applications.

Course Outcomes (COs):

Description of the Course Outcome: At the end of the course the student will be able to:		Mapping to POs(1-12)/ PSOs (13,14)		
		Substantial Level (3)	Moderate Level (2)	Slight Level (1)
CO-1	Explain the construction and working of various positive displacement pumps and hydraulic principles.	-	1, 2	-
CO-2	Discuss different types of actuators and their performance parameters.	-	1, 2	-
CO-3	Explain various control components used in fluid power systems.	-	1,2	-
CO-4	Design hydraulic circuits with various hydraulic components for mechanical applications.	1	2,3	-
CO-5	Discuss working principles & maintenance procedures of pneumatic & electro pneumatic components and design application circuits.	1	2,3	-

POs/PSOs	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Mapping Level	2.4	2	2	-	-	-	-	-	-	-	-	-	-	-

Prerequisites: Nil

Contents:

Unit - I

Introduction to Fluid Power: Hydraulic system Components, Pneumatics system components, advantages, applications in the field of M/c tools, material handling, hydraulic presses, mobile & stationary machines, Pascal's Law and its application, Problems on Pascal's Law, Types of Hydraulic fluid petroleum based, synthetic & water based. Properties of fluids. Selection of fluids, ISO Symbols for hydraulic & pneumatic circuits.

The Source of Hydraulic power: Pumping theory, Classification, Principle of working and constructional details of Gear Pump, Vane Pump, Axial and Radial Piston Pumps, Variable displacement Pumps, Power and Efficiency calculations, Pump Selection for hydraulic power transmission. **10 Hrs**

Unit – II

Hydraulic Actuators and Motors: Classification cylinder and hydraulic motors, Linear Hydraulic Actuators [cylinders], single and double acting cylinder, Mechanics of Hydraulic Cylinder Loading, mounting arrangements, cushioning, special types of cylinders, problems on cylinders, construction and working of rotary actuators such as gear, vane, piston motors, Hydraulic Motor Theoretical Torque, Power and Flow Rate, Hydraulic Motor Performance, problems, symbolic representation of hydraulic actuators (cylinders and motors) **10 Hrs**

Unit - III

Control Components in fluid power:

Pressure Control Valves: Necessity of pressure control directional control, flow control valves, Principle of pressure control valves, direct operated, pilot operated, relief valves pressure reducing valve, sequence valve & methods of actuation of valves.

Flow Control Valves: Principle of operation, pressure compensated, temp. Compensated flow control valves,

Direction Control Valves: Check valves, types of D.C. Valves : Two way two position, four way three position, four way two position valves, open center, close center tandem center valves, method of actuation of valves, manually operated solenoid operated, pilot operated etc. **10 Hrs**

Unit - IV

Hydraulic Circuit Design and Analysis:

Control of Single and Double -Acting Hydraulic Cylinder, Regenerative circuit, Pump Unloading Circuit, Double Pump Hydraulic System, Counter balance Valve Application, Hydraulic Cylinder Sequencing Circuits, Automatic cylinder reciprocating system, Locked Cylinder using Pilot check Valve, Cylinder synchronizing circuit using different methods, factors affecting synchronization, Hydraulic circuit for force multiplication, Speed Control of Hydraulic Cylinder,

Speed Control of Hydraulic Motors, Safety circuit, Accumulators, types, construction and applications with circuits. **10 Hrs**

Unit – V

Basic Pneumatic control and Electro pneumatics: Physical properties in pneumatics, DC valves, linear and rotary actuators, flow control valves, pneumatic symbols and control element description, Symbols, Impulse operation, Speed control, sequencing of motion, vacuum handling. Introduction, actuating magnets, construction of electromagnet, contactors and switches, relays, limit switch, electro pneumatic circuits, single acting and double acting cylinder control examples.

Maintenance and Troubleshooting: Maintenance need of pneumatic systems, common problems in pneumatic systems, maintenance schedule of pneumatic system, trouble shooting and maintenance tips. **12 Hrs**

Reference Books:

1) Anthony Esposito, “Fluid Power with applications”, 7th edition, PHI, 2009.
2) S. R. Majumdar, “Pneumatic systems”, Tata McGraw Hill New Delhi, 2010.
3) F. Don Norvelle “Fluid Power Technology”, West Publishing Company, Minneapolis, 1995.
4) S. R. Majumdar, “Oil hydraulic systems”, PHI, 2010.

21UMEL603	Thermal Engineering Lab - III	(0-0-2) 1

Contact Hours: 26

Course Learning Objectives (CLOs): The objectives of this course are to make the student to learn:

1. Basic principles of heat transfer.
2. Theoretical aspects of heat transfer and physical approaches and measuring parameters significance.
3. Importance of effectiveness of heat exchangers.
4. Validation of natural convection and forced convection with theoretical values of heat transfer coefficients.
5. Working and performance of vapor compression refrigeration and air-conditioning.

Course outcomes (COs):

Description of the Course Outcome: At the end of the course the student will be able to:		**Mapping to POs(1-12)/ PSOs (13,14)**		
		Substantial Level (3)	**Moderate Level (2)**	**Slight Level (1)**
CO-1	Determine performance parameters for different modes of heat transfer.	-	1, 2	4, 9
CO-2	Calculate the efficiency of different types of fins.	-	1, 2	4, 9
CO-3	Evaluate heat transfer coefficient related to film & drop wise condensation.	-	1, 2	3, 9
CO-4	Evaluate time and temperature relation for lumped system.	-	1	3, 9
CO-5	Conduct performance test on VCR refrigeration, heat exchanger and air conditioning.	-	1, 2	3

POs/PSOs	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**
Mapping Level	2	2	1	1	-	-	-	-	1	-	-	-	-	-

Prerequisites: Nil

1. Determine the thermal conductivity of composite wall.
2. Determine the thermal conductivity of lagged pipe.
3. Determine the thermal conductivity of insulating powder in sphere.
4. Determination of (natural) convection heat transfer coefficient for air.
5. Determination of (forced) convection heat transfer coefficient for air.

6. Pin-fin (Natural convection).
7. Pin-fin (Forced convection).
8. Determine the critical Heat flux of a wire.
9. Heat exchanger Parallel flow and counter flow.
10. Determination of the Stefan Boltzmann's constant.
11. Boiling and condensation.
12. Transient heat transfer.
13. VCR (Vapor compression refrigeration) & AC-test rig.

Data Hand Book:

1) Heat Transfer data hand book by C P Kothandaraman, S Subramanyan, 8th edition, New Age International Publisher Delhi.

21UMEL604 Computer Aided Engineering Analysis Laboratory (0-0-2) 1

Contact Hours: 26

Course Learning Objectives (CLOs): The objectives of this course are to make the student to learn:

1. Simulation tools.
2. Computer Aided Engineering (CAE)
3. CAM simulation

Course outcomes (COs):

Description of the Course Outcome: At the end of the course the student will be able to:		**Mapping to POs(1-12)/ PSOs (13,14)**		
		Substantial Level (3)	**Moderate Level (2)**	**Slight Level (1)**
CO-1	Use FEA tool to solve loaded bars and trusses.	-	-	3, 4
CO-2	Analyze the behavior of beams under different loading patterns.	5	-	4
CO-3	Validate stresses in 2D structural and thermal problems.	5	-	3,4
CO-4	Determine the natural frequency of bars and beams.	-	5	3, 4
CO-5	Use CAM simulation packages for tool path generation.	-	-	5

POs/PSOs	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**
Mapping Level	-	-	1	1	2.3	-	-	-	-	-	-	-	-	-

Prerequisites: Nil

Course Contents:

PART - A

Study of a FEA package and modeling stress analysis of

1. Bars of constant cross section area, tapered cross section area and stepped bar
2. Trusses – (Minimum 2 exercises)
3. Beams – Simply supported, cantilever, beams with UDL, beams with varying load etc (Minimum 4 exercises)

PART - B

1. Stress analysis of a rectangular plate with a circular hole
2. Thermal Analysis – 1D & 2D problem with conduction and convection boundary conditions (Minimum 2 exercises)
3. Dynamic Analysis
    1) Fixed – fixed beam for natural frequency determination
    2) Bar subjected to forcing function
    3) Fixed – fixed beam subjected to forcing function
4. Tool path generation for milling operation using CAM software package. (2-Exercises)

Reference Books:

1) Anand V Kulkarni & Venkatesh K. Havanur, “A Primer on Finite Element Analysis”, Laxmi Publications (University Science Press) New Delhi, 2011.
2) Dr. S.M.Musa, A.V.Kulkarni and V.K.Havanur, “Finite Element Analysis”, A Primer by Mercury Learning Information, U.S.A., 2013.

21UMEL605	Minor Project - II	(0-0-3) 1

Contact Hours: 26

Course Learning Objectives (CLOs): The objectives of this course are to make the student to learn:

1. Practical significance of projects.
2. Engineering concepts and its application to real world problems.
3. Manufacturing problems associated with fabrication.
4. Creativity as an essential component of engineering application.

Course outcomes (COs):

Description of the Course Outcome: At the end of the course the student will be able to:		**Mapping to POs(1-12)/ PSOs (13,14)**		
		Substantial Level (3)	**Moderate Level (2)**	**Slight Level (1)**
CO-1	Identify, formulate & solve a problem using basic engineering principles.	1,2	4	12
CO-2	Design the machine parts, components of a system that meets particular requirement.	3	7	6,12
CO-3	Use the software tools to prepare & analyze models or prototypes and conduct simulation using it.	5,13	2	-
CO-4	Use the machine tools to prepare models or prototypes.	5,13	2	-
CO-5	Work in teams and communicate effectively for in time completion of projects.	10	8,11,12	-
CO-6	Prepare a report and PPT based on the project work.	13,14	9,10,11	-

POs/PSOs	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**
Mapping level	3	2.4	3	2	3	1	2	2	2	2.5	2	1.4	3	3

Prerequisites: Nil

Course Contents:

Every student is advised to conduct a mini project covering relevant thrust areas of Mechanical Engineering and to device and analyze the problem in consultation with a faculty guide of his choice. There will be at least 3

presentation phases culminating with a final project presentation to the examiners.

Note: Activities for self-study to be initiated by the guide.

21UHUL606	Soft Skills/Aptitude	(0-0-2) 1

Contact Hours: 26

Course Learning Objectives (CLOs):

This is included with the objectives of improving the communication skills, proficiency in English language and aptitude ability of the student to enhance the employability.

Course Outcomes (COs):

Description of the Course Outcome: At the end of the course the student will be able to:		**Mapping to POs(1-12)/ PSOs (13,14)**		
		Substantial Level (3)	**Moderate Level (2)**	**Slight Level (1)**
CO-1	Explain the significance of communication in the profession.	-	10	-
CO-2	Use the English language with proficiency	-	10	12
CO-3	Solve Aptitude related problems	-	9	12
CO-4	Demonstrate the competency in the placement activities.	-	9	-

POs/PSOs	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**
Mapping Level	-	-	-	-	-	-	-	-	2.0	2.0	-	-	-	-

Prerequisites: Nil

Course Contents:

Training on communication skills, proficiency in English language and aptitude ability involving the internal and external resource.

Soft skills / Aptitude: This is included with an objective of improving the communication skills, proficiency in English language and aptitude ability of the student. This is a credit course and aimed to enhance the employability. Both the internal and external resource persons shall be engaged in imparting the related knowledge and shall have only CIE as the evaluation component as. The mode of evaluation shall be as per the guidelines by the central authorities.

21UMEE621	CAD/CAM (Computer aided design/Computer aided manufacturing)	(3-0-0) 3

Contact Hours: 39

Course Learning Objectives: The objectives of this course are to make the student to learn:

1. Basics of CAD/CAM
2. Automation concepts, graphics & modeling
3. Latest CAD/CAM technologies and FEA

Course outcomes (COs):

Description of the Course Outcome: At the end of the course the student will be able to:		**Mapping to POs(1-12)/ PSOs (13,14)**		
		Substantial Level (3)	**Moderate Level (2)**	**Slight Level (1)**
CO-1	Explain the role of CAD/CAM, hardware and computer graphics in today's manufacturing automation.	1,2	-	-
CO-2	Develop geometric model of engineering problem by various modelling schemes using geometric transformations.	1	-	4
CO-3	Discuss stages in FEA and concepts of CNC machine tools and tooling.	1,2	-	4
CO-4	Write manual and advanced part programs for a given geometry during milling and turning operations.	2,3	-	1
CO-5	Use of manufacturing simulation packages to solve turning and milling problems.	1,2	-	4
CO-6	Explain the material handling systems like robots and AGVs, along with concepts of FMS, CIM and CAPP.	3	-	1,2

POs/PSOs	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**
Mapping Level	2.3	2.6	3	1	-	-	-	-	-	-	-	-	-	-

Prerequisites: Nil

Course Contents:

Unit - I

Fundamentals of CAD: Definition of CAD /- Product cycle in conventional and CAD/CAM environment- Automation & CAD / CAM- Design Process (Application of computers for design) - Advantages & Disadvantages of CAD.

CAD Networking and Computer Graphics: Design Workstation-Architecture of typical graphics workstation, Network and its topologies. Software configuration of a Graphic system- Graphical Kernel System- Graphic standards- Functions of Graphics package. **8 Hrs**

Unit - II

Geometric Modeling: Construction of Geometry- Data structures- Data base for Graphic modeling- CSG- Boundary representation- parametric modeling variant approach- Wire frame- surface & solid modeling advantages and disadvantages.

Transformations: 2-D Transformation- 3-D Transformation- Concatenation- Homogeneous Transformation- Clipping & Windowing- Viewing Transformations- Windowing Transformation. 3 - D modeling Concepts. **8 Hrs**

Unit - III

Introduction to FEA: Preprocessing- Analysis- Post processing- Discretization- Element types- Nodes- Degrees of freedom- constraints- Loads.

Introduction NC-CNC-DNC: NC, CNC & DNC- Elements- CNC machining centers- CNC Turning Centers- High speed machine tools- MCU & Supporting Systems.

CNC Tooling - Turning Tool geometry- Milling tooling- systems- Tool presetting - ATC Work-holding devices. **8 Hrs**

Unit - IV

CNC Part Programming: Part program fundamentals- Manual part programming a) milling b) Turning

Advanced part programming Methods: Parameters- Looping & Jumping- Subroutines and Macros. **8 Hrs**

Unit - V

Computer Aided part programming - Introduction to CAM simulation packages.

Material handling systems – Introduction to Robots-Anotomy, Configurations, Work volume, Robot end effectors, Robotic Sensors, applications. AGVs - Introduction to FMS & CIM- Group Technology & CAPP. **7 Hrs**

Reference Books:

1) Grover, “CAD/CAM”, Tata Mc Greaw hill, 2003.
2) P.N. Rao, “CAD/CAM”, Principles and Application, Tata Mc Grew Hill 2010.
3) Ibrahim Zeid, “CAM/CAM”, 2nd edition, Tata Mc Grew hill, 2010.
4) Newman and Sproull, “Principles and Interactive Computer Graphics”, TATA McGrew Hill, 1995.

21UMEE622	Advanced Automobile Design (Ready Engineer by TATA Technologies)	(3-0-0) 3

Contact Hours: 39

Course Learning Objectives: The objectives of this course are to make the student to learn:

1. Concepts of Computer Aided Engineering (CAE) in automotive industry overview.
2. Various stages in CAE.
3. Modal analysis.
4. Safety considerations in automobiles.

Course Outcomes (COs):

Description of the Course Outcome: At the end of the course the student will be able to:		**Mapping to POs(1-12)/ PSOs (13,14)**		
		Substantial Level (3)	**Moderate Level (2)**	**Slight Level (1)**
CO-1	Identify requirements, PLM and importance of BIW parts	1	-	-
CO-2	Investigate Design process of BIW and TRIMS parts and the study of different materials and grades	-	2	-
CO-3	Identify Trim materials and its applications Understand various methods involved in Manufacturing of plastic trims	1	-	-
CO-4	Analyse the Design Failure Mode and Effect Analysis (DFMEA) methodology and verification of process	3	4,5,6	2
CO-5	Analyze Noise Vibration and Harshness (NVH) using CAE tool and its importance	3	4,5,6	-
CO-6	Identify different methods of test validation and Assessment of Vehicles	-	-	2

POs/PSOs	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**
Mapping Level	3	1.7	3	2	2	2	-	-	-	-	-	-	-	-

Prerequisites: Nil

Course Contents:

Unit - I

Requirement Specification in the Pre-Program Stage: Introduction to pre-program stages like voice of customer, competitor insight, innovation, Project and quality planning, legislation, system strategy.

Product life cycle and important gateways for Body in White (BIW): Definition of PLM. Product life cycle: Design milestones, Types of builds, Launch of Vehicle. Flow chart of

Product life cycle Management (PLM), Design gateways: Design phases like virtual build, Prototype build, Mass
Production. Launch of Vehicle

Introduction to BIW. Identification of commodities for BIW: Closures, Body Shell. BIW terminology. BIW Assembly, future trends in BIW, Case studies. Definition of PLM.

Practical sessions:

Session 1: Exercise to obtain the outer surface Computer Aided Styling (CAS) of a bonnet based on car style.

Session 2: Writing the Requirement Specification of car bonnet (idea is to provide this as input to source a supplier)

Session 3: Basic introduction to CAD & suitable software (Siemens NX, Catia)

4L+3P Hrs

Unit - II

Design concepts and considerations in BIW: BIW parts: Sheet metal, Extrusion, Cast, Moulding. Factors driving BIW Design like Package Space, Master Sections, Cost, Weight, Assembly Process, Manufacturing Methods, Vehicle regulations. Design considerations for Sheet Metal Parts for Manufacture, Assembly and Part location on a vehicle.

BIW Materials and Grades: (Steel, Aluminium, composites): Evolution of automobile to modern Design. Basic material selection criteria for automotive: Emissions, Safety and weight, Material Choice, which is driven by Cost, Safety, Risk, Weight, Market Image, Emission. Classification of steel grade and their properties.Use of aluminium in automotive domain and its properties.Use of Composites in automotive domain and its properties.Light weight material for future automotive industry. Applications of Composite used in automotive domain.

Practical sessions:

Session 1: CAD design of a bonnet – 1

Session 2: CAD design of a bonnet - 2

Session 3: Application of CAE simulation on bonnet CAD (air flow, water flow, etc.)

4L+3P Hrs

Unit – III

Geometric Dimensioning & Tolerancing (GD & T) for BIW: Concept of GD & T, Importance of GD&T. International standards for GD&T like BS, ASME, ISO. Role of GD & T on drawing, BIW Dimensional Requirement. BIW Dimensional applications. GD&T Symbols. 3-2-1 Principle. Types of locators. Principles of location. Illustration of Feature Control Frame.

GD & T - Simulation of Datums for inspections BIW Examples and case studies.

Identification of commodities: Introduction to trim, Necessity of trim in automobile, Identification of various trim parts and their positions in vehicle. Various commodities of interior trim like Instrument panel, Centre console, Door trims, Pillar Trims, Seating Trims, Overhead Trims, Floor Carpets & Trunk trims.

Sheet Metal Joining Process: Importance. Welding, Resistant Spot welding (RSW), Advantages and Disadvantages. Concept of Tailor Welded Blanks (TWB), Types of TWB. Laser Beam Welding (LBW), Types, Advantages and Disadvantages. Self Piercing Rivets (SPR) and its advantages. Adhesive Bonding: Types, Types of joints used in it. Conventional Bonding Techniques like bolting and riveting. Classification of Metal joining process.

Practical sessions:

Session 1: Application of CAE simulation on bonnet CAD (strength & stiffness, debt resistance)

Session 2: Fixture design.

Session 3: Assembly & disassembly considerations for components (after sales, service) **4L+3P Hrs**

Unit - IV

Trim Materials in Automotive: Material Classification and Properties, Plastic Material and their applications: Polypropylene, Acrylonitrile Butadiene Styrene (ABS), Polycarbonate, Poly-oxy-methylene, Polyethylene, Polyamides, Usage and Selection Criteria, Plastic Additives: Types of additives, Impact of additives, Application in instrument Panel Assembly.

Design of Plastic part: Overview, Wall thickness, Radii, Draft angle, Ribs, Bosses, Snaps.

Design verification: CAE methods and Gateway supports: Automotive interior trim, Automotive exterior trim, CAE Load cases for Interior Trims: Interior Head impact analysis, Airbag deployment, Side occupant protection, Interior trims durability, Mould flow analysis. Gateway support.

Practical sessions:

Session 1: Design for manufacture of plastic parts (mould flow, draft angle etc.)

Session 2: Bench marking a bonnet by studying competitor data (2 or 3 examples) **8L+2P Hrs**

Unit - V

DFMEA (Design Failure Mode and Effect Analysis): Concept, Objectives of DFMEA. Overview of DFMEA process, Benefits of DFMEA, Prerequisites of DFMEA, DFMEA Flow, DFMEA team, DFMEA inputs & Outputs, DFMEA Methodology, Logical relationship between DFMEA. DFMEA S/O/D/ rating**.**

Introduction to Design Verification. Concept of Design Verification. Process of verifying Design. Commonly used verification methods like Demonstration, Inspection, analysis, Similarity, Testing. Preparation of verification activities. Conducting verification activities. Gateway support for Design verification.

CAE methods for Design verification of BIW viz. Structural Analysis, Fatigue life Prediction, Noise and vibration, Crash Impact analysis, Multibody Dynamics, Thermal analysis, CFD. Verification and Validation with respect to FEA

CAE Analysis: NVH, Crash & Durability: Concept of CAE & FEA. NVH Analysis, Load cases for NVH analysis: Static Bending stiffness, Static torsion stiffness, Natural frequency and normal modes, Crashworthiness, Crash Analysis: Full vehicle level: Frontal, Side and rear Impact, Component Level: Seating and roof crush., Durability analysis: Various load cases like Front and Rear Recovery analysis, Trailed towing analysis, Luggage retention hook analysis, Floor pan fatigue, Roof and Body side oil canning, Vehicle jacking analysis, Vehicle hoisting analysis, Fatigue analysis of BIW.

Design of Plastic part: Overview, Wall thickness, Radii, Draft angle, Ribs, Bosses, Snaps,

Design verification: CAE methods and Gateway supports: Automotive interior trim, Automotive exterior trim, CAE Load cases for Interior Trims: Interior Head impact analysis, Airbag deployment, Side occupant protection, Interior trims durability, Mould flow analysis. Gateway support.

Manufacturing Processes: Vacuum Forming, Injection Moulding, Heat Staking, Extrusion Blow moulding along with their applications characteristics and limitations.

Test Validation & Assessment: Vehicle physical testing, Crash test requirements, Frontal Crash test, Rear and side impact testing, Pedestrian head impact test and roll over. Four post durability tests. Wind tunnel testing

Manufacturing - Sequence (after validation): Welding, Assembly sequence Body shop, Paint Shop, Trim- chassis, Final assembly.

Future Trends in BIW: Energy Storing Body Panels, light Weight Vehicle Technology, Latest Joining Technologies Used in BIW

Practical sessions:

Session 1: Example DFMEA practical 1 - how to analyze risk & define counter measures.

Session 2: Example DFMEA practical's 2 - how to analyze risk & define counter measures.

6L+2P Hrs

Reference Books:

1) Morello, L., Rosti Rossini, L., Pia, G., & Tonoli, A. (2010). The Automotive Body: Volume I: Components Design (Mechanical Engineering Series). Retrieved from http://www.springer.com/1161---A2
2) Huang, M. (2002). Vehicle crash mechanics. CRC Press.-A2
3) Boljanovic, V. (2004). SHEET METAL FORMING PROCESSES AND DIE DESIGN. A1 and A2
4) Morello, L., Rosti Rossini, L., Pia, G., & Tonoli, A. (2010). The Automotive Body: Volume II: System Design (Mechanical Engineering Series). Retrieved from http://www.springer.com/1161-A2
5) Weber, J. (2009). Automotive development processes: Processes for successful customer oriented vehicle development. Automotive Development Processes: Processes for Successful Customer Oriented Vehicle Development. Springer Berlin Heidelberg. https://doi.org/10.1007/978-3-642-01253-2--A2
6) An Introduction to Modern Vehicle Design. Edited by Julian Happian-Smith,© Reed Educational and Professional Publishing Ltd 2002—A2
7) Automotive Product Development. A Systems Engineering Implementation, by Vivek D. Bhise,© 2017 by Taylor & Francis Group, LLC CRC Press is an imprint of Taylor & Francis Group, an Informa business.—A2
8) Design and Manufacture of Plastic Components for Multifunctionality. (2016). In Design and Manufacture of Plastic Components for Multifunctionality. https://doi.org/10.1016/c2014-0-00223-7-A2
9) Effective FMEAs: Achieving Safe, Reliable, and Economical Products and Processes using Failure Mode and Effects Analysis, Carlson, June 2012.

21UMEE623	Refrigeration and Air-Conditioning	(3-0-0) 3

Contact Hours: 39

Course Learning Objectives (CLOs): The objectives of this course are to make the student to learn:

1. Vapour compression systems of single stage and multi stage and carnot Vapour compression cycle and effect of volumetric efficiency and pressure change and optimum inter mediate pressure, sub-cooling and super heating on COP.
2. Principles of Vapour absorption and water, air refrigeration.
3. Uses and properties of refrigerants also application of secondary refrigerants.
4. Principles of psychrometry and basic processes of air conditioning.
5. Cooling and heating load calculation for air-conditioning and refrigeration.
6. Applications of refrigeration.

Course Outcomes (COs):

Description of the Course Outcome: At the end of the course the student will be able to:		**Mapping to POs(1-12)/ PSOs (13,14)**		
		Substantial Level (3)	**Moderate Level (2)**	**Slight Level (1)**
CO-1	Discuss basic concepts & various methods in refrigeration and air-conditioning.	1,2	-	-
CO-2	Compute performance parameters for single & multi stage VCR.	1,2	-	-
CO-3	Explain VAR system and air conditioning processes.	-	1,2	-
CO-4	Estimate heating and cooling loads for refrigeration and air conditioning systems.	1,2	-	3
CO-5	Discuss non-conventional refrigeration systems, refrigerants and its applications.	-	-	1,2

POs/PSOs	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**
Mapping Level	2.8	2.8	1	-	-	-	-	-	-	-	-	-	-	-

Prerequisites: Nil

Course Contents:

Unit - I

Introduction: Basic Definition of Refrigeration and Air-Conditioning, History of Refrigeration and Air-Conditioning**,** Necessity of Refrigeration and Air-Conditioning, Different methods of Refrigeration.

Air Refrigeration: Carnot refrigeration cycle, Brayton refrigeration cycle- Aircraft refrigeration system – necessity Classification- Basic aircraft refrigeration cycle- Boot strap air refrigeration system Regenerative air refrigeration system- reduced ambient air refrigeration system. **9 Hrs**

Unit - II

Single and Multi stage VCR: Vapour Compression Refrigeration Cycle Single stage systems - Effect of pressure changes on COP- Effect of sub-cooling and super heating- actual vapour compression cycle. Use of p-h chart, Refrigeration property tables. Two stage with given intermediate pressure- Effect of volumetric efficiency on multi staging- optimum inter stage pressure- Cascade refrigeration system- multi evaporator system- Booster system.

Water Refrigeration: Introduction- principle of operation - Centrifugal refrigeration- Steam jet refrigeration. **8 Hrs**

Unit - III

Vapour Absorption system: Simple and Improved Ammonia absorption systems- Maximum COP- Lithium Bromide absorption system- Electrolux system.

Psychrometry of Air Conditioning Processes: Mixing process- Basic processes in conditioning of air- Psychrometric process in Air conditioning equipment- Simple air conditioning system- State and mass rate of supply air-summer air conditioning – Apparatus dew point- winter air conditioning.

8 Hrs

Unit - IV

Cooling and Heat load Calculations: Selection of design temperatures-Sources of heat load- Capacity of Refrigeration system- Cooling load calculations- Heat transfer through structure- Solar radiation- Electrical appliances- Infiltration and Ventilation- Heat generation inside the conditioned space- Air conditioning and cooling loads and apparatus selection- Heating load calculations. **7 Hrs**

Unit - V

Nonconventional Refrigeration Systems, Refrigerants and Applications: Basic principle of operation, Thermodynamic analysis, advantages and disadvantages of Vortex tube, Pulse tube and Thermoelectric refrigeration system;

Refrigerants: Introduction**,** Classification- Nomenclature- Desirable properties-Common refrigerants and Secondary refrigerants. **Applications:** All the year–round air conditioner, Air conditioning in Transport: Air conditioning systems for automobiles, Air conditioning systems for trains, Comfort Air Conditioning: Residential air conditioning, Commercial air conditioning; Industrial air

conditioning and Refrigeration: Chemical and process industries, Dairy plants and Petroleum refineries, Food processing plants. **7 Hrs**

Reference Books:

1) Manohar Prasad, ‘‘Refrigeration and Air-conditioning’’, 2nd edition, Wiley Eastern Publication, 2010
2) C. P. Arora, ‘‘Refrigeration and Air-conditioning’’, 2nd Edition, Tata McGraw Hill Publication, 2000.
3) L. N. Mishra - Vani, ‘’Refrigeration and Air-conditioning’’, Educational Books, New Delhi- 1985.
4) Jordon and Priester, ‘’Refrigeration and Air conditioning’’, PHI Publication, 1995.

21UMEE624	Advanced Fluid Dynamics	(3-0-0) 3

Contact Hours: 39

Course Learning Objectives (CLOs): The objectives of this course are to make the student to learn:

1. Fluid and its properties, laws governing fluid flow and mathematical interpretation.
2. Fluid flow concepts, velocity potential, ideal fluid flow concepts and stream functions.
3. Fluid dynamics continuity equation, Navier stokes equation and application of it.
4. Low Reynolds number flow and viscous flow.
5. Compressible flow, sonic velocity Mach number isentropic flow.

Course outcomes (COs):

Description of the Course Outcome: At the end of the course the student will be able to:		Mapping to POs(1-12)/ PSOs (13,14)		
		Substantial Level (3)	Moderate Level (2)	Slight Level (1)
CO-1	Explain basic fluid flow concepts and governing equations.	-	1,2	-
CO-2	Analyze various applications of Navier -Stokes equation of motion.	1,2	-	-
CO-3	Explain boundary layer concepts and solve related problems.	-	1,2	-
CO-4	Analyze low Reynolds number flows and Reynolds equation of lubrication.	1,2	-	-
CO-5	Determine forces on submerged bodies and solve problems related to lift and drag.	1,2	-	-
CO-6	Discuss integral flow equation and flow measuring devices.	-	1,2,3	-

POs/PSOs	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Mapping Level	2.5	2.5	2	-	-	-	-	-	-	-	-	-	-	-

Prerequisites: Nil

Course Contents:

Unit - I

Introduction to fluid mechanics: Fluid properties, Continuity equation 2D & 3D (Cartesian and cylindrical co-ordinates derivation and problems) Navier Stokes equation (3D Cartesian co-ordinates), Ideal flows. **8 Hrs**

Unit - II

Viscous flow: Flow inside a circular pipe, flow between two parallel plates, Power transmission through pipes with numerical problems.

Compressible flow: Introduction, Sonic velocity, mach number, stagnation properties, flow through nozzles with numerical problems. **9 Hrs**

Unit - III

Boundary Layer theory: Definitions, Hydrodynamic boundary layer, boundary layer thickness, displacement, momentum & energy thickness, (Derivations and problems) Vonkarman integral separation, Thermal boundary layer. **7Hrs**

Unit - IV

Low Reynolds number flow: Lubrication theory and Reynolds equation of lubrication, flow past immersed bodies; lift & drag with numerical problems.

Integral flow: Reynolds transport theorem, continuity, momentum, moment of momentum, Energy equations. **8 Hrs**

Unit - V

Flow measuring devices: Positive displacement meters, flow meters, Notches, pressure probes (with numerical problems), Hot wire Anemometer & Wind tunnels. **7 Hrs**

Reference Books:

1) Batchelor G, “An introduction to fluid dynamics”, Cambridge university press 2000.
2) Frank M. White, “Fluid Mechanics”, McGraw Hill India, 8th edition, 2015.
3) S.W. Yuan, Foundation of fluid mechanics, SI Unit Edition 1988.
4) K Muralidhar & G. Biswas, “Advanced Engineering Fluid Mechanics”, 2nd edition, Narosa Publisher, 2013.
5) Dr. R.K.Bansal, “A text book of Fluid Mechanics and Hydraulic machines”, 9th Edition, Laxmi Publications, 2005.

21UMEE625	Tool Design Engineering	(3-0-0) 3

Contact Hours: 39

Course Objectives: The objectives of this course are to make the student to learn:

1. Tools for sheet metal component manufacturing and plastic components manufacturing
2. Methods of locating and clamping work pieces while machining
3. Design of Jigs & Fixtures
4. Design of press tools for sheet metal parts manufacturing
5. Design of moulds for plastic parts manufacturing

Course outcomes (Cos): At the end of the course Students will be able to

Description of the Course Outcome: At the end of the course the student will be able to:		**Mapping to POs(1-12)/ PSOs (13,14)**		
		Substantial Level (3)	**Moderate Level (2)**	**Slight Level (1)**
CO-1	Explain the basic concepts of press tool principles and parameters.	1	-	-
CO-2	Illustrate the method of locating and clamping of work pieces.	-	1	-
CO-3	Illustrate the working of drill jigs, mould, press tools and milling fixtures.	-	1	-
CO-4	Draw the strip lay out as related to press tools.	-	1	-
CO-5	Design press tools, jigs, fixtures, and moulds with sketches and drawings.	1	3	2
CO-6	Calculate the parameters required for designing the tools.	1	-	-

POs/PSOs	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**
Mapping Level	2.5	1	2	-	-	-	-	-	-	-	-	-	-	-

Prerequisites: Nil

Course Contents:

Unit - I

Introduction to tool design: Tooling, requirements of a tool designer, General tool design procedure, Drafting and Design techniques, Tool Making practice,

Locating and clamping methods: Introduction, Basic principles of location, Locating methods and Locator pins/plugs, Basic principles of clamping, Types of clamps. **7 Hrs**

Unit - II

Design of drill Jigs: Introduction, Need and advantages of jig, Types of drill jigs- Latch/leaf jig, Plate jig, Channel jig, Box jig, Tumble jig, Post jig, Indexing jig, Drill bush & types, Design of drill jig for the given component. **7 Hrs**

Unit - III

Design of Fixtures: Introduction, Need and advantages of fixtures, Types of fixtures- Vise fixture, Milling fixture, Lathe fixture, Boring fixture, Broaching fixture, Grinding fixture. **7 Hrs**

Unit - IV

Design of sheet metal Blanking and Piercing Dies: Introduction, Die cutting operations, Power presses, press terminology, Cutting action in punch and die operation, Die clearance, Cutting force and Press force calculation, Types of Press tools- Progressive, Compound, Combination, Inverted dies, Die design fundamentals, Blanking and Piercing die design construction, Strip layout, Economy factor, Design exercises on blanking and piercing dies for simple components. **9 Hrs**

Unit – V

Design of Bending and Drawing Dies: Introduction, Bend allowance-formula, Spring back, Methods to overcome spring back, Blank length calculation, Bend force calculation, Principle of V bending- Air bending and bottoming out, Edge bending, U- bending, Drawing Dies, Drawing operations, Metal flow, Variables affecting metal flow, Determination of blank size and drawing force, Single action and double action draw dies.

Introduction to Design of Moulds: Moulding process, Types of Plastics- Thermoplast and Thermoset resins, Classification of moulding- Injection moulding, Compression moulding, Details of Injection Moulding Tool (single cavity, two cavity mould). **9 Hrs**

Assignments: To prepare designs on the following as Term Work sheets:
1) Jig Design **2)** Fixture Design **3)**Press Tool Design

Reference Books:

1) C. Donaldson, G.H.LeCain, V.C. Goold, “Tool design”, 3rd Edition, Tata McGraw Hill Pubication.1976.
2) M H A Kempster, “Introduction to Jig and Tool Design”, ELBS, 1974.
3) J.R. Paquin & R.E. Crowley, “Die Design Fundamentals”, Industrial Inc Press
4) R.G.W. Pye; “Injection Mould Design”, 3rd Edition, Godwin Books, 1983.

21UMEE626	Industry 4.0 & Artificial Intelligence	(3-0-0) 3

Contact Hours: 39

Course Learning Objectives (CLOs): The objectives of this course are to make the student to learn:

1. To present a problem oriented in depth knowledge of Industry 4.0 & Artificial Intelligence
2. To address the underlying concepts, methods and application of Industry 4.0 & Artificial Intelligence

Course Outcomes (COs):

Description of the Course Outcome: At the end of the course the student will be able to:		Mapping to POs(1-12)/ PSOs (13,14)		
		Substantial Level (3)	Moderate Level (2)	Slight Level (1)
CO-1	Develop real life IIoT applications using hardware and software.	1	2	-
CO-2	Explain various IIoT Layers and their relative importance.	-	1,2	-
CO-3	Realize the importance of Data Analytics in IIoT	-	1,2	-
CO-4	Identify appropriate representation & algorithm for an AI problem domain.	-	1,2	-
CO-5	Explain various learning techniques to solve AI problems.	-	1,2	-

POs/PSOs	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Mapping Level	2.2	2	-	-	-	-	-	-	-	-	-	-	-	-

Pre requisites: Nil

Course Contents:

Unit - I

Industry 4.0: Globalization, the Fourth Revolution, LEAN Production Systems 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 **8 Hrs**

Unit - II

IIoT-Introduction, Industrial IoT: Business Model and Referece Architerture: IIoT-Business Models, Industrial IoT- Layers: IIoT Sensing, IIoT Processing, IIoT Communication, IIoT NetworkingBig Data Analytics and Software Defined Networks, Machine Learning and Data Science. **8 Hrs**

Unit - III

Industrial IoT: Security and Fog Computing - Cloud Computing in IIoT, Fog Computing in IIoT, Security in IIoT.

Industrial IoT- Application Domains: Oil, chemical and pharmaceutical industry, Applications of UAVs in Industries, Real case studies: Milk Processing and Packaging Industries, Manufacturing Industries. **7 Hrs**

Unit - IV

Introduction to Artificial Intelligence: Applications- Games, theorem proving, natural language processing, vision and speech processing, robotics, expert systems. AI techniques- search knowledge, abstraction.

State space search; Production systems, search space control: depth-first, breadth-first search. Heuristic search - Hill climbing, best-first search, branch and bound. Problem Reduction, Constraint Satisfaction End, Means-End Analysis. **8 Hrs**

Unit - V

Predicate Logic: unification, modus pones, resolution, dependency directed backtracking. Rule based Systems: forward reasoning, conflict resolution, backward reasoning, use of no backtracks. Structured Knowledge Representation: semantic net slots, exceptions and default frames, conceptual dependency, scripts.

Introduction to NLP: Basics of Syntactic Processing, Basics of Semantic Analysis, Basics of Parsing techniques, context free and transformational grammars, transition nets, augmented transition nets, Shanks Conceptual Dependency, Scripts ,Basics of grammar free analyzers, Basics of sentence generation, and Basics of translation. **8 Hrs**

Reference Books:

1) Adastair Gilchrist, “Industry 4.0: The Industrial Internet of Things”, 2017.
2) D. W. Patterson, “Introduction to AI and Expert Systems”, PHI, 1992.
3) Sabina Jeschke, Christian Brecher, Houbing Song, Danda B. Rawat, “Industrial Internet of Things: Cyber manufacturing systems”, Springer, 2017.
4) E. Rich and K. Knight, “Artificial intelligence”, 2nd edition, McGraw Hill, 1992.
5) N.J. Nilsson, “Principles of AI”, Narosa Publ. House, 2000.
6) Robin R Murphy, “Introduction to AI Robotics”, PHI Publication, 2000
7) R. J. Schalkoff, “Artificial Intelligence - an Engineering Approach”, McGraw Hill Int. Ed., Singapore, 1992.
8) George Lugar, “AI-Structures and Strategies for and Strategies for Complex Problem solving”, 4th edition, Pearson Education, 2002.

21UMEE627	Turbo Machines	(3-0-0) 3

Contact Hours: 39

Course Learning Objectives (CLOs): The objectives of this course are to make the student to learn:

1. Concepts and construction of turbo machine.
2. Euler's turbine equation degree of reaction, and terms related to performance of turbo machines.
3. Velocity diagrams for turbines and pumps and compressors and evaluate performance parameters.
4. General mechanisms for flow through passages

Course Outcomes (COs):

Description of the Course Outcome: At the end of the course the student will be able to:		**Mapping to POs(1-12)/ PSOs (13,14)**		
		Substantial Level (3)	**Moderate Level (2)**	**Slight Level (1)**
CO-1	Explain basic terms and concepts of turbo machines.	-	1	-
CO-2	Derive Euler equation for turbo machines with velocity triangles.	-	1,2	-
CO-3	Analyze different performance parameters and characteristic curves of water turbines	-	1,2	3
CO-4	Explain the effect of exit blade angles on the performance of power absorbing machines and their characteristics.	-	1,2	-
CO-5	Analyze different performance parameters of steam turbines and nozzles.	1,2	-	3

POs/PSOs	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**
Mapping Level	2.2	2.3	1	-	-	-	-	-	-	-	-	-	-	-

Pre requisites: Basic Thermodynamics concepts, Fluid Mechanics

Course Contents:

Unit - I

Introduction: Classification of Turbo machines, Positive displacement machines and comparison, Static & stagnation properties- efficiencies of expansion & compression processes, Dimensional analysis concern to turbo machines specific speed and its significance in the design of Turbo machines (with numerical problems). **6L+2T Hrs**

Unit - II

Energy Exchange in a Turbo machine: Euler's equation for a Turbo machine Impulse & Reaction machines- Axial flow and radial flow machines- utilization factor, degree of reaction & efficiencies of Turbo machines significance of blade discharge angle in turbo machines (with numerical problems).

6L+2T Hrs

Unit - III

Hydraulic Turbines: Classification of hydraulic turbines- Pelton wheel -Francis turbine- Kaplan turbine .Draft tubes. Cavitation, characteristic curves.

5L+2T Hrs

Unit – IV

Centrifugal Pumps: Main Parts of centrifugal pump, basic terms and definitions, work done, minimum speed for starting centrifugal pump, Classifications- Performance characteristics of centrifugal pumps. Multistage pumps characteristic curves.

Centrifugal Blowers & Compressors: Centrifugal blower - types- size & speed- vane shape & efficiency- vane shape & stresses- vane shape & characteristics- actual performances characteristics- slip.

6L+1T Hrs

Unit - V

Flow Through Nozzles & Blade Passages: Steady flow through nozzles- area changes- effect of friction- characteristics of converging- diverging nozzles (with numerical problems).

Steam and gas Turbines: Impulse turbines, Staging - expression for work done in a 2 stage velocity compounded turbine- effect of blade & nozzle losses- Reaction staging- reheat factor- performance characteristics, problems using Mollier's chart & introduction to gas turbines. **7L+2T Hrs**

Reference Books:

1) V Kadambi & Manohar Prasad, "Energy conversion". vol 3,Turbomachinery, Tata McGraw Hill, 2008.
2) D. G. *Shepherd*, "Principles of Turbo machinery", The Macmillan Company, 1964.
3) M.S. Govindgouda and Dr,A.M. Nagaraj "Text book of Turbo machines", 5th Edition 2015.
4) B U Pai "Turbo machines" Wiley Publication, 2018.
5) R.K. Bansal "A text book of fluid mechanics and hydraulic machines", Ninth edition, Laxmi publication New Delhi, 2016.
6) Dixon S.L, "Fluid Mechanics & Thermodynamics of Turbo machinery", 5th edition, Elsevier, 2005.

21UMEE631 Introduction to Composites Materials (3-0-0) 3

Contact Hours: 39

Course Learning Objectives (CLOs): The objectives of this course are to make the student to learn:

1. composite properties including longitudinal and lateral moduli, Poisson's ratio, and shear modulus
2. To determine the generalized stiffness and compliance matrix relating in plane stresses to strains for a composite layer assuming plane stiffness
3. Powder metallurgy applications & know what are surface treatments for materials

Course Outcomes (COs):

Description of the Course Outcome: At the end of the course the student will be able to:		**Mapping to POs(1-12)/ PSOs (13,14)**		
		Substantial Level (3)	**Moderate Level (2)**	**Slight Level (1)**
CO-1	Explain the basic terms and concepts of composite materials.	-	1, 4	3
CO-2	Use generalized Hooks law for evaluating stiffness and compliance matrix for different conditions	3	4	1
CO-3	Evaluate mechanical properties of composite materials.	3	4	1
CO-4	Explain fabrication and machining methods of composite laminates.	-	4	2, 3
CO-5	Discuss the defects in composite laminates, and applications of composites in various fields.	-	4	2

POs/PSOs	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**
Mapping Level	1.3	1	2	2	-	-	-	-	-	-	-	-	-	-

Prerequisites: Nil

Course Content:

Unit - I

Introduction to Composite Materials: Definition, Classification, Types of matrices material and reinforcements, Characteristics & selection, Fiber composites, laminated composites, Particulate composites, Prepegs, and sandwich construction. Metal Matrix Composites: Reinforcement materials, Types, Characteristics and selection, Applications**.** **8 Hrs**

Unit - II

Macro Mechanics of a Lamina: Hooke's law for different types of materials, Number of elastic constants, Derivation of nine independent constants for orthotropic material, Two - dimensional relationship of compliance and stiffness matrix. Hooke's law for two-dimensional angle lamina, engineering constants - Numerical problems. Invariant properties. Stress-Strain relations for lamina of arbitrary orientation, Numerical problems. **9Hrs**

Unit - III

Micro Mechanical Analysis of a Lamina: Introduction, Evaluation of the four elastic moduli, Rule of mixture, Numerical problems. Experimental Characterization of Lamina- Elastic Moduli and Strengths. *Failure Criteria:* Failure criteria for an elementary composite layer or Ply, Maximum Stress and Strain Criteria, Approximate strength criteria, Inter-laminar Strength, Tsai-Hill theory, Tsai, Wu tensor theory, Numerical problem, practical recommendations. **8 Hrs**

Unit - IV

Manufacturing and Testing: Layup and curing - open and closed mould processing, Hand lay-up techniques, Bag moulding and filament winding. Pultrusion, Pulforming, Thermoforming, Injection moulding, Cutting, Machining, joining and repair. **7 Hrs**

Unit - V

NDT tests: Purpose, Types of defects, NDT method - Ultrasonic inspection, Radiography, Acoustic emission and Acoustic ultrasonic method.

Applications: Aircrafts, missiles, Space hardware, automobile, Electrical and Electronics, Marine, Recreational and sports equipment-future potential of composites. **7 Hrs**

Reference Books:

1) Autar K. Kaw, “Mechanics of composite materials” CRC press, 2nd Edition, 2006.
2) Robert M. Jones, “Mechanics of Composite Materials” Taylor & Francis, 1998.
3) Krishan K Chawla, “composite materials” Springer, 2nd edition, 1998.

21UMEE632	Non-Traditional Machining	(3-0-0) 3

Contact Hours: 39

Course Learning Objectives (CLOs): The objectives of this course are to make the student to learn:

1. Various concepts related to modern machining processes & their applications.
2. The differences between conventional and non-conventional machining processes.
3. Functional understanding of non-traditional manufacturing equipment.
4. Various process parameters and their influence on performance and their applications.

Course outcomes (COs):

Description of the Course Outcome: At the end of the course the student will be able to:		**Mapping to POs (1-12)/ PSOs (13,14)**		
		Substantial Level (3)	**Moderate Level (2)**	**Slight Level (1)**
CO-1	Enumerate need of non-traditional machining processes and explain Ultrasonic machining process.	1	2,3	-
CO-2	Explain working principles of Chemical and electro-chemical machining processes.	1	2,3	-
CO-3	Discuss working principle and various aspects of EDM process.	1	2,3	-
CO-4	Explain principles of Abrasive Jet Machining & Plasma Arc Machining.	1	2,3	-
CO-5	Describe working principles of LBM & EBM processes.	1	2,3	-

POs/PSOs	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**
Mapping Level	3	2	2	-	-	-	-	-	-	-	-	-	-	-

Prerequisites: Nil

Course contents:

Unit - I

Introduction: Introduction to Non-traditional machining, Need for and Comparison between traditional and non-traditional machining, Classification of Non-traditional machining processes based on nature of energy employed in

machining, selection, Advantages, limitations and applications of non-traditional machining processes.

Ultrasonic Machining (USM): Introduction, Equipment and material process, Effect of process parameters: Effect of amplitude and frequency, Effect of abrasive grain diameter, effect of slurry, tool & work material. Process characteristics: Material removal rate, tool wear, accuracy, surface finish, applications, advantages & limitations of USM. **7 Hrs**

Unit - II

Electro Chemical Machining (ECM): Introduction, Principle of electro chemical machining, ECM equipment, elements of ECM operation, Chemistry of ECM. ECM Process characteristics: Material removal rate, accuracy, surface finish. Process parameters: Current density, Tool feed rate, Gap between tool & work piece, velocity of electrolyte flow, type of electrolyte, its concentration temperature, and choice of electrolytes. ECM Tooling: ECM tooling technique & example, Tool & insulation materials. Applications ECM: Electrochemical grinding and electrochemical honing process. Advantages, disadvantages and application of ECG, ECH.

Chemical Machining (CHM): Elements of the process, Resists (maskants), Etchants. Types of chemical machining process-chemical blanking process, chemical milling process. Process characteristics of CHM: material removal rate, accuracy, surface finish, advantages, limitations and applications of chemical machining process. **9 Hrs**

Unit - III

Electrical Discharge Machining (EDM): Introduction, mechanism of metal removal, EDM equipment: spark erosion generator (relaxation type), dielectric medium-its functions & desirable properties, electrode feed control system. Flushing types; pressure flushing, suction flushing, side flushing, pulsed flushing. EDM process parameters: Spark frequency, current & spark gap, surface finish, Heat Affected Zone. Advantages, limitations & applications of EDM, Electrical discharge grinding, Traveling wire EDM. **8 Hrs**

Unit - IV

Abrasive Jet Machining (AJM): Introduction, Equipment and process of material removal, process variables: carrier gas, type of abrasive, work material, stand-off distance (SOD). Process characteristics-Material removal rate, Nozzle wear, accuracy & surface finish. Applications, advantages & limitations of AJM.

Plasma Arc Machining (PAM): Introduction, non-thermal generation of plasma, equipment mechanism of metal removal, Plasma torch, process parameters, process characteristics. Safety precautions. Safety precautions, applications, advantages and limitations. **8 Hrs**

Unit - V

Laser Beam Machining (LBM): Introduction, generation of LASER, Equipment and mechanism of metal removal, LBM parameters and characteristics, Applications, Advantages & limitations.
Electron Beam Machining (EBM): Introduction, Principle, equipment and mechanism of metal removal, applications, advantages and limitations**.**

7 Hrs

Reference Books:

1) P.C Pandey and H S Shah, “Modern Machining Process”, McGraw Hill Education India Pvt. Ltd., 2000.
2) Production technology HMT McGraw Hill Education India Pvt. Ltd 2001
3) Dr. Amitabha Bhattacharyya, “New Technology”, The Institute of Engineers India, 2000.
4) M. Adithan, “Modern Machining process”, 2002.
5) Gary F. Benedict, “Nontraditional manufacturing processes”, Marcel Dekker, Inc. 1987.

21UMEE633	Cryogenics	(3-0-0) 3

Contact Hours: 39

Course Learning Objectives (CLOs): The objectives of this course are to make the student to learn:

1. Principles of cryogenics and applications.
2. Low temperature properties of engineering materials.
3. Gas separation and gas purification and production of ultralow temperature.
4. Vacuum technology cryogenics insulation fluid storage and applications.

Course outcomes (COs):

Description of the Course Outcome: At the end of the course the student will be able to:		**Mapping to POs(1-12)/ PSOs (13,14)**		
		Substantial Level (3)	**Moderate Level (2)**	**Slight Level (1)**
CO-1	Explain different cryogenic terms, processes and material properties.	1	-	2
CO-2	Discuss various cryogenic systems and thermodynamics of ideal systems.	1,2	-	-
CO-3	Describe the importance of effectiveness of heat exchanger used in cryogenics.	1,2	-	-
CO-4	Illustrate various methods of measurements in cryogenics.	-	1,2,3	-
CO-5	Compare various insulation systems, vacuum pumps and suspension systems.	1,2	-	-
CO-6	Discuss cryogenics applications in the field of food preservation, medicine, super conductors and space technology.	1,2	-	-

POs/PSOs	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**
Mapping Level	2.8	2.5	2	-	-	-	-	-	-	-	-	-	-	-

Prerequisites: Nil

Course Contents:

Unit – I

Introduction and Low temperature properties of engineering materials: Cryogenic Systems. Applications and Areas of Cryogenic Engineering. Mechanical properties, Thermal properties, Electrical properties.

Gas liquefaction Systems: Introduction The thermodynamically Ideal system Production of low temperatures- joule Thomson Effect Adiabatic expansion Liquefaction systems for Air/Nitrogen/Oxygen- Simple Linde -Hampson System, Pre cooled LH System, Claude System, Kapitza System. Comparison of Liquefaction Systems. **8 Hrs**

Unit – II

Gas liquefaction Systems and heat exchanger: Liquefaction Systems for hydrogen, (pre cooled linde-hampson and pre cooled Claude systems),helium liquefaction systems (collin's system and Simon's system) Heat exchanger effectiveness.

Gas separation: Thermodynamics ideal separation system, Principles of gas separation. Linde single column air separation. Linde double column air separation. **8 Hrs**

Unit – III

Gas purification systems: Absorption**,** Adsorption Process and Combined purification method.

Cryogenic refrigeration systems: Ideal Refrigeration system (Isothermal source), Joule Thomson Refrigeration systems, Solvay Refrigerator. Magnetic Refrigeration systems, He3_He4 Dilution refrigerator. **7 Hrs**

UNIT – IV

Measurement systems: Resistance thermometers Thermocouples Thermistors Gas Thermometry. Liquid level sensors, vacuum pumps, Ion Pumps, Diffusion pumps,

Cryogenic Insulation: Heat transfer due to conduction, Evacuated porous insulation powder& Fibers, Opacified powder insulation, Gas filled powders &Fibrous materials, Multilayer super-insulation, Composite insulation.**8 Hrs**

Unit – V

Cryogenic fluid storage and suspension systems: Design of cryogenic fluid storage vessels Inner vessel Outer vessel Insulation Suspension system.

Application of cryogenic systems: Cryogenic applications for food preservation, Biology and Medicines, Super conductive devices, space technology. **8 Hrs**

Reference Books:

1) Mamata Mukhopadhyay, “Fundamentals of Cryogenic Engineering”, PHI publications, 2010.
2) Randal Barron, “Cryogenics Systems”, oxford Press, 1985.
3) Marshall Sitting D.Van Nostrand, “Cryogenics, Research and application co.inc Princeton New Jersy, 1989.
4) Klaus D. Timmerhaus & Thomas M. Flynn, Cryogenic process Engineering, Plenum Press, New York & London, 1989.
5) Thomas M Flynn, Marcel Dekker, Cryogenic Engineering Inc. N.Y.Basal, 1997.

21UMEE634	Alternative Fuels	(3-0-0) 3

Contact Hours: 39

Course Learning Objectives (CLOs): The objectives of this course are to make the student to learn:

1. Basic principles of energy sources.
2. Energy analysis and understanding the basic mechanism of energy transfer such as solar wind biomass and hydrogen energy.
3. Multidimensionality and dependence of variables on performance parameter.
4. Thermal conditions on surfaces and obtain mathematical relations connected to temperature, efficiency and conversion.

Course outcomes (COs):

Description of the Course Outcome: At the end of the course the student will be able to:		**Mapping to POs(1-12)/ PSOs (13,14)**		
		Substantial Level (3)	**Moderate Level (2)**	**Slight Level (1)**
CO-1	Outline the need for energy, sources, scope and their applications.	1	3	-
CO-2	Explain the production methods and properties of liquid fuels for IC engines.	1	2	-
CO-3	Discuss the utilization of solar PV cells for Electric & Hybrid vehicles.	1	2	3
CO-4	Describe the methods of production of gaseous fuels and their properties.	1	1,3	-
CO-5	Explain the impact of using alternate fuels on environment and economy.	1	1,2	7, 8

POs/PSOs	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**
Mapping Level	2.7	2	1.5	-	-	-	1	1	-	-	-	-	-	-

Prerequisites: Nil

Course Contents:

Unit - I

Introduction: Sources of fuels, Need for renewable, sustainable and alternative fuels, Sources of alternative fuels for SI and CI engines, advantages and justification, potential of different fuels, Status of renewable energy in India. Scope of availability of fossil fuel in future. Significance of air fuel ratio and equivalence ratio, proximate and ultimate analysis. Advanced techniques for determining the composition and structure of alternate fuels. Numericals.

Biofuels: Different type's liquid (Alcohols and biodiesels) and gaseous fuels (LPG, CNG, hydrogen, biogas and producer gas), properties and its utilization for SI and CI engines. Comparison between conventional and alternative fuels. **8 Hrs**

Unit - II

Vegetable oils as fuels: Various vegetable oils and their properties, Different methods of using vegetable oils in engines (Blending, preheating and Transesterification and emulsification of Vegetable oils), Production of biodiesels of different origin using conventional and advanced fuel processing methods, Properties of biodiesel in comparison with diesel fuel.

Alcohols as fuels: Production methods of alcohols (Methanol/Ethanol). Properties of alcohols in comparison with gasoline and diesel fuel. Methods of using alcohols in CI and SI engines. **8 Hrs**

Unit - III

Solar Power: Solar cells for energy collection. Storage batteries, layout of solar powered automobiles. Advantages and limitations.

Electric & Hybrid Vehicles: Layout of an electric vehicles, advantages & limitations. Systems components, advantages, I. C. engine and batteries powered vehicles, Drive systems, Batteries and its types (high energy and power density batteries). Vehicles with electrical drive system, Series and parallel HVs. **8 Hrs**

Unit - IV

Gaseous fuels: Production of Biogas and producer gas, Gasifiers, types and its merits and demerits, Properties of gaseous fuels, Factors affecting the gas yield, Properties and its utilization in I. C. engines

Hydrogen as engine fuel: Production methods of hydrogen. Properties of hydrogen, Combustive properties of hydrogen. Advantages of hydrogen as fuel, Hydrogen storage, material difficulties. Problems associated with hydrogen as fuel and solutions. Different methods of using hydrogen in SI and CI engines. Hydrogen storage – safety aspects of hydrogen. **8 Hrs**

Unit – V

Performance and emission characteristics of an I C engine: Influence of fuel properties on the performance and emission characteristics of SI and CI engine operating on biofuels. Dual fuels engine, Advantages of dual fuel engine, Factors affecting the dual fuel engine

Emissions: Emission standards, global warming, regulated and unregulated emission levels, control of emission levels from I C engines. Environmental assessment of alternative fuels, Economic considerations of alternative fuels. **7 Hrs**

Reference Books:

1) Dr. S. Thipse, "Alternate Fuels: Concepts, Technologies and Developments", 1st Edition, Jaico Publishers, 2010.
2) Richard L. Bechtold, "Alternative Fuels Guidebook - Properties, Storage, Dispensing, and Vehicle Facility Modifications", SAE International Publisher, United States, 1999.
3) Michael Frank Hordeski, "Alternative Fuels: The Future of Hydrogen", Third Edition, CRC press, Taylor and Francis publications, 2013.
4) Ganeshan, "Internal Combustion Engines" 2nd edition, Tata McGraw Hill publisher. New Delhi, India.
5) G.D.Rai, "Non-Conventional energy sources", Khanna publications, 6th Edition, India.
6) Richard Folkson, "Alternative Fuels and Advanced Vehicle Technologies for Improved Environmental Performance", 1st Edition, Elsevier – Wood head Publishing Limited publisher.
7) Jan C.J. Bart N Palmeri Stefano Cavallaro, "Biodiesel Science and Technology", 1st Edition, Elsevier – Wood head publishing Limited publisher, 2010.
8) The Biogas Handbook-Science, Production and Applications, Wood head Publishing Limited publisher, 2013.
9) Arthur Wellinger Jerry Murphy David Baxter, "The Biogas Handbook-Science: Production and Applications", 1st Edition, Elsevier – Wood head publishing Limited publisher, 2013.

21UMEE635	Tribology and Bearing Design	(3-0-0) 3

Contact Hours: 39

Course Learning Objectives (CLOs): The objectives of this course are to make the student to learn:

1. Laws of friction, and fluid flow, mechanisms of friction and lubrication friction space, stiction, stick slip, and surface temperature.
2. Various modes of wear: adhesive, delamination, fretting, abrasive, erosive, corrosive and the wear-mechanism maps.
3. Design and applications of sliding contact bearings.
4. Applications of rolling contacts, Magnetic bearing and elimination of leakage using seals.

Course Outcomes (COs):

Description of the Course Outcome: At the end of the course the student will be able to:		**Mapping to POs(1-12)/ PSOs (13,14)**		
		Substantial Level (3)	**Moderate Level (2)**	**Slight Level (1)**
CO-1	Explain laws of fluid flow and different lubrication methods.		1	2
CO-2	Compute power losses and frictional forces in hydrodynamic bearings.	1	2	-
CO-3	Explain different fluid film formation mechanisms in bearings.	-	1	-
CO-4	Analyze pressure distribution around the hydrostatic journal bearing.	1	-	2
CO-5	Discuss different wear mechanisms and advanced bearings and its components.	-	1, 2	-

POs/PSOs	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**
Mapping Level	2.4	1.5	-	-	-	-	-	-	-	-	-	-	-	-

Pre requisites: Nil.

Course Contents:

Unit - I

Introduction: Properties of oil, equation of flow, absolute viscosity, Hagen Poiseullie's law, flow between parallel stationary plates, apparatus for measuring viscosity, factors that affect viscosity. **8 Hrs**

Unit - II

Hydrodynamic Lubrication: Tower's experiments, Petroff's equation, friction forces, power losses in lightly loaded bearings, mechanism of pressure development in an oil film, numericals on Petroff's equation and oil flow through capillary. **8 Hrs**

Unit - III

Reynolds equation in two dimensional flow: idealized journal bearing friction forces, power losses, pivoted shoe bearing, friction forces, power losses, collar thrust bearing with end leakage, thermal equilibrium. **8 Hrs**

Unit - IV

Hydrostatic Lubrication: Application of hydrostatic lubrication, hydrostatic thrust bearing, introduction to hydrostatic journal bearing and numerical. **8 Hrs**

Unit - V

Wear and abrasion: Wear mechanism, Mechanism of wear in elastomers, wear Measurements.

Introduction: Magnetic and foil bearings, seals and types. **7 Hrs**

Reference Books:

1) E.I. Radzimovsky, "Lubrication of Bearings", The Ronold Press Company, 1959.
2) Suhilkumar Srivastava, "Industrial Tribology", S.C. Chand And Company, 2001.
3) B.C Muzumdar, "Lubrication of Bearings", Wheeler Publishers1996.
4) K. Lingaiah, "Design Data Hand book", Vol2, Suma publishers 1984.

21UMEE636	Theory of Elasticity	(3-0-0) 3

Contact Hours: 39

Course Learning Objectives (CLOs): The objectives of this course are to make the student to learn:

1. Basics of stresses, strains, equilibrium, compatibility and governing equations.
2. Solving problems in plane stress, plane strain, torsion and bending.
3. Concepts of three-dimensional problems.

Course Outcomes (COs):

Description of the Course Outcome: At the end of the course the student will be able to:		Mapping to POs(1-12)/ PSOs (13,14)		
		Substantial Level (3)	Moderate Level (2)	Slight Level (1)
CO-1	Discuss the fundamentals of stress, strain and their relations with numerical problems.	1,2	3	12
CO-2	Solve problems in Cartesian co-ordinates using Biharmonic Equation and Airy's Stress Function.	1,2	-	-
CO-3	Solve problems on Thick cylinders & shrink fits using polar coordinates.	1,3	4	-
CO-4	Compute Stress concentration and stresses for various structural members.	1,2	-	3
CO-5	Derive torsional equation for solving problems on circular, non-circular and thin tubes.	1,2	-	-

POs/PSOs	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Mapping Level	3	3	2	2	-	-	-	-	-	-	-	1	-	-

Prerequisites: Nil

Course Contents:

Unit - I

Stress: Definition notation and sign convention of stress; Equilibrium equations; Stress components on an arbitrary plane.

Principle stresses- maximum shear stress, octahedral stresses- boundary conditions. **8 Hrs**

Unit - II

Strain: Definitions – strain - displacement relations - compatibility equations Principal strains.
Generalized Hooke's law; Generalized Hooke's law in terms of engineering elastic constants; strain energy. **8 Hrs**

Unit - III

Two dimensional problems in Cartesian co-ordinates: Plane stress and plane strain conditions- Bi-harmonic equation- Investigation of Airy's stress function for simple beam problems- Solution for cantilever beam under end load and simply supported under uniformly distributed load.
Stress concentration in an infinite plate with circular hole subjected to uniaxial load, General equations in polar co-ordinates: Thick cylinder under pressure – Analysis of shrink fit, Stresses in rotating Hollow and solid discs and cylinders. **8 Hrs**

Unit - IV

Torsion of circular and elliptical bars; Membrane analogy.
Torsion of thin open sections, torsion of thin tubes. **7 Hrs**

Unit - V

Uniqueness theorem - Saint Venant's Principle - Principle of super position - Reciprocal theorem.
Rayleigh - Ritz method; Galerkin method; Reciprocal theorem and Castiglione's theorems. **8 Hrs**

Reference Books:

1) L. S. Srinath, "Advanced Mechanics of solids", 3rd edition, Tata McGraw-Hill book Company, 2009.
2) S. P. Timoshenko and J. N. Goodier, "Theory of Elasticity", 3rd edition- McGraw Hill- New York- 2010.
3) C. T. Wang, "Applied Elasticity" McGraw Hill Book Co., 1953.
4) T. G. Sitharam & L. Govinda Raju, "Applied Elasticity", Interline Publishing, 2008.

21UMEE637	Scientific Computing - I	(3-0-0) 3

Contact Hours: 39

Course Learning Objectives (CLOs): The objectives of this course are to make the student to learn:

1. To improve their ability in solving mathematical problems using Python software
2. To develop skills in handling errors, functions and loops in program, enhance problems solving capability.
3. To emphasize signification of plotting graphs and interpreting the data's in Python software.
4. To gain knowledge in scientific methods and familiarize with application of differential equation and integration to solve engineering problems.

Course Outcomes (COs):

Description of the Course Outcome: At the end of the course the student will be able to:		**Mapping to POs(1,12) / PSO (13,14)**		
		Substantial Level (3)	**Moderate Level (2)**	**Slight Level (1)**
CO-1	Develop program by analyzing problem and handling errors in Python software.	5	1,2	3
CO-2	Use data structures in programming approach.	5	1,2	3
CO-3	Apply function features to develop realistic programs.	5	1,2	3
CO-4	Develop Python Programs using NumPy array and matplotlib for solving problems	5	1,2	3
CO-5	Use various package's and libraries SciPy, ODEINT to solve a mathematical problem.	5	1,2	3

POs/PSOs	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**
Mapping Level	2	2	1	-	3	-	-	-	-	-	-	-	-	-

Prerequisites: Nil

Course Contents:

Unit - I

Introduction: Introduction to Python, Installing Python, Tools for Writing Programs, Using Idle to Write the Program, How to Run the Program, variables, expressions and statements, Reserved Words in Python, Evaluating Standard

Mathematical Functions, Interactive Computing, Exercises. **7 Hrs**

Unit - II

Loops and Lists: While Loops, Lists, Getting Individual Values in a List with Indexes, Negative Indexes, Getting Sublists with Slices, Getting a List's Length with len(), Changing Values in a List with Indexes Implementations with Lists and Loops, Tuples. **8 Hrs**

Unit - III

Functions: Basics of functions, Functions of One Variable, Local and Global Variables, Multiple Arguments, Function Input and Output, Functions as Arguments to Functions, Lambda Functions, Exercises **8 Hrs**

Unit - IV

Array Computing and Curve Plotting: Basic array methods, Reading and writing an array to a file, Polynomials, Linear algebra, Matrices, computation with matrix, dot product, cross product, inverse matrix. **Matplotlib:** Introduction, Matplotlib basics, Contour plots, 3D plots **8 Hrs**

Unit - V

Differential Equations and Integration: The Simplest Case, ordinary differential equation and partial differential equation, Integration and double integration, initial value problems, optimization. **8 Hrs**

Activity Beyond Syllabus: working with simple real-time application in Python software.

Reference Books:

1) Allen B. Downey, "Think Python", 2nd Edition, O'Reilly Publication, 2015.
2) Christian Hill, "Learning Scientific Programming with Python", Cambridge University Press, 2015.
3) Charles Dierbach, "Introduction to Computer Science Using Python", 1st Edition, Wiley India Pvt Ltd, 2015.
4) T.R. Padmanabhan, "Programming with Python", Springer, 2016.
5) Hans Petter Langtangen, "A Primer on Scientific Programming with Python", Springer; 3rd Edition, 2012.

21UMEO641	Smart Materials and Structures	(3-0-0) 3

Contact Hours: 39

Course Learning Objectives (CLOs): The objectives of this course are to make the student to learn:

1. Concept of smart materials and its application
2. Modeling concept in smart materials
3. Fibre optics, piezoelectric sensing and actuation.

Course outcomes (COs):

Description of the Course Outcome: At the end of the course the student will be able to:		Mapping to POs(1-12)/ PSOs (13,14)		
		Substantial Level (3)	Moderate Level (2)	Slight Level (1)
CO-1	Explain basic concepts of smart materials, structures and their characteristics.	1	2	-
CO-2	Model smart materials for various applications.	1	2	-
CO-3	Analyze the properties of smart structures.	1	-	2
CO-4	Describe various fiber optics sensors and their applications.	1	2	-

POs/PSOs	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Mapping Level	3	1.8	-	-	-	-	-	-	-	-	-	-	-	-

Prerequisites: Nil

Course Contents:

Unit - I

Introduction: Introduction of Smart Materials, Piezoelectric Material, Magnetostrictive smart Material, Active Smart Polymer, Shape Memory Alloys, Applications of Smart Material, difference between traditional structure and smart structure. **9 Hrs**

Unit - II

Shape Memory Alloys: Introduction, Phenomenology, and Influence of stress on characteristic temperatures, modelling of shape memory effect. Vibration control through shape memory alloys. **8 Hrs**

Unit - III

Electro rheological and Magneto rheological Fluids: Mechanisms and Properties, Characteristics, Fluid composition and behavior, Discovery and Early developments, Summary of material properties. Applications of ER and MR fluids (Clutches, Dampers, others). **8 Hrs**

Unit - IV

Modelling: Piezoelectric material, modelling of Magnetostrictive material, Modelling of Shape memory Alloys, Smart Actuators, Smart Materials based MEMS, Energy Harvesting, and Concept of Self-Healing. **6 Hrs**

Unit - V

Fibreoptics: Introduction, Physical Phenomenon, Characteristics, Fibre optic strain sensors, Twisted and Braided Fibre Optic sensors, Optical fibres as load bearing elements, Crack detection applications, Integration of Fibre optic sensors and shape memory elements. **8 Hrs**

Reference Books:

1) M. V. Gandhi and B. S. Thompson “Smart Materials and Structures”, Chapmen & Hall, London, 1992.
2) A. V. Srinivasan, D. Michael McFarland “Smart Structures - Analysis and Design”, Cambridge University Press, New York, 2000.
3) Gauenzi, P, “Smart Structures”, Wiley, 2009.
4) Cady, W. G, “Piezoelectricity”, Dover Publication 1950 Publication, 1950.
5) Crawley, E. F, “Intelligent Structures for Aerospace: a technology overview and assessment”, AIAA, 33 (8), 1994, pp. 1689 assessment, AIAA, 33 (8), 1994.

21UMEO642 Introduction to Aircraft Industry & Aircraft Systems (3-0-0) 3

Contact Hours: 39

Course Learning Objectives (CLOs): The objectives of this course are to make the student to learn:

1. Theoretical concepts of aircraft industry overview and aircraft systems.
2. Importance of basics of flight and components of an aircraft and different types.
3. Analytical skills associated with the understanding of basics of flight mechanics.
4. Principles of flights to build aircraft models and to understand the mechanics of flight.

Course outcomes (COs):

Description of the Course Outcome: At the end of the course the student will be able to:		**Mapping to POs(1-12)/ PSOs (13,14)**		
		Substantial Level (3)	**Moderate Level (2)**	**Slight Level (1)**
CO-1	Identify the manufacturing requirements of aircraft industry & global scenario of airline industry.	-	1, 2	-
CO-2	Explain basic components of aircraft and design configurations	-	1	3, 9
CO-3	Discuss different aircraft systems.	1	-	-
CO-4	Analyze principles of flight & its parameters	1,2	3	-
CO-5	Explain basics of flight mechanics.	-	1,2	-

POs/PSOs	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**
Mapping level	2.4	2.3	1.5	-	-	-	-	-	1	-	-	-	-	-

Pre requisites: Nil

Contents:

Unit - I

Aircraft industry overview: Evolution and History of Flight, Types Of Aerospace Industry, Key Players in Aerospace industry, Aerospace Manufacturing, Industry Supply Chain, Prime contractors, Tier 1 Suppliers, Key

challenges in Industry Supply Chain, OEM Supply Chain Strategies, Mergers and Acquisitions, Aerospace Industry Trends, Advances in Engineering/CAD/CAM/CAE Tools and Materials technology, Global and Indian Aircraft Scenario. **8 Hrs**

Unit - II

Introduction to Aircrafts: Basic components of an Aircraft, Structural members, Aircraft Axis System, Aircraft Motions, Control surfaces and High lift Devices, Types of Aircrafts - Lighter than Air/Heavier than Air Aircrafts Conventional Design Configurations based on Power Plant Location, Wing vertical location, intake location, Tail Unit Arrangements, Landing Gear Arrangements. Unconventional Configurations-Biplane, Variable Sweep, Canard Layout, Twin Boom Layouts, Span loaders, Blended Body Wing Layout, STOL and STOVL Aircraft, Stealth Aircraft. Advantages and disadvantages of these Configurations. **8 Hrs**

Unit - III

Introduction to Aircraft Systems: Types of Aircraft Systems. Mechanical Systems. Electrical and Electronic Systems. Auxiliary systems. Mechanical Systems: Environmental control systems (ECS), Pneumatic systems, Hydraulic systems, Fuel systems, Landing gear systems, Engine Control Systems, Ice and rain protection systems, Cabin Pressurization and Air Conditioning Systems, Steering and Brakes Systems Auxiliary Power Unit, Electrical systems: Avionics, Flight controls, Autopilot and Flight Management Systems, Navigation Systems, Communication, Information systems, Radar System. **8 Hrs**

Unit - IV

Basic Principles of Flight: Significance of speed of Sound, Air speed and Ground Speed, Properties of Atmosphere, Bernoulli's Equation, Forces on the airplane, Airflow over wing section, Pressure Distribution over a wing section, Generation of Lift, Drag, Pitching moments, Types of Drag, Lift curve, Drag Curve, Lift/Drag Ratio Curve, Factors affecting Lift and Drag, Center of Pressure and its effects. Aerofoil Nomenclature, Types of Aerofoil, Wing Section- Aerodynamic Center, Aspect Ratio, Effects of lift, Drag, speed, Air density on drag. **8 Hrs**

Unit - V

Basics of Flight Mechanics: Types of Structural members of Fuselage and wing section Ribs, Spars, Frames, Stringers, Longer on, Splices, Stability and Control Degree of Stability- Lateral, Longitudinal and Directional Stability and controls of Aircraft. Effects of Flaps and Slats on Lift Coefficients, Control Tabs, Stalling, Landing, Gliding Turning. **7 Hrs**

Reference Books:

1) A.C Kermode, “Flight without Formulae”, 10th edition, Pearson Education. 2004.
2) A.C Kermode, “Mechanics of Flight”, 11th edition, Pearson Education, 2009.
3) Dave Anderson, “Introduction to Flight”, McGraw Hill Education, 6th edition, 2017.
4) Richard S. Shevell, “Fundamentals of Flight”, Pearson, 2nd edition, 1988.

Note: The assignments for Electives could include the following,

- Seminars from the topics related to Aerospace Industry.
- Report preparation on Aerospace industries which could involve. History and Evolution of major players, the OEM's and in Aerospace and related businesses.

21UMEO643 Design of Renewable Energy Systems (3-0-0) 3

Contact Hours: 39

Course Objectives (CLO's): The objectives of this course are to make the student to learn:

1. Energy sources and need of alternative resources.
2. Principles for design and analysis of Renewable Energy Systems
3. Economics & Environmental of energy conversion in renewable energy systems
4. Renewable energy systems for sustainability

Course Outcomes (CO's):

Description of the Course Outcome: At the end of the course the student will be able to:		**Mapping to POs(1-12)/ PSOs (13,14)**		
		Substantial Level (3)	**Moderate Level (2)**	**Slight Level (1)**
CO-1	Review the need of renewable energy sources for energy requirement	-	1	2
CO-2	Analyze the renewable energy source conversion to different forms of energy	-	2,3	-
CO-3	Design different renewable source for small to large scale applications	-	2,3	7
CO-4	Illustrate the economic viability and sustainability of renewable energy systems	-	-	1,14
CO-5	Compare different renewable energy systems based on techno-economic feasibility	-	2	7,14

POs/PSOs	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**
Mapping Level	1.5	1.7	2	-	-	-	1	-	-	-	-	-	-	1

Pre requisites: Nil

Contents:

Unit - I

Renewable Energy sources: Introduction, Factors affecting the use of renewable energy sources, Global warming and sustainable development.

Renewable energy resources, type's brief energy conversion methods and use pattern of Renewable energy sources in present context in India.

Solar thermal energy systems: Introduction to solar energy, solar radiation data, methods of conversion, different conversion devices Flat plate collectors, concentrating collectors. Principle of design for thermal and other forms of conversion. Principal of solar thermal devices. **8 Hrs**

Unit - II

Solar Direct and Indirect conversion: Direct conversion of solar energy to electrical energy, Performance evaluation of PV cell, modules, Panels and arrays and optimization. Principal of conversion solar energy to electrical by using heat engines.

Wind energy systems (WES): Characteristics of wind, wind power profile, aerodynamics of wind turbines. Basic elements of WES, Siting and sizing of WES, Wind turbine site matching, Applications. **9 Hrs**

Unit - III

Biomass energy systems: Densification, Biomass combustion technology, Thermo-chemical and biochemical conversion to useful energy conversion such as thermal, electrical and mechanical energy. Material, size and types of biogas plants.Bio-fuels importance & production. Principal components of Engine Biomass systems.

Other renewable energy systems & hybridization: Wave, Tidal, OTEC, Geothermal, And Hydrogen: Principal of conversion and its utilization individually and in hybrid form. **9 Hrs**

Unit - IV

Economic and environmental aspects of renewable systems: Economic analysis of renewable sources. Based on the life cycle pollution aspect of renewable systems. **7 Hrs**

Unit - V

Solar thermal energy systems: Wind energy systems (WES): Biomass energy systems design analysis including economic aspects of the renewable systems. Energy, exergy analysis of above systems. **6 Hrs**

Reference Books:

1) G. D. Rai, "Non-Conventional Energy Sources", Khanna Publishers, New Delhi, Dec 2004.

2) S. Rao, Dr. B. B. Parulekar, “Energy Technology”, 3rd edition, Khanna Publishers, Delhi, 2007.
3) Ziyad Salameh, “Renewable Energy System Design”, Academic Press, ELISIEVIR.2014.
4) S. P. Sukatme, “Solar Energy”, TATA McGraw Hill, 1996.
5) Kreith & Goswami, “Solar Energy”, Taylor & Francis 1999.

21UMEO644 Optimization Techniques in Engineering (3-0-0) 3

Contact Hours: 39

Course Objectives (CLO's): The objectives of this course are to make the student to learn:

1. Fundamentals of design process and analysis
2. Formulation of problems relating to design optimization
3. Manufacturing methods and constraints for design interpretation.
4. Multistage decision processes in dynamic programming

Course Outcomes (CO's):

Description of the Course Outcome: At the end of the course the student will be able to:		Mapping to POs(1-12)/ PSOs (13,14)		
		Substantial Level (3)	Moderate Level (2)	Slight Level (1)
CO-1	Review engineering design practices and its revolution	-	2	-
CO-2	Formulate design optimization problems	-	1,2	14
CO-3	Able to solve linear and non-linear approximation solutions	-	1,3,4	7
CO-4	Fine tune optimization of multiple static and dynamic loading problems and solve multi stage decision processes on dynamic programming	-	1,3,4	5,14

POs/PSOs	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Mapping Level	2	2	2	2	1	-	-	-	-	-	-	-	-	1

Prerequisites: Nil

Course Contents:

Unit - I

Engineering Design Practice: Evolution of Design Technology, Introduction to Design and the Design Process, Design versus Analysis, Role of Computers in Design Cycle, Impact of CAE on Design, Numerical Modeling with FEA and Correlation with Physical Tests.

Applications of Optimization in Engineering Design: Automotive, Aerospace and General Industry Applications, Optimization of Metallic and Composite

Structures, Minimization and Maximization Problems, MDO and MOO.

10 Hrs

Unit - II

Optimum Design Problem Formulation: Types of Optimization Problems, the Mathematics of Optimization, Design Variables and Design Constraints, Feasible and Infeasible Designs, Equality and Inequality Constraints, Discrete and Continuous Optimization, Linear and Non Linear Optimization.

Optimization Theory – Fundamental Concepts, Global and Local Minimum, Gradient Vector and Hessian Matrix, Concept of Necessary and Sufficient Conditions, Constrained and Unconstrained Problems, Lagrange Multipliers and Kuhn Tucker Conditions. **10Hrs**

Unit - III

Sensitivity Analysis, Linear and Non Linear Approximations. Gradient Based Optimization Methods – Dual and Direct.

Optimization Disciplines: Conceptual Design Optimization and Design Fine Tuning, Combined Optimization, Optimization of Multiple Static and Dynamic Loads, Transient Simulations, Equivalent Static Load Methods. Internal and External Responses, Design Variables in Each Discipline. **10 Hrs**

Unit - IV

Manufacturability in Optimization Problems: Design For Manufacturing, Manufacturing Methods and Rules, Applying ManufacturingConstraints to Optimization Problems.

Design Interpretation: Unbound Problems, Over Constrained Problems, Problems with No of Multiple Solutions, Active and InactiveConstraints, Constraint Violations and Constraint Screening, Design Move Limits, Local and Global Optimum. **10 Hrs**

Unit - V

Dynamic Programming: Introduction, Multistage decision processes, Pri nciple of optimality, Computational Procedure in dynamic programming, Initial value problem, Examples. **10Hrs**

Reference Books:

1) S.S.Rao, Engineering Optimization: Theory and Practice, John Wiley, 2009
2) JasbirArora, Introduction to Optimum Design, McGraw Hill, 2011.
3) Optimisation and Probability in System Engg - Ram, Van Nostrand.
4) Optimization methods - K. V. Mital and C. Mohan, New age International Publishers, 1999.
5) Optimization methods for Engg. Design - R.L Fox, Addison – Wesley, 1971