Academic Program: UG

Academic Year 2021-22

Syllabus

VII & VIII 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)

Ph: **0836-2447465Fax: 0836-2464638 Web:** www.sdmcet.ac.in

SDM College of Engineering & Technology, Dharwad

It is certified that the scheme and syllabus for VII & VIII 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 2021-22 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 VII 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.
18UMEC700	PC	Mechanical Vibrations	3 - 2 - 0	4	50	100	3	-	-
18UMEC701	PC	Control Engineering	3 - 2 - 0	4	50	100	3	-	-
18UMEE7XX	PE	Program Elective-4	3 - 0 - 0	3	50	100	3	-	-
18UMEO7XX	OE	Open Elective-2	3 - 0 - 0	3	50	100	3	--	--
18UMEL702	PC	Dynamics Lab	0 - 0 - 2	1	50	--	--	50	3
18UMEL703	PC	Major Project Phase-1	0- 0 - 4	2	50	--	--	50	3
18UMEL704	PC	Internship	4 w e e k s	2	50	--	--	50	3
Total			**12 - 4 -6**	**19**	**350**	**400**		**150**	

PC- Program Core, PE-Program Elective, OE- Open Elective and HU- Humanities

Electives

Course code	Elective Courses (PE-4)	Course code	Elective Courses (OE–2)
18UMEE721	Power Plant Engineering	18UMEO731	Introduction To Aircraft Systems
18UMEE722	Design of Heat Exchangers	18UMEO732	Project Management
18UMEE723	Hybrid Vehicle Technology	18UMEO733	Energy Management
18UMEE724	Computational Fluid Dynamics	18UMEO734	Design of Renewable Energy Systems
18UMEE725	Advanced Heat Transfer		
18UMEE726	Heating Ventilation and Air Conditioning		
18UMEE727	Battery and Fuel Cell Technology		

Scheme for VIII 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.
18UMEC800	PC	Fluid Power Control	4 - 0 - 0	4	50	100	3	-	-
18UMEE8XX	PE	Program Elective-5	3 - 0 - 0	3	50	100	3	-	-
18UMEE8XX	PE	Program Elective-6	3 - 0 - 0	3	50	100	3	--	--
18UMEL801	PC	Technical Seminar / Independent study	0 - 0 - 2	1	50	--	--	--	--
18UMEL802	PC	Major Project Phase-2	0- 0 -12	7	50	--	--	50	3
Total			**10 - 0 - 14**	**18**	**250**	**300**	**--**	**50**	**--**

PC- Program Core, PE-Program Elective and OE- Open Elective

Electives

Course code	Elective Courses (PE- 5)	Course code	Elective Courses (PE- 6)
18UMEE821	Operation Research	18UMEE831	Design of Aircraft structures
18UMEE822	Computer Integrated Manufacturing	18UMEE832	Mechanics of Composite Materials
18UMEE823	Organizational Behavior	18UMEE833	Modeling & Simulation of Dynamic Systems
18UMEE824	Industrial Robotics	18UMEE834	Tribology & Bearing Design
18UMEE825	Rapid Prototyping And Rapid Tooling	18UMEE835	Failure Analysis
18UMEE826	Design For Manufacturing And Assembly	18UMEE836	Surface Engineering
18UMEE827	Estimation and Costing in Mechanical Engineering	18UMEE837	Industry 4.0 & Artificial intelligence

VII Semester

18UMEC700	Mechanical Vibrations	(3-2-0) 4

Contact Hours: 52

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

1. Concepts and types of vibrations.
2. Natural frequencies of physical problems.
3. Vibration transmission and methods to reduce vibrations.
4. Numerical methods to solve multi degree 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 concepts and terms in mechanical vibration.	-	-	1
CO-2	Derive mathematical model using Newton's and energy methods for one and two degree of freedom mechanical systems.	1	2	3
CO-3	Evaluate the performance parameters of SDOF systems under forced vibrations and explain working of vibration measuring instruments.	1,2	4	-
CO-4	Formulate mathematical relations for over damped, critical damped and under damped systems.	1,2	3	-
CO-5	Determine natural frequency of multi-degree freedom systems using numerical methods.	-	1, 4, 5	-

POs/PSOs	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Mapping Level	2.4	2.7	1.5	2	2	-	-	-	-	-	-	-	-	-

Prerequisites: Nil.

Contents:

Unit - I

Fundamental of Vibrations: Types, Causes, Effects, Terms in Vibration, Simple Harmonic Motion, Representation of SHM, Combination of SHM, Beats, Fourier series.

Single Degree Freedom System: (Undamped) Natural Frequency, Equivalent System, Parallel Springs, Series Springs, Inclined Springs, Geared System. Energy Method-Energy Principle. **Determination of natural frequency of simple pendulum using simulation software.**

11 Hrs

Unit – II

Single Degree Freedom System: (Damped) Damping Models- Viscous Damping, Structural Damping, Coulomb Damping Single Degree Freedom System with Damping- Over Damped, Under Damped, Critically Damped, Logarithmic Decrement. **7L+2T Hrs**

Unit – III

Single Degree Freedom System – Forced Vibrations: Forced Vibrations with constant Excitation – Steady State Vibrations, Forced Vibrations with Rotating and Reciprocating unbalance, Forced Vibration due to base excitation, Critical Speed of shaft.

Experimental Methods in Mechanical Vibrations: Vibrometers, Accelerometers, Frequency Measuring Instruments, FFT Analyzer.

8L+2T Hrs

Unit – IV

Two Degree Freedom System: Free Vibration of spring Coupled system, Principle mode of vibrations, combined rectilinear and angular modes, Vibration Absorbers, Forced Damped Vibrations. **Determination of natural frequencies of car suspension system using simulation software.**

Continuous System: Vibration of String, Longitudinal Vibration of Bars Lateral Vibration of beams. **9L+2T Hrs**

Unit – V

Numerical Methods: Holzer Method, matrix method & matrix iteration method. Determination of natural frequencies of arrangement of power plant system using simulation software. **7L+4T Hrs**

Text Book:

1) S. S. Rao, “Mechanical Vibrations”, 4th Edition, Pearson Publications, 2009.

Reference Books:

1) Graham Kelly, “Fundamentals of Mechanical Vibrations”, 2nd Edition, McGraw Hill Publications, 2000.
2) G. K. Grover, “Mechanical Vibrations”, TATA McGraw Hill Publications.
3) Seto, “Mechanical Vibrations”, Schaum series publication TATA McGraw Hill Publications.
4) Kelly S. G, “Mechanical Vibrations”, McGraw Hill, 2014.

18UMEC701	Control Engineering	(3-2-0) 4

Contact Hours: 52

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

1. Various mathematical models, methods and limitations of physical models and their mathematical equivalents.
2. Transfer functions of various systems such as thermal, hydraulic and pneumatic systems.
3. Transient and steady state analysis for step, ramp, impulse and sinusoidal inputs.
4. Different types of plots used for analysis of stability of control systems.
5. Types of compensators and controllers.

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 different aspects of control systems and Convert different control systems into mathematical model.	1,2	4	-
CO-2	Obtain transfer functions for block diagrams & signal flow graphs and parameters of time responses to various inputs.	1, 2	4	3
CO-3	Determine the stability of control systems by Routh's stability criterion and root locus plots and plot the graphs using MATLAB.	1, 2, 4	3	-
CO-4	Find the stability of control systems by constructing bode plots and plot the graphs using MATLAB.	1, 2, 4	3	-
CO-5	Determine the stability by constructing Polar, Nyquist Diagrams and plot the graphs using MATLAB.	3, 4	2	1
CO-6	Explain various controllers and compensators.	-	-	1

POs/PSOs	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Mapping Level	2.3	2.8	2	2.6	-	-	-	-	-	-	-	-	-	-

Prerequisites: Nil

Contents:

Unit - I

Introduction: Introduction to control systems, Classification of control systems, open loop & closed loop control systems, elements of Control systems, Characteristics, advantages & disadvantages of control system.

Mathematical modelling: Mechanical systems (translation & rotational), Electrical systems, servos, D.C Motors, A.C Servomotors, Hydraulic (liquid level, Fluid power), Thermal systems, Hydraulic servomotor, Temperature control, Error detectors. **8L+2T Hrs**

Unit - II

Representation of control systems: Block diagram representation of system elements**,** reduction of block diagrams; Signal flow graphs, basic properties, transfer function, Masons gain formula.

System response: First and second order response to step, ramp and sinusoidal inputs, concept of time constant, and speed of response.

10L+2T Hrs

Unit - III

System design: Routh's stability criterion, Root locus Method, Definition, construction of root loci and plot the graphs using Matlab, Graphical relationship for setting system gain. **10 Hrs**

Unit - IV

Analysis using logarithmic plots: Bode attenuation diagrams, stability using Bode diagrams and plot the graphs using Matlab. **8L+2T Hrs**

Unit - V

Frequency response: Polar and rectangular plots for frequency response, analysis using Nyquist Diagrams, Relative stability, gain and phase margin, M and N circles and plot the graphs using Matlab.

Design in frequency Domain: Control action & system compensation: Types of controllers, proportional, integral, and differential, PID Controllers

(basic concepts), series and feedback compensation design of control parameters, Physical devices for system compensation. **10 Hrs**

Text Books:

1) U. A. Bakshi & V. A. Bakshi **“**“Control systems”, 1st Edition, Technical publication Pune, 2010.
2) A. Anandkumar **“**“Control systems”, 2nd Edition, PHI, 2014.

Reference Books:

1) K. Ogatta, “Modern Control Engineering”, 5th edition, Prentice Hall (India), Pearson Education, 2010.
2) I. J. Nagarath and M. Gopal, “Control systems Engineering”, 5th edition, New Age International Publishers, 2010.
3) B. C. Kuo, “Automatic Control Systems”, 8th edition, Prentice Hall (India), 2010.
4) Schaum’s series, “Feedback Control Systems”, McGraw Hill, 2001.

18UMEL702	Dynamics Lab	(0-0-2) 1

Contact Hours: 26

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

1. Balancing of rotating masses whirling of shafts, SDOF systems Concept of governors and their characteristics.
2. Principles of strain gauges and photo elasticity.
3. Importance of Pressure distribution around journal bearing.
4. Effect of unbalance in machinery & method of balancing of rotary and reciprocating forces.
5. Concept of gyroscope and gyroscopic effect in automobiles. Aero planes & ships.

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	Balance rotating masses in single plane and multi planes.	3	4	-
CO-2	Conduct the experiment on gyroscope to verify gyroscope equation.	-	4	-
CO-3	Conduct the experiments using strain gauges and photo elastic bench to compute stresses and strains.	-	4	-
CO-4	Determine theoretical and experimental natural frequencies of various SDOF vibrational systems.	-	3	-
CO-5	Evaluate the performance of different governors.	-	4	-

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

Prerequisites: Nil

Contents:

Part A

1. Experiments on Balancing of Rotating masses in single and multiple planes.
2. Experiments on Porter Governors.
3. Experiments on Whirling of shafts.
4. Experiments on single degree of freedom vibrating systems.
5. Experiments on strain gauges.
6. Experiments on Photo elastic bench.
7. Experiments on Gyroscope.

PART B

(Dynamic simulation lab – Any two of the below) (Demo)

1. Modeling of crank-rocker, double lever and crank-crank mechanisms using Grashoff's law.
2. Kinematic analysis of slider crank mechanism.- 1 exercise
3. Kinematic analysis of four bar mechanism. - 1 exercise.
4. Static force analysis of slider crank mechanism – 2 exercises.
5. Static force analysis of four bar mechanism – 1 exercise.
6. Dynamic force analysis of slider crank mechanism – 1 exercise.
7. Dynamic force analysis of four bar mechanism – 1 exercise.
8. Modeling of single DOF spring mass system.
9. Modeling of multi DOF spring mass system.

Reference Books:

1. Rattan S. S. "Theory of Machines", 2nd Edition, Tata McGraw Hill Publishing Company Ltd., New Delhi, 2006.
2. Shigley and Uicker, "Theory of Machines and Mechanisms", International edition, McGraw Hill.1995
3. Multi body dynamics tutorials.
4. Dynamic simulation lab manual.

18UMEL703	Major Project Phase - 1	(0-0-4) 2

Contact Hours: 60

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 and solve a problem using basic engineering principles.	1,2	4	1,2
CO-2	Recognize the need and able to design and fabricate the machine parts, components of a system that meets particular requirement.	3	7	6,12
CO-3	Use the software tools to prepare and analyze models or prototypes and conduct simulation using it.	5, 13	2	-
CO-4	Work in teams and communicate effectively for completion of projects in time.	10	8,11,12	-
CO-5	Prepare a report based on their project and present the concept using ppt.	13, 14	9,10,11	-

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

Prerequisites: Nil

Course Contents:

Major project phase-1 in which the students are expected to locate the state of the art technology in his domain of interest by an extensive literature survey and Select a topic from an emerging area relevant to electrical sciences

and/or other relevant branches and define the problem for the project work. The material collection, survey, visits, data collection, preliminary design, analysis etc. is to be done in this phase. The project shall consist of a team of students not more than 4. Each batch shall be assigned with a guide. A committee consisting of minimum 3 faculty members of which guide is a member shall evaluate at the end for CIE. There is a viva voce examination which shall be examined by two internal examiners appointed by COE based on the suggestions by the respective HoD.

18UMEL704	Internship	(4 Weeks) 2

Contact Hours: 4 Weeks

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

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	Study of existing procedures in the organization.	1	13	9
CO-2	Analyze and evaluate the problem in hand.	-	2,13	-
CO-3	Suggest alternative solutions to the problem.	-	6, 12, 13	5, 3, 4
CO-4	Prepare report based on work carried out.	10	-	-

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

Prerequisites: Nil

Contents:

Internship: The students are to undergo internship in Private industries / R&D organizations / Centres of Excellence / Laboratories of Reputed Institutions / Govt. & Semi Govt. organizations, PSUs, construction companies, entrepreneurial organizations, inter departments within the college etc. to get en exposure to the external world for a period of 4 weeks in the summer vacation after VI sem and before start of VII semester. The students are to prepare a report on the internship work carried out. The internal faculty shall monitor the student and award CIE marks. The student shall present his work before a panel of examiners consisting of HoD, Guide and one faculty member during VII semester as final exam. The performance shall be communicated to the CoE office and the same shall reflect in the VII semester grade card.

18UMEE721	Power Plant Engineering	(3-0-0) 3

Contact Hours: 39

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

1. Working of steam power plants used for power generation and their auxiliaries.
2. Thermal power generation through coal and gas turbines.
3. Accessories used in a boiler to enhance efficiency of power generation.
4. Disposal of flue gas effluents and Waste disposal in Nuclear power plants into the environment.
5. Hydroelectric plants, Nuclear power plants in comparison with thermal power plants.
6. Selection of site and economics of power plant.

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	Apply the basic thermodynamic cycle on conventional power plant to improve the power plant efficiency	1, 2	3	-
CO-2	Explain the working of different sections of a thermal power plant	-	1	-
CO-3	Determine preliminary sizing of heat exchanging devices of thermal power plant	-	1,3	-
CO-4	Explain the pollution control strategies in power plant and determine efficiency of hydroelectric power plant	-	2,	1
CO-5	Evaluate the cost of power generation and economic viability of power stations	-	2	1,14

POs/PSOs	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**
Mapping Level	1.8	2.3	2.5	-	-	-	-	-	-	-	-	-	-	1

Pre requisites: Nil.

Contents:

Unit - I

Introduction to power generation: Indian energy Scenario, energy resources used for power generation Conventional sources.

Applied thermodynamics of power generation: Rankine & Brayton cycle/ Regeneration & Reheat power cycle. **9 Hrs**

Unit - II

Conventional power plants: Thermal power plants-Introduction, Layout of Modern steam power plant, Fuel handling, Combustion equipment's, Ash handling, Steam generators. **Gas turbine power plant-** Closed cycle and open cycle plants. **Nuclear Power Plant-** Nuclear fission and chain reaction, types of reactors, PWR, BWR, gas cooled reactor (GCR), Breeder reactor. **Combined Cycles-** steam and gas combined cycle power plant, a combined cycle for Nuclear power plants. Only qualitative discussion. **9 Hrs**

Unit - III

Thermal analysis of heat exchanger equipment in power plant: Boiler condenser, super-heater, economizer, cooling tower calculations. Numerical problems. **6 Hrs**

Unit - IV

Hydroelectric Power plant Merits and demerits of waterpower, Essential elements of a hydroelectric power plant, classification of Hydro-electric power plants. Numerical.

Pollution and its control: Various Pollution from thermal, nuclear power plants and their control strategies. **6 Hrs**

Unit - V

Economics of Power Generations: Conventional power plant economics- Load duration curves, Location of Power plants, Power Plant Economics, Coal-Fueled Electricity Generating Unit. Numerical problems Power plant economics. Numerical problem. **9 Hrs**

Text Book:

1) P. K. Nag, "Power Plant Engineering", 3rd edition, Tata McGraw Hill Publishing Co. Ltd., New Delhi, 2011.
2) S. C. Arora and S. Dumkunadwar, "A course in Power plant Engineering", Dhanpat Rai & Co., (P) Ld., NaiSarak, Delhi. 2011.

Reference Books:

1) M MEL. Wakil, “Power Plant Technology”, McGraw Hill Book-Coy. New York, 2010.
2) R. K. Rajput, “A textbook of Power Plant Engineering”, 4th Laxmi publications (p) Ltd., New Delhi, 2010.

18UMEE722	Design of Heat Exchangers	(3-0-0) 3

Contact Hours: 39

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

1. Significance of heat transfer and applications of heat exchangers.
2. Theory of heat exchangers and their performance analysis based on LMTD and NTU methods.
3. Process of boiling and condensation and the correlation used for the governing process.
4. Design and development of heat exchangers and utilization of heat transfer data available for solving the problems
5. Use of Heat transfer Data Handbook to solve the 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	Classify heat exchangers based on different criteria	-	1,2	-
CO-2	Explain different methods of analysis for heat exchangers.	-	1,2	-
CO-3	Design double pipe, shell & tube type heat exchangers for size and rating.	-	1,2,3	-
CO-4	Evaluate the rate of heat transfer and area for different heat exchangers	-	1,2,3	-
CO-5	Determine size and rate of heat transfer in air heat exchanger and combustion chambers.	-	2,3	-

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

Pre requisites: Nil

Contents:

Unit - I

Introduction to Heat Exchanger Design: Types of heat exchangers and their applications: Flow arrangements and temperature distributions in transfer type of heat exchangers. Overall heat transfer coefficient: - Clean overall heat transfer coefficient, dirt factor, Dirt overall heat transfer coefficient, dirt factors for various process services. Basic design equation. Mean temperature difference Concept: LMTD for parallel flow and counter flow arrangement, correction factor for LMTD for cross flow and multi-pass heat exchangers. Effectiveness-NTU method for heat exchanger design /analysis. Rating and sizing problems**.** **9 Hrs**

Unit - II

Double Pipe Heat Exchangers: Constructional features. Applications, Design Parameters Tube side and shell side film coefficients, cut and twist factor, fin efficiency, overall heat transfer coefficient, mean temperature difference, available surface area, fin geometry, fin height , number of fins, tube side and shell side pressure drop, calculation procedure for the design/analysis of double pipe heat exchanger. **6 Hrs**

Unit - III

Shell and Tube Heat Exchangers: Constructional features. Applications, Correlations for tube side pressure drop and heat transfer coefficients. Pressure drop and heat transfer Coefficient correlations for shell side flow:- Effect of By - pass and leakage. Calculation procedure for Shell and Tube Heat Exchanger:- Heat balance equations; LMTD; Reference temperature calculation; Evaluation of overall heat transfer coefficient, calculation of surface area, calculation of tube side and shell side pressure drops, specifications of other details as per TEMA standards; calculation procedure for 1-2 and 2-4 heat exchanger. **8 Hrs**

Unit - IV

Compact Heat Exchangers: Introduction; Definition of Geometric Terms: Plate fin surface geometries and surface performance data; correlation of heat transfer and friction data; Goodness factor comparisons; specification and Calculation procedure of rating and sizing problems.

Air-Cooled Heat Exchangers: Air as coolant for industrial processes; Custom- built units; Fin-tube systems for air coolers; Fin-tube bundles; Thermal rating; tube side flow arrangement; cooling air supply by fans; cooling air supply in natural draft towers. **10 Hrs**

Unit - V

Furnaces and Combustion Chambers: Introduction; Process heaters and boilers; Heat transfer in furnaces: - Heat source; Heat sink; Refractory surfaces; Heat transfer to the sink; Design methods: - Method of Lobo and Evans; Method of Wilson, Lobo and Hottel; the Orrok-Hudson equation; Wohlenberg simplified method. **6 Hrs**

Text Books:

1) Donald Q. Kern, "Process Heat Transfer" Tata McGraw-Hill, 1997.
2) Necati Ozisik, "Heat Transfer-A Basic Approach" McGraw-Hill International edition, 1985.

Reference Books:

1) Sadik kakac, “Heat exchangers selection, rating and thermal design”, 2nd edition, CRC press 2002.
2) W. M. Kays & A. L. London, "Compact Heat Exchangers", McGraw-Hill co. 1997.
3) Ernst U Schlunder et.al, "Heat Exchanger Design Hand Book", Volumes 2 and 3, Hemisphere Publishing Co. 1983.

18UMEE723	Hybrid Vehicle 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. Explain the basics of electric and hybrid electric vehicles, their architecture, technologies and fundamentals.
2. Explain plug – in hybrid electric vehicle architecture, design and component sizing and the power electronics devices used in hybrid electric vehicles.
3. Analyze various electric drives suitable for hybrid electric vehicles.
4. Discuss different energy storage technologies used for hybrid electric vehicles and their control.
5. Demonstrate different configurations of electric vehicles and its components, hybrid vehicle configuration by different techniques, sizing of components and design optimization and energy management

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 working of IC engines and factors affecting the combustion	-	1	-
CO-2	Discuss different configurations of electric and hybrid vehicles and their parts.	-	1,2	-
CO-3	Describe various aspects of hybrid and electric vehicle drive trains	-	1,2	3
CO-4	Discuss different energy storage technologies and control	-	1,2	-
CO-5	Explain sizing of drive system, components, and pollution aspects	-	2,6, 7	3

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

Prerequisites: Nil

Contents:

Unit - I

Conventional Vehicles: Introduction to conventional internal combustion engines, Basics of vehicle performance, vehicle power source, Power transmission, Fuel economy characteristics of internal combustion engine.

Introduction to Hybrid Electric Vehicles: History of hybrid and electric vehicles, social and environmental importance of hybrid and electric vehicles, Merits and demerits of electric and hybrid vehicles. **8 Hrs**

Unit - II

Basic concept of Electrical and Hybrid vehicles: Hybrid traction, introduction to various hybrid drive-train topologies, Vehicle power plant and transmission characteristics and vehicle performance including braking performance. Basic architecture of hybrid drive train and analysis series drive train. Analysis of parallel, series parallel and complex drive trains and power flow in each case. Basic concept of electric traction and architecture. Topologies for electric drive-train and their analysis, power flow control in electric drive-train topologies. **8 Hrs**

Unit - III

Electric Propulsion Systems: Components used in hybrid and electric vehicles, Electric drives used in HEV/EVs, their classifications and general characteristics. Induction motors, their configurations and optimization for HEV/EVs. Induction motor drives, their control and applications in EV/HEVs. DC Motor drives and their principle of operation and performance including multi-quadrant control. Permanent magnet motors, their configurations and optimization. Permanent magnet motor drives, their control and applications in EV/HEVs. Configuration and control of DC and Induction Motor drives. **8 Hrs**

Unit - IV

Energy Storage: Introduction to Energy Storage Requirements in Hybrid and Electric Vehicles, Battery based energy storage and its analysis and simplified models of battery. Fuel Cell based energy storage and its analysis, Hybridization of different energy storage devices. **7 Hrs**

Unit - V

Sizing the drive system: Matching the electric drive and ICE, Transmission selection and gear step selection. Sizing the propulsion

motor, sizing the power electronics, selecting the energy storage technology.

Air pollution and global warming: Impact of different transportation technologies on environment and energy supply. **8 Hrs**

Reference Books:

1) James Larminie, John Lowry, “Electric Vehicle Technology Explained”, Wiley, 2003.
2) Mehrdad Ehsani, Yimi Gao, Sebastian E. Gay, Ali Emadi, “Modern Electric, Hybrid Electric and Fuel Cell Vehicles: Fundamentals, Theory and Design”, CRC Press, 2004.
3) Iqbal Hussein, “Electric and Hybrid Vehicles: Design Fundamentals”, CRC Press, 2003.
4) R1. Mehrdad Ehsani, Yimin Gao, Ali Emadi, “Modern Electric, Hybrid Electric, and Fuel Cell Vehicles: Fundamentals”, CRC Press, 2010.
5) Sandeep Dhameja, “Electric Vehicle Battery Systems”, Newnes, 2000.
6) John B Heywood, “IC Engine Fundamentals”, International Editions, Automobile Technology Series, McGraw hill, 2010.
7) M. L. Mathur and R. P. Sharma, “I.C. Engines”, Dhanpat Rai & Sons, New Delhi, 2011.

18UMEE724	Computational 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. Governing equations of fluid flow
2. Methods of discretizing the governing equations.
3. Methods of solving discretized equations.
4. Fluid flow problems and solutions using software package.

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	Explain the need, advantages and disadvantages and steps involved in CFD.	-	1	-
CO-2	Derive governing equations of fluid flow and explain the scope and applicability of such equations.	--	1,2	-
CO-3	Discretize governing equations of fluid flow using finite difference/finite volume method.	1,2	-	-
CO-4	Explain Maccormach's and SIMPLE Scheme of solving fluid flow problems.	-	1,2	-
CO-5	Solve set of algebraic equation using numerical methods	-	1,2	-

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

Pre requisites: Nil

Contents:

Unit - I

Introduction to Computational Fluid Dynamics, Advantages, limitations and applications. **CFD solution procedure**: Preprocessing, solving and post processing. **Governing equations** for CFD-Continuity equation.

7 Hrs

Unit - II

Governing equations for CFD momentum equation, Energy equation, Physical boundary conditions, Introduction to Turbulence and *k-ε* turbulence model. **8 Hrs**

Unit - III

Classification of partial differential equations, general behavior of different classes of partial differential equations, well posed problems.

CFD techniques: Discretisation of governing equations by FDM, converting governing equations to algebraic equation system, implicit and explicit approaches. **8 Hrs**

Unit - IV

Discretisation of governing equations by FVM, converting governing equations to algebraic equation system, implicit and explicit approaches,

Numerical solution of algebraic equations: direct and iterative methods, Thomas algorithm, Jacobi and Gauss-Siedel methods. **8 Hrs**

Unit - V

Central difference and upwind schemes applied to 1-D situation involving convection and diffusion terms, Maccormack's technique applied to unsteady 2-D inviscid flow, pressure velocity coupling (SIMPLE scheme applied to incompressible viscous flow).

CFD solution analysis: Consistency, stability, convergence, accuracy and efficiency, sources of solution errors, verification and validation. **8 Hrs**

Text Book:

1) Anderson, J. D. Jr., "Computational Fluid Dynamics-The Basics with Applications", McGraw-Hill, New York, 1995.

Reference Books:

1) Suhas V. Patankar, "Numerical Heat Transfer and Fluid Flow", Taylor & Francis, 2012.
2) Jiyuan Tu, Guan Heng Yeoh, and Chaoqun Liu, "Computational Fluid Dynamics: A Practical Approach", Butterworth-Heinemann, 2008.
3) J.C. Tannehill, D. A. Anderson and R.H. Pletcher, "Computational Fluid Mechanics and Heat Transfer", 2nd Edition, Taylor & Francis, 1997.

18UMEE725	Advanced Heat Transfer	(3-0-0) 3

Contact Hours: 39

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

1. Heat transfer concepts for finned systems,
2. Heat transfer concepts for turbulence flows, and high-speed flows.
3. Thermal analysis and sizing of heat exchangers and to learn the heat transfer coefficient for compact heat exchanges.
4. The numerical techniques to handle heat transfer problems

Course Outcomes (COs):

Description of the Course Outcome: At the end of the course the student will be able to:		Mapping to POs(1-4)		
		Substantial Level(3)	**Moderate Level(2)**	**Slight Level(1)**
CO-1	Summarize physics and mathematical treatment of advanced topics of heat transfer.	-	1	2
CO-2	Apply principles of heat transfer to develop mathematical models for fins.	-	1,2,3	--
CO-3	Solve 2D and 3D heat conduction problems using mathematical functions and charts.	-	1, 2, 3	--
CO-4	Solve free and forced convection problems with proper boundary conditions.	-	1,2	-
CO-5	Use the concepts of radiation heat transfer for enclosure analysis.	-	1,2	

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

Prerequisites: Nil

Content:

Unit - I

Introduction and one-dimensional heat transfer: The differential equation of heat conduction, heat generation, two dimensional steady state heat conduction, unsteady state processes, extended surfaces- fins of uniform cross section and non-uniform cross sections, Thermal resistance networks and applications. Numerical heat Transfer: Numerical techniques for solving heat conduction problems, the finite difference method for steady state situations, the finite difference method for unsteady state situations, Controlling Numerical Errors, problems. **9 Hrs**

Unit - II

Thermal radiation: Basic concepts and laws of thermal radiation, the shape factor, Eradiant heat exchange in enclosures ,black and Grey surfaces ,radiation shields and Radiation Effect on temperature measurements. Radiation properties of participating Medium, Emissivity and absorbivity of Gases and Gas Mixtures, Heat transfer from the Human Body problems. **6 Hrs**

Unit - III

Analysis of Convection Heat Transfer: Boundary layer fundamentals evaluation of convection heat transfer coefficient, Analytical solution for laminar boundary layer flow over a flat plate ,Approximate integral boundary layer analysis, Analogy between momentum and heat transfer in turbulent flow over a flat surface, Reynolds Analogy for Turbulent Flow Over Plane Surfaces, Mixed Boundary Layer, Special Boundary Conditions and High-Speed Flow. **8 Hrs**

Unit - IV

Natural convection: Introduction, Similarity Parameters for Natural Convection, Empirical Correlation for Various Shapes, Rotating Cylinders, Disks, and Spheres, Finned Surfaces. Heat transfer by forced convection: Introduction, Analysis of Laminar Forced Convection in a Long Tube, Correlations for Laminar Forced Convection, Analogy Between Heat and Momentum Transfer in Turbulent Flow, Empirical Correlations for Turbulent Forced Convection, Heat Transfer Enhancement and Electronic-Device Cooling, Flow Over Bluff Bodies , Packed Beds, Free Jets. **9 Hrs**

Unit - V

Heat exchangers: Basic concepts, types of heat exchangers, Analysis of heat exchangers, Counter-Flow Heat Exchangers, Multipass and Cross-Flow Heat Exchangers, Use of a Correction Factor , Selection of Heat Exchangers such as Heat Transfer Rate ,Cost ,Pumping Power, Size and Weight ,Type, Materials, Other Considerations, Compact Heat Exchangers. Heat Exchangers for multi phaseflow. **7 Hrs**

Reference Books:

1) Ozisik M.N., “Heat Transfer – A Basic Approach”, 1st edition, McGraw-Hill Publications, 1985
2) Holmon J. P, “Heat Transfer “, McGraw-Hill Publications, 6th Edition.
3) Frank Kreith, “Principles of Heat Transfer”, 7th Edition.Thomson Publications,
4) Yunus A Cengel, “Heat Transfer- A practical Aproach”, 2nd edition, McGraw-Hill Publications.2002.

18UMEE726 Heating ventilation and air conditioning (HVAC) (3-0-0) 3

Contact Hours: 39

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

1. The thermodynamic cycle employed in of air-conditioning
2. Properties of air and ventilation in building and its significance
3. The types and working of air-conditioning systems
4. Heating and cooling load calculation for thermal comfort in building
5. Fluid flow and duct design for air conditioning system

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 thermodynamics of vapor compression cycle	-	1,2	-
CO-2	Calculate properties of air through equations and psychrometric chart	1,2	-	-
CO-3	Explain heating, and ventilation of different air conditioning systems	1,2	-	-
CO-4	Determine cooling load on the air conditioning system	-	1,3	-
CO-5	Calculate insulation thickness, duct size and list the noise control strategies for A/C systems	-	1,2	-

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

Pre-requisites: Nil

Contents:

Unit - I

Introduction: Review of vapor compression refrigeration cycles, T-S and PH charts, refrigerants, and components

Psychrometry: Properties and relations Psychrometric processes Winter air conditioning system and summer air conditioning system and year around air condition system psychrometric chart. **8 Hrs**

Unit - II

Ventilation and infiltration factors affecting thermal comfort, comfort charts, indoor air quality, outdoor design conditions, natural and mechanical ventilation, air distribution devices.

Heating systems: Warm air, hot water and steam heating systems, panel and infrared heating system. **8 Hrs**

Unit - III

Cooling load calculation for design of air conditioning systems heat sources, heat loads in building, design of air conditioning systems, bypass factor effective sensible heat factor cooling coils and dehumidifying air washers and numericals **8 Hrs**

Unit - IV

Air conditioning systems: Central, Unitary and district air conditioning systems, all water, all air, air-water systems factory air conditioning

Insulation for air conditioning systems: desired properties, factors and types of insulating materials. Heat transfer through insulation, economical thickness, selection of insulating material **8 Hrs**

Unit - V

Fluid flow and duct design for air conditioning systems: Pressure loss duct sections, distribution and design, air distribution and ventilation systems, temperature gradients Noise control in air conditioning systems. **7 Hrs**

Reference Books:

1) Arora and domkundwar, dhanpat rai and sons, “A course on Refrigeration and air conditioning”, 2018.
2) Manohar Prasad, “Refrigeration and air conditioning”, Newage international (P) Limited, publishers 2006.
3) Kreider, Peter S Curtiss, “Heating and cooling of building”, principals and practice of energy efficient design, Jan F CRC Press 2018.
4) ASHRAE hand book (HVAC systems)
5) Stocker W.F and Jones J W. “Refrigeration and air conditioning”, Mc Graw hill 1982.
6) ASHRAE, “Air conditioning System Design manual”, 2nd Edition

18UMEE727 Battery and Fuel Cell 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. Significance of fuel cells in present energy context of India
2. Working of different batteries
3. Working of different fuel cell and thermodynamics
4. Hydrogen production and storage methods

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 energy scenario and fuel cells as future source of power	-	1	7
CO-2	Describe the working of primary and secondary types of batteries	-	1, 2	6
CO-3	Explain the working principles of fuel cells.	-	1	7
CO-4	Evaluate efficiency and thermodynamic parameters related to fuel cells.	1	2	7
CO-5	Describe different methods of production and storage of hydrogen for fuel cells.	-	1	6, 7

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

Prerequisites: Nil

Contents:

Unit - I

Indian energy scenario , sector wise energy patterns, need for alternate sources of energy, fuel cell as an alternate sources of energy pros and cons, brief historical background of fuel cells and batteries , basic working principle and comparison of fuel cell and batteries , international and national status of fuel cell development and application. Fuels for Fuel Cells: Hydrogen,

methane, methanol - Sources and preparation, reformation processes for hydrogen. **6 Hrs**

Unit - II

Batteries: Introduction, working of primary and secondary batteries: The chemistry, fabrication, and performance aspects, packing classification and rating of the following batteries: Zinc-carbon, zinc alkaline zinc/air batteries; Lithium primary cells - liquid cathode, solid cathode and lithium-ferrous sulphide cells

Secondary batteries: Lead acid, nickel-cadmium, nickel-zinc, nickel-metal hydride batteries, lithium-ion batteries, ultrathin lithium polymer cells. Advanced Batteries for electric vehicles, requirements of the battery, depth of discharge, sodium-beta and redox batteries. **8 Hrs**

Unit - III

Fuel Cells: Description, working principle, anodic, cathodic and cell reactions, fabrication of electrodes and other components, applications, advantages, disadvantages and environmental aspects of the following types of fuel cells: Proton Exchange Membrane Fuel Cells, alkaline fuel cells, phosphoric acid, solid oxide, molten carbonate, direct methanol fuel cells.

Membranes for fuel cells: Nafion – Polymer blends and composite membranes; assessment of performance – recent developments. **9 Hrs**

Unit - IV

Thermodynamics of fuel cells: First law second law, heat potential reaction enthalpies, Gibbes free energy , reversible voltages, fuel cell efficiency, Nernst equation analysis effect of temperature and pressure and concentration, concept of electrochemical potential calculation of standard electrode potential **9 Hrs**

Unit - V

Hydrogen production and storage: Advantages and disadvantages of using hydrogen as fuel, hydrogen production methods, hydrogen storage, recent developments in storage and production of hydrogen. **7 Hrs**

Reference Books:

1) M. Aulice Scibioh and B. Viswanathan “Fuel Cells – principles and applications”, University Press, India, 2006.
2) F. Barbir, “PEM fuel cells: theory and practice”, Elsevier, Burlington, MA, 2005.
3) Dell, Ronald M Rand, David A J, “Understanding Batteries”, Royal Society of Chemistry, 2001.
4) G. Hoogers, “Fuel cell handbook”, CRC, Boca Raton, FL, 2003.

5) Ryan P. O'Hayre, Suk-Won Cha, Whitney Colella and Fritz B. Prinz, Fuel cell fundamentals, John Wiley and Sons, 2006

18UMEO731 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**

Text 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.

Reference Books:

1) Dave Anderson, “Introduction to Flight”, McGraw Hill Education, 6th edition, 2017.
2) 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.

18UMEO732	Project 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. Concepts and different aspects related to projects.
2. Applications of different aspects of management of projects.
3. Analytical skills associated with techniques of managing projects.

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 various aspects of project management, project stakeholders, project life cycle phases, tools & techniques.	1	11	-
CO-2	Analyze the influence of project organizational structures on project management.	11	-	-
CO-3	Explain the importance of contracting and tendering in project management.	-	11	-
CO-4	Apply PERT & CPM to evaluate project time and cost trade- off.	11	5,14	1, 2
CO-5	Apply the concepts of economics and project finance to estimate project feasibility.	11	14	1

POs/PSOs	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**
Mapping Level	1.2	1	-	-	2	-	-	-	-	-	2.6	-	-	2

Prerequisites: Nil

Contents:

Unit - I

Concepts of Projects /Project Management: Definition of Projects, Categories, Comparison of Project management with routine management. Overview of project management.Objectives and goals of project. Project stake holders, some tools and techniques used in project management.
Project management Knowledge areas and Processes. Project phases, Project life cycle, Software development life cycle, Project management processes, Process interactions. **8 Hrs**

Unit - II

Organizing and Staffing: Roles and responsibilities of project leader, Skills and abilities required. Organizational systems, Line and staff functions, project manager as a staff assistant, as a consultant, as a specialized function in an organization, Matrix organization, Task force organization. Influence of Organizational structures on projects. **7 Hrs**

Unit - III

Contracts: Need, 3R's of Contracts, Factors affecting number of contracts, Types of re-imbursement. Risk: To the owner and to the contractor. Tendering and selection of contractor sequential steps.
Project Design: Project work system, Work packaging, Work break down structures-examples, advantages. Project execution plan, Systems and procedure plan. **8 Hrs**

Unit - IV

Project Time management: Bar (Gantt)chart, Networks, Types, Critical Path method (CPM), Program Evaluation Review Technique(PERT), construction of network, Estimation of completion time, Computation of slack, Crashing of network. Numerical examples. **8 Hrs**

Unit - V

Estimation of Project Viability: Project cost elements, Means of Finance, Project cost management, Financial Ratio, Evaluation of profitability: Breakeven Analysis, Pay- back period, Return on Investment, Net Present Value, Benefit cost ratio. Numerical examples. Feasibility report need and contents. **8 Hrs**

Text Book:

1) Patel B, "Project Management", 2nd Edition, 2010.

References Books:

1) S. Choudhary, “Project Management”, TMH publication, 2010.
2) A Guide to project Management Project Management Body of Knowledge”, Project Management Institute. Published 2012.
3) L. S. Srinath, “PERT & CPM” principles & applications”, 3rd Ed., EWP Pvt. Ltd., 2000.

18UMEO733	Energy 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. Energy management, energy patterns audit and utilization.
2. Thermodynamics of energy conservations.
3. Energy conservation and electrical thermal utility.
4. Cogeneration and performance evaluation.
5. Utilization of electrical energy.

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	Explain energy use pattern of various sectors in India, and the terms used in energy conservation.	-	1, 2	-
CO-2	Perform economic analysis for energy systems based on life cycle costs.	1	11	14
CO-3	Apply heat transfer and thermodynamic concepts to waste heat management of energy systems.	1	2	-
CO-4	Determine thickness of insulation for thermal & electrical systems.	-	1, 2	-
CO-5	Evaluate parameters related to electric lighting systems and energy efficient electrical utilities.	1	2	7

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

Pre requisites: Nil

Contents:

Unit - I

Introduction: General Energy problem, Energy use patterns in sectors such as domestic, industrial, agriculture and commercial and energy saving opportunities and scope of conservation. Need of Energy management program, Organizing, Initiating Managing an Energy Management program.
Energy Audit: Elements and concepts Types of energy audits mini, maxi audit preliminary and detailed energy audits procedure involved. Instruments used in energy auditing of various sectors. **8 Hrs**

Unit – II

Economic Analysis: Cash flows diagram, Time value of money, Formulae relating present and future cash flows, single amount and uniform series. Numerical Problems. Financial appraisal methods, Payback period, Net present value, Benefit-cost ratio, Internal-rate of return Life cycle costs/benefits. **8 Hrs**

Unit - III

Energy Efficiency in Thermal Utilities: Energy efficiency of utilities, Oil coal & gas combustors, FEC boilers, Steam & condensate system, Furnaces.
Cogeneration: Concepts of cogeneration Types of cogeneration systems, Waste heat recovery equipment, Turbines & heat exchangers, Problems on Rankine cycle for cogeneration plants. **8 Hrs**

Unit - IV

Industrial Insulation & Refractories; Types and applications, economic and critical insulation thickness, Heat saving criteria, Applications of refractories, Heat loss.

Utilization of Electrical energy: Heating methods, Types of light sources incandescent bulbs, Fluorescent tube, Dielectric Heating, Space heating in buildings, Illumination Engineering, Energy conservation in illumination systems. **8 Hrs**

Unit - V

Conservation of Electrical Energy: Industry energy costs and two – part tariff, Energy conservation in utility by improving load factor, Load curve analysis, Energy efficient motors, Importance of Power factor in energy conservation Power factor improvement methods. **7 Hrs**

Reference Books:

1) S. C. Tripathy, “Electric Energy Utilization and Conservation”, Tata McGraw Hill, New Delhi, 1991.
2) “Energy Management Proceedings”, published under AICTE Continuing Education Program New Delhi. 1998.
3) B. L. Theraja, “Electric Energy Utilization”, 2nd edition, Tata McGraw Hill New, Delhi, 1999.
4) P. K. Nag, “Applied Thermodynamic”, 2nd edition, Tata McGraw Hill, New Delhi, 2010.
5) T. C. Kandpal and H. P. Garg, “Financial evaluation of renewable energy technologies”, Macmillan publications India Ltd Delhi, 2003
6) Wayne C. Turner, “Energy management handbook”, 7th edition, CRC Press, 2009.

18UMEO734 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**

Text 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.

Reference Books:

1) Ziyad Salameh, “Renewable Energy System Design”, Academic Press, ELISIEVIR.2014.
2) S. P. Sukatme, “Solar Energy”, TATA McGraw Hill, 1996.
3) Kreith & Goswami, “Solar Energy”, Taylor & Francis 1999.

VIII Semester

18UMEC801	Fluid Power Control	(4-0-0) 4

Contact Hours: 52

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**

Text Book:

1) Anthony Esposito, “Fluid Power with applications”, 7th edition, PHI, 2009.

Reference Books:

1) S. R. Majumdar, “Pneumatic systems”, Tata McGraw Hill New Delhi, 2010.
2) F. Don Norvelle “Fluid Power Technology”, West Publishing Company, Minneapolis, 1995.
3) S. R. Majumdar, “Oil hydraulic systems”, PHI, 2010.

18UMEL801	Technical Seminar	(0-0-2) 1

Contact Hours: 30

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

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	Refer to the learning resources, recognize and collect the required information.	2	4	12
CO-2	Describe the usefulness of information and make effective oral presentation using ppt.	10	2	4
CO-3	Compile the information published and prepare a technically sound report.	10	5	-
CO-4	Justify the technical solutions presented and draw the concluding remarks.	4	10	6

POs/PSOs	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Mapping Level	-	2.5	-	2	2	1	-	-	-	2.7	-	1	-	-

Prerequisites: Nil

Contents:

Technical Seminar: The students are expected to learn how to carry out literature survey to locate the state of the art technology in engineering domain of their interest. They are required to carry out selection of an emerging topic beyond the syllabus relevant to the branch of study, understand the concept, analyze and present effectively for 15-20 minutes followed by 5 minutes of questions and answers before their classmates and faculty. They can also present the technical innovative/novel work carried out in the laboratory. They are also required to learn the effective communication and modalities of technical interactions. Further, they have to submit the seminar material in the form of a paper in IEEE format. All the students are required to attend all the session throughout the semester.

Procedure to conduct technical Seminar:

- All the students are informed to select a topic from the field of their interest from their branch or relevant to their branch and register the topic with the faculty (ies) In charge of Seminar.
- Two faculty members assigned to carry out this activity. The faculty members prepare the schedule of the seminar spread over the entire semester and display the same in the notice board.
- Change of seminar topic is not allowed once registered, however in the case of genuine reasons only once change of topic may be permitted.
- Based on the number of hours mentioned in the scheme, 4-6 students shall present the seminar in one slot of 2/3 hours.
- The faculty members shall conduct the seminar session every week as per the schedule in the slot mentioned on the time table and carry out the evaluation.
- Attendance is compulsory for all the students for all the seminars.
- The students are required to submit two hard copies of report not exceeding 6 pages and one soft copy of seminar report one week prior to their date of presentation.
- Report shall be in IEEE format viz A4 size paper, Title**:** Bold, Times new Roman Font 14, Sub heading & Body of the text**:** Times new Roman font 12. Margin for left should be 1 ½.
- Student name, USN, seminar date should be mentioned on the report.
- Presentation is for about 15-20 minutes, followed by 5 minutes for questions and answers.
- Typical evaluation methodology: The seminar shall be evaluated for maximum 50 marks. The breakup of marks shall be:
  Presentation: a) 40 marks b) Report: 10 marks.
  For presentation, the following points not limited to may be considered.
  Concept, understanding, depth of the knowledge, originality of the topic, Quality of PPT, communication skills etc.
  For report evaluation, the following points not limited to may be considered
  Adherence to IEEE format, relevance of topic, subject depth and originality in writing etc.

The seminar is aimed at as an educative program for the students. This is because, the students shall listen to 60- 70 seminars on different topics from emerging areas is as good as undergoing a course on latest happenings in the related branch of Engineering.

18UMEL802	Major Project Phase - 2	(0-0-12) 7

Contact Hours: 100

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, design related analysis and numerical concepts.
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 and solve a problem using basic engineering principles.	1,2	4	1,2
CO-2	Recognize the need and able to design and fabricate the machine parts, components of a system that meets particular requirement.	3	7	6,12
CO-3	Use the software tools to prepare and 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 completion of projects in time.	10	8,11,12	-
CO-6	Prepare a report based on their project and present the concept using ppt.	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

Contents:

Major project phase-2 is the continuation from phase –I in which the students are expected to go for material collection, survey, visits, data collection, preliminary design, analysis, model development, code writing, field work etc. The same project team formed for phase –I will continue the work under the guidance of the same faculty member. For all the projects, problems may be domain specific or interdisciplinary also in nature. A committee consisting of minimum 3 faculty members of which guide is a member shall evaluate at the end for CIE. There is a viva voce examination which shall be examined by two examiners one internal and one external to the college appointed by COE based on the suggestions by the respective HoD.

The reference materials for the project work are as listed below but not limited to:

Reference materials / Books:

1. Engineering books.
2. Journals.
3. Manuals and data sheets.
4. Software packages.
5. Previous project reports.
6. Product information brochures.
7. Interaction with academia and industrial experts.
8. Internet etc.

18UMEE821	Operations Research	(2-2-0) 3

Contact Hours: 39

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

1. Modeling, solving and analyzing the problems using linear programming with emphasis on theory and applications.
2. Mathematical tools that are needed to solve optimization 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	Formulate the industrial and real-world problems as linear programming problem and solve LPP by using Simplex algorithm.	1, 2	3	6
CO-2	Formulate transportation, assignment models and derive solutions through various approaches.	1, 2	3	6
CO-3	Solve various Sequencing and queuing problems.	1, 2	3	6
CO-4	Estimate various parameters of projects using PERT and CPM approaches.	11	1,2	6
CO-5	Solve Games for value, suitable strategies and integer programming problems.	1, 2	-	-

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

Prerequisites: Nil

Contents:

Unit - I

Introduction: Linear programming, Definition, scope of Operations Research (O.R) approach and limitations of OR Models, Characteristics and phases of OR Mathematical formulation of L.P. Problems. Graphical solution methods.

Linear Programming Problems: The simplex method - slack, surplus and artificial variables, degeneracy and procedure for resolving degenerate cases,artificial variables techniques, special cases, concept of duality, dual simplex method. **7L+2T Hrs**

Unit - II

Transportation Problem: Formulation of transportation model, Basic feasible solution using different methods, Optimality Methods, Unbalanced transportation problem, Degeneracy in transportation problems, Applications of Transportation problems.

Assignment Problem: Formulation, unbalanced assignment problem, Traveling salesman problem. **6L+2T Hrs**

Unit - III

Sequencing: Johnson's algorithm, n - jobs to 2 machines, n jobs 3 machines, n jobs m machines without passing sequence. 2 jobs n machines with passing. Graphical solution.

Queuing Theory: Queuing system and their characteristics. The M/M/1 Queuing system, Steady state performance analysing of M/M/ 1 and M/M/C queuing model. **7L+2T Hrs**

Unit - IV

PERT-CPM Techniques: Network construction, determining critical path, floats, scheduling by network, project duration, variance under probabilistic models, prediction of date of completion, crashing of simple networks.

5L+2T Hrs

Unit - V

Game Theory: Formulation of games, two person - Zero sum game, games with and without saddle point, Graphical solution (2x n, m x 2 game), dominance property, method of sub-groups.

Integer programming: Gommory's technique, branch and bound logarithm for integer programming problems, zero one algorithm. **6 Hrs**

Text Books:

1) S. D. Sharma, "Operations Research", Kedarnath Ramnath & Co, 2002.
2) Prem Kumar Gupta and D S Hira, "Operations Research", 7th edition, S Chand Pub. New Delhi, 2007.

Reference Books:

1) Taha H. A, “Operation Operations Research and Introduction”, 9th edition, Pearson Education, 2014.
2) Hiller and Lieberman, “Introduction to operation research”, 5th edition, McGraw Hill, 2001.

18UMEE822 Computer Integrated Manufacturing (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 Computer Integrated Manufacturing.
2. Automated assembly system.
3. Latest computerized manufacturing practices.
4. Shop floor control & quality.

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 concepts of automation, flow lines, line balancing and high-volume production systems.	-	1, 2	-
CO-2	Analyze different Automated Flow Line, and line balancing.	1	2	-
CO-3	Analyze different Automated Assembly systems. Describe Material handling system, Automated guided vehicle system.	1	2	-
CO-4	Describe Computerized Manufacturing & Planning Systems and basics of Robotics in industry.	-	1, 2	-
CO-5	Describe shop floor control systems and computer aided quality control systems in a factory environment.	-	1, 2	-

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

Prerequisites: Nil.

Contents:

Unit - I

Computer Integrated Manufacturing System: Introduction, Types of Automation, Production concepts, Mathematical Models, Automation Strategies (Numerical).

High Volume Production System: Automated FLOW lines, Work Part Transport Mechanism, Buffer Storage (Numerical). **8 Hrs**

Unit - II

Analysis of Automated Flow Line and line balancing: Analysis of Transfer Lines without storage and with storage, Partial automation, Manual Assembly Lines, Methods of line balancing, Computerized line balancing (Numerical) **8 Hrs**

Unit - III

Automated Assembly System: Types, Parts feeding Devices, Analysis of single station assembly machine, Analysis of multi station assembly machine, automated material handling system, Automated guided vehicle system. **8 Hrs**

Unit - IV

Computerized Manufacturing Planning System: Computer Aided Process Planning: Retrieval Type, Generative type. Material Requirement Planning, Fundamental concepts of MRP, Inputs to MRP, Capacitive Planning.

Robotics: Introduction to Robot, Robot anatomy and configuration, work volume, end effectors, Robot sensors and Robot applications. **8 Hrs**

Unit - V

Shop Floor Control: Factory Data Collection System, Automatic Identification System.

Computer Aided Quality Control: Contact inspection methods, Non-contact inspection methods, Co-ordinate Measuring Machine. **7 Hrs**

Text Book:

1) Mikell O. Groover, “Automation, Production system and Computer Integrated Manufacturing”, 3rd edition, PHI, New Delhi, 2010.

Reference Books:

1) Mikell P. Groover, “CAD/CAM”, 3rd edition PHI, New Delhi, 2003.
2) Ibrahim Zeid, “CAD/CAM”, 2nd edition, Tata McGraw Hill, 2010.

18UMEE823	Organizational Behavior	(3-0-0) 3

Contact Hours: 39

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

1. Human behavior when working in groups.
2. Scientific methods of motivation.
3. Theories of leadership.
4. Managing self and managing teams.
5. Developing the Proficiency in managing different activities in any organization.

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 various basic and related terminology of organizational behavior.	-	1, 2	8
CO-2	Explain various concepts and techniques of organizational behavior.	-	-	1, 2
CO-3	Describe various theories pertaining to individual and group behaviors.	-	1, 2	-
CO-4	Discus organizational change, stress management, and quality of working life (QWL)	-	1, 2	-
CO-5	Explain conflict process, different bargaining strategies, and organizational structures.	-	1, 2	-

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

Prerequisites: Nil.

Contents:

Unit - I

Introduction: Definition of O.B., functions of a manager, Fields contributing to the development of O.B, Challenges and opportunities to O.B. ethics. The Individual: Foundations of individual behavior, Ability. Learning – theories of learning, Reinforcement types, aptitude and interests of the individual. **8 Hrs**

Unit - II

Values, Attitudes, Job Satisfaction & Perception: Definitions, Types of values and their importance Types of attitudes – Job satisfaction Job involvement and organizational commitment. Perception: Definition, Factors affecting perception, making judgments about others, selective perception, projection and stereotyping. **8 Hrs**

Unit - III

Motivation: Definition, Early theories of motivation – Maslow's hierarchy of needs theory, McGregor's Theory X and Theory Y, Herzberg's two factor theory, Contemporary theories – David McClelande's three needs theory, Equity theory, Goal setting theory **8 Hrs**

Unit - IV

The Group: Definition and classification of groups, Factors affecting group formation, Stages in group development, Group norms Hawthorne studies, Group decision making and its techniques. Leadership: Definition, Theories of leadership – Blake and Mouton managerial grid, Heresy – Blanchard's situational theory, Fiedler's model. Leadership style. **8 Hrs**

Unit - V

The organisation: Definition of conflict, conflict process. Functional and Dysfunctional conflict, Negotiation – Bargaining strategies. Mechanistic and Organic structures. Mintzberg's basic elements of organization, Organizational change and stress management, QWL (Quality of Work Life). **7 Hrs**

Reference Books:

1) Stephen Robbins and SeemaSanghi, "Organizational Behavior", 13th edition Pearson educational publications New Delhi ISBN 0131914359, 2009.
2) Fred Luthens, "Organizational Behavior", 11th International Edition, McGraw Hill publications New York 2011 ISBN 0-07-124762-9 2008.

18UMEE824	Industrial Robotics	(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 elements of Robotics.
2. Kinematics of robots.
3. Modeling and analysis concepts of various robotics systems.
4. Trajectory planning and various sensors used in robotics.

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 structure and performance characteristics of an industrial robot.	-	1	2
CO-2	Describe different types of sensors and vision system in a robot.	-	1	2
CO-3	Derive a mathematical model and equations of motion for a robot.	1	2	3
CO-4	Analyze kinematically serial manipulators.	1	2	3,5
CO-5	Plan the motion of robot using different trajectory planning schemes and explain types of end effectors.	-	1	2,5

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

Prerequisites: Nil

Contents:

Unit - I

Introduction: Definition: manipulators, Robotics, Brief history of robotics, Overview of robots, social & economic aspects of robots, Advantages of using robots in industries, Future applications.

Structure of robotic systems: Classification, Geometrical configuration, wrist & its motions, Degrees of freedom, work Envelop, Links and joint, effectors and its type, Robot drive system: Hydraulic, electric selection of drive system, Resolution, accuracy & repeatability, Specifications of robots. **8 Hrs**

Unit - II

Sensors: State and Transducers, Classification, Internal & External sensors, Interlocks, Tactile and non- tactile sensors, Proximity and range sensing, force – torque, Static and dynamic characteristics, Selection of sensors, Elements of computer vision, Sensing and digitizing, Lighting techniques, A/D conversion, sampling quantization, Image storage, Image processing and analysis, Feature Extraction &object Recognition.

Robot Programming: Introduction, Types robot programming, Teach pendant, Lead through programming, Programming languages VAL, RAIL, AML, Programming with graphics, storing & operating. **8 Hrs**

Unit - III

Robot Motion Analysis: Kinematics, Introduction, Direct & inverse kinematics, Classification, Transformations homogenous transformations, Rotation, matrix, Composite rotation matrix, Rotation matrix about an arbitrary axis, Euler angle representation, Links, joints and their parameters D-H representation. **10 Hrs**

Unit - IV

Robot Arm Dynamics: Euler Lagrange formulations, Joint velocities, K.E., P.E, motion equations of a robot manipulator.

Control Systems and Components: Basic control system concepts and models, Transfer function with block diagram of spring mass system, Transient response to second order systems, controllers on/off, proportional and integral, PID, Digital, Adoptive control, AI. **7 Hrs**

Unit - V

Trajectory Planning: Introduction, General considerations on trajectory planning, Joint interpolated trajectories, 4-3-4 trajectory examples, Planning of Cartesian path Trajectories.

Robot End Effectors: types of end effectors, Mechanical Grippers, Other types of Grippers, tools as End effectors, the robot/end effector interface, considerations in gripper selection and design. **6 Hrs**

Text Book:

1) Mohsen Shahinpoor, “A Robot Engineering Textbook”, Harper & Row.

Reference Books:

1) Mikell P Grover, Mitchel Weiss, Roger N Nagel, Nicholas G Odrey & Ashish Dutta, “Industrial Robots”, McGraw Hill, 2003.
2) K.S. Fu, R. C. Gonzalez & C.S.G. Lee, “Robotics- control, sensing, vision and intelligence”, McGraw Hill, International, New Delhi 2001.
3) Yoram Koren, “Robotics for Engineers”, McGraw Hill International, New Delhi 2001.
4) Richard Paul, “Robot manipulators-Mathematics, Programming and control”, 2000.
5) Saeed B. Niku, “Introduction to Robotics”, Wiley student edition, second edition, 2011.
6) S. K. Saha, “Introduction to Robotics”, McGraw Hill, second edition, 2015.

18UMEE825 Rapid Prototyping and Rapid Tooling (3-0-0) 3

Contact Hours: 39

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

1. The basics of rapid prototyping techniques for processing of CAD models.
2. Apply fundamentals of rapid prototyping techniques and concept modellers.
3. To distinguish appropriate software for rapid prototyping processes.
4. To recognize rapid prototyping and rapid tooling techniques for different tooling industries.

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 concepts, and classifications of prototyping in current product design scenario.	-	1, 2, 5	-
CO-2	Describe Stereo Lithography and Selective Laser Sintering processes.	1	5	-
CO-3	Discuss FDM, SGC and LOM RP processes, and functionality of Concept Modellers.	1	5	-
CO-4	Describe various Rapid Tooling systems in industrial sectors.	1	5	-
CO-5	Explain the different process optimizing techniques and software tools in Rapid Prototyping	-	1, 5	

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

Pre requisites: Nil.

Contents:

Unit - I

Introduction: Introduction to Prototyping, Traditional Prototyping Vs. Rapid Prototyping (RP), Classification of Rapid Manufacturing Processes: Additive, Subtractive, Formative, Generic RP process. Need for the compression in product development, history of RP systems, Survey of applications, Growth of RP industry, and classification of RP systems.**6 Hrs**

Unit - II

Stereo Lithography Systems: Principle, Process parameter, Process details, Data preparation, data files and machine details, Application.

Selective Laser Sintering: Type of machine, Principle of operation, process parameters, Data preparation for SLS, Applications. **7 Hrs**

Unit - III

Fusion Deposition Modelling: Principle, Process parameter, Path generation, Applications.

Solid Ground Curing: Principle of operation, Machine details, Applications. **Laminated Object Manufacturing:** Principle of operation, LOM materials. Process details, application.

Concept Modellers: Principle, Thermal jet printer, Sander's model market, 3-D printer. GenisysXs printer HP system 5, object Quadra systems.**10 Hrs**

Unit - IV

Rapid Tooling: Indirect Rapid tooling: Silicon rubber tooling, Aluminium filled epoxy tooling, Spray metal tooling.

Direct rapid tooling: Quick cast process, copper Polyamide, DMILS explanation, Prometals, sand casting tooling, Laminate tooling, Soft tooling & hard tooling. **8 Hrs**

Unit - V

Software for RP: STL files, Overview of Solid view, magics, imics, magic communicator, etc. Internet based software, Collaboration tools.

Rapid Manufacturing Process Optimization: factors influencing accuracy. Data preparation errors, Part building errors, Error in finishing, influence of build orientation. **8 Hrs**

Reference Books:

1) Chua C K, Leong K F, Chu S L, "Rapid Prototyping", Principles and Applications in Manufacturing, World Scientific.

2) Gibson D W Rosen, Brent Stucker, “Additive Manufacturing Technologies: Rapid Prototyping to Direct Digital Manufacturing”, Springer.
3) Noorani R, “Rapid Prototyping: Principles and Applications in Manufacturing”, John Wiley & Sons.
4) Hilton P, Jacobs P F, “Rapid Tooling: Technologies and Industrial Applications”, CRC press.
5) Liou W L, Liou F W, “Rapid Prototyping and Engineering applications: A tool box for prototype development”, CRC Press.
6) Kamrani A K, Nasr E A, “Rapid Prototyping: Theory and practice”, Springer

18UMEE826	Design For Manufacturing And Assembly	(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 identify major phases of design, effect of material properties on design, material selection process, tolerance analysis, review of tolerance grades through different manufacturing processes.
2. Identifying and analyzing various interchangeable part assembly, group tolerance, and functional datum.
3. Reviewing design considerations in casting, special sand cores, component design, component milling, drilling and finished machining.
4. Identifying and discriminating conventional feature location, tolerance, virtual size concept, position tolerance, functional gauge.
5. Identifying the importance of design of gauges for components checking in assembly.

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 effect of material properties on design, and explain tolerance analysis	1,2	-	3
CO-2	Discuss various interchangeable part assemblies, group tolerance, and functional datum.	1	-	3
CO-3	Review design considerations in various manufacturing processes.	-	1,2	-
CO-4	Explain component design for various machining processes.	-	1, 2	-
CO-5	Explain various tolerancing methods and gauge design.	-	1, 2	-

POs/PSOs	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**
Mapping Level	2.4	2.7	1	-	-	-	-	-	-	-	-	-	-	-

Content:

Unit - I

Effect of Materials And Manufacturing Process On Design: Major phases of design. Effect of material properties on design Effect of manufacturing processes on design. Material selection process- cost per unit property, Weighted properties and limits on properties methods.

Tolerance Analysis: Process capability, mean, varience, skewness, kurtosis, Process capability metrics, Cp, Cpk, Cost aspects, Feature tolerances, Geometries tolerances, Geometric tolerances, Surface finish, Review of relationship between attainable tolerance grades and different machining process. Cumulative effect of tolerance – Sure fit law and truncated normal law. **8 Hrs**

Unit - II

Selective Assembly: Interchangeable part manufacture and selective assembly, Deciding the number of groups -Model-1: Group tolerance of mating parts equal, Model total and group tolerances of shaft equal. Control of axial play-Introducing secondary machining operations, laminated shims, examples.

Datum Features: Functional datum, Datum for manufacturing, changing the datum. Examples. **7 Hrs**

Unit - III

Design Considerations: Design of components with casting consideration. Pattern, Mould, and Parting line. Cored holes and machined holes. Identifying the possible and probable parting line. Casting requiring special sand cores. Designing to obviates and cores. **10 Hrs**

Unit - IV

Component Design: Component design with machining considerations link design for turning components-milling, Drilling and other related processes including finish- machining operations. **6 Hrs**

Unit - V

True positional theory: Comparison between coordinate and convention method of feature location. Tolerance and true position tolerancing virtual size concept, Floating and fixed fasteners. Projected tolerance zone. Assembly with gasket, zero position tolerance. Functional gauges, Paper layout gauging.

Design of Gauges: Design of gauges for checking components in assemble with emphasis on various types of limit gauges for both hole and shaft. **8 Hrs**

Reference Books:

1) Harry Peck, “Designing for Manufacturing”, Pitman Publications, 1983.
2) Dieter, “Machine Design”, McGraw-Hill Higher Education, -2008
3) R. K. Jain, "Engineering Metrology", Khanna Publishers, 1986
4) Geoffrey Boothroyd “Product design for manufacture and assembly”, 3rd Edition, Peterdewhurst, Winston Knight, Merceldekker. Inc. CRC Press,
5) “Material selection and Design” Vol. 20 - ASM Hand book.

18UMEE827 Estimation and Costing in Mechanical Engineering (3-0-0) 3

Contact Hours: 39

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

1. The estimation and costing procedure in industries.
2. The actual costing process and calculation of selling prices.
3. The depreciation of equipment, plants and to know the different methods of calculating depreciation.
4. The procedure for calculating material cost of various components.
5. The procedure for estimation of various shop, labour wages and incentives.

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 estimation and costing procedure in industries.	-	1,2,11, 14	9,12
CO-2	Calculate the actual cost and selling prices.	14	1,2,6,11	9,12
CO-3	Estimate the depreciation of equipments, plants and machineries.	14	1,2,6,11	9,12
CO-4	Estimate material cost of various components	14	1,2,6,11	9,12
CO-5	Calculate various costs of various shops, labour wages and incentives	14	1,2,6,11	9,12

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

Pre requisites: Nil.

Contents:

Unit - I

Introduction to Estimation and costing: Estimation - Definition, Importance and Aims, Qualities and functions of an Estimator,

Source of errors in estimation, Constituents of Estimation, Costing - Definition and Aims, Standard cost and its Advantages, Difference between estimation and costing, Advantages of efficient costing

Elements of costs: Elements of cost- material, labour, expenses, Material - Direct material, indirect material and examples, Calculation of Material cost, Labour - direct, indirect labour and examples. Calculation of labour cost, Expenses - direct, indirect expenses and examples, Classification of expenses - factory, administrative, selling and distribution expenses and examples, Fixed and variable expenses and examples, Components of cost - prime cost, factory cost, office cost, total cost, Selling price, Block diagram to show the relationship between elements and components of cost, problems on above, Allocation of on-cost - methods and simple problems **8 Hrs**

Unit – II

Indirect expenses and depreciation: Indirect expenses - depreciation, obsolescence, inadequacy, idleness, repair and maintenance, Depreciation - causes, methods of calculating depreciation, Simple problems on each method

Mensuration and Estimation of material cost: Area of regular plane figures, Volume and surface area of solids (formulae only), Estimation of material costs of step pulley, spindle lathe centre, Rivets, Fly wheel, Crankshaft, Chain link, Wedge and Gib-headed key. **8 Hrs**

Unit - III

Mechanical Estimation: Estimation in machine shop - Definition of cutting speed, feed, depth of cut, Estimation of time for various operations like Turning, Knurling, Facing, Drilling, Boring, Reaming, Threading, Tapping, Milling, Grinding, Shaping and Planning, Estimation in sheet metal shop - Sheet material and gauge number, Sheet metal joints, Select suitable formula for estimation, Estimate the material required for preparation of container open on one side Cylindrical drum, funnel and tray, Estimation in foundry shop-pattern allowances, estimation of pattern cost, simple problems on C.I pulley and C.I. Wheel, Estimation in welding shop - estimation of gas welding cost, estimation of arc welding cost -Simple problems **10 Hrs**

Unit - IV

Wages and incentives: Definition of wages, normal wages, real wages, living wages, fair wages minimum wages, methods of wage payment, Incentives - definition of incentive, types of incentives, examples, Characteristics of a good wage and incentive systems, Standard time - work measurement, Bonus system - collective bonus system, group bonus system. **6 Hrs**

Unit - V

Project planning and Break even analysis: Concept of project work, Project planning like market survey, project capacity, selection of site, plant layout, product design, drawing, specification, material requirement operation planning, Break even analysis - break event chart, diagram to illustrate break event point, Simple problems on break even analysis.

7 Hrs

Reference Books:

1) T. R. Banga and S. C. Sharma “Mechanical estimation and costing”, Khanna Publishers,
2) Acharya and Narang “Estimation and costing”,
3) Banga and Sharma, “Industrial Organisation and Engineering Economics”,
4) Malhotra, “Mechanical Estimation”,

18UMEE831	Design of Aircraft 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. Aerodynamics, aerospace materials, aircraft and spacecraft structures, aircraft and space propulsion, flight mechanics, stability and control systems, orbital mechanics, space environment
2. Determination and control, telecommunications and design competence of aircraft and spacecraft using systems engineering principles;
3. Independent research opportunities, involving teamwork and exposure to modern engineering analytical and computational tools;
4. Application based analysis and innovation.

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	Discuss the requirements, functions & design process of aircraft structural components.	-	1,2	-
CO-2	Analyze aircraft loads & their effect on aircraft structure.	1	3, 9	8
CO-3	Discuss aircraft materials, manufacturing methods, aircraft structural damage & repair.	-	1	10
CO-4	Analyze aircraft cell for torsion loads.	1,2	3	-
CO-5	Perform structural analysis of aircraft structures using thin plates & shell theory.	1	3, 2	-

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

Pre-requisites: Introduction to Aircraft Industry & Aircraft Systems

Contents:

Unit - I

Overview of the Aircraft Design Process: Introduction, Phases of Aircraft Design, Aircraft Conceptual Design Process, Conceptual Stage, Preliminary Design, Detailed Design, Design Methodologies.

Fundamentals of Structural Analysis: Review of Hooke's Law, Principal stresses, Equilibrium and Compatibility, Determinate Structures, St. Venant's Principle, Conservation of Energy, Stress Transformation, Stress Strain Relations, Numerical problems on principle stresses, critical stresses in structural members of the aircraft etc. **10 Hrs**

Unit - II

Introduction to Aircraft Structures: Sectional Properties of structural members and their loads, Types of structural joints, Type of Loads on structural joints.

Aircraft Loads: Aerodynamic Loads, Inertial Loads, Loads due to engine, Actuator Loads, Maneuver Loads, VN diagrams, Gust Loads, Ground Loads, Ground conditions, Miscellaneous Loads. **7 Hrs**

Unit - III

Aircraft Materials and Manufacturing processes: Material selection criteria, Aluminum Alloys, Titanium Alloys, Steel Alloys, Magnesium Alloys, copper Alloys, Nimonic Alloys, Non-Metallic Materials, Composite Materials, Use of Advanced materials Smart materials, Manufacturing of A/C structural members, Overview of Types of manufacturing processes for Composites, Sheet metal Fabrication, Machining, Welding, Superplastic Forming and Diffusion Bonding.

Airworthiness and Aircraft Certification: Definition, Airworthiness Regulations, FAR-25, Regulatory Bodies, Type certification, General Requirements, Requirements Related to Aircraft Design Covers, Performance and Flight Requirements, Airframe Requirements, Landing Requirements, Fatigue and Failsafe requirements, Emergency Provisions, Emergency Landing requirements. **10 Hrs**

Unit - IV

Torsion Theory, Aircraft Structural Repair: Theory of Torsion- Shafts of Non-Circular Sections, Torsion in Closed Section Beams, Torsion in Open Section Beams, Multi Cell Sections, Sample Exercises. Types of Structural damage, Nonconformance, Rework, Repair, Allowable damage

Limit, Repairable Damage Limit, Overview of ADL Analysis, Types of Repair, Repair Considerations, best practices. **5 Hrs**

Unit - V

Structural Analysis of Aircraft Structures: Theory of Plates- Analysis of plates for bending, stresses due to bending (No derivation), Plate deflection under different end conditions, Strain energy due to bending of circular, rectangular plates, Plate buckling, Compression buckling, shear buckling, Buckling due to in plane bending moments. Theory of Shells-Analysis of Shell Panels for Buckling, Compression loading, Shear Loading / Shell Shear Factor, (No derivations) Circumferential Buckling Stress, sample exercises Theory of Beams-Symmetric Beams in Pure Bending, Deflection of beams. Sample Exercises. **7 Hrs**

Tutorials / Assignments

The assignments for Electives could include the following,

- Hands-on calculation on Exercises related to Fundamentals of Structural Analysis
- Hands-on Calculation on Exercises involving, plate theory, beam theory and shell theory, Panel buckling, Shear-flow
- Exercises in Aircraft Structures.

Text Book:

1) T. H. G. Megson, "Aircraft Structures", Elsevier Aerospace Engineering Series, Fourth Edition, Elsevier publications.

Reference Books:

1) Ian Moir, Allan Seabridge, "Aircraft Systems", Mechanical, Electrical and Avionics Subsystems Integration
2) Daniel P. Raymer, "Aircraft Design-A Conceptual Approach", 6th edition AIAA education series,
3) Michael Niu, "Airframe Structural", 2nd edition, Design Conmilit Press, 1988.
4) Michael Niu, "Airframe Stress Analysis and Sizing", 3rd edition, Conmilit Press, 1999.

18UMEE832	Mechanics of Composite 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. Various properties of composite materials.
2. To determine the generalized stiffness and compliance matrix relating in plane stresses to strains for a composite layer assuming plane stiffness.
3. Manufacturing and testing methods of composites.

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 various aspects of composite materials.	-	1,2	-
CO-2	Apply the generalized Hooks law for macro mechanics of lamina.	1	2	3
CO-3	Discuss various failure criteria and evaluate parameters related to micro mechanics of lamina.	-	1	2
CO-4	Describe various composite manufacturing methods.	-	1, 2	-
CO-5	Discuss non-destructive testing methods and applications of composites.	-	1	2

POs/PSOs	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**
Mapping Level	2.2	1.6	1	-	-	-	-	-	-	-	-	-	-	-

Pre requisites: Nil.

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. **6 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. **9 Hrs**

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. **9 Hrs**

Unit - IV

Manufacturing: 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. **8 Hrs**

Unit - V

Non-Destructive testing: 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", Taylor and Francis group.
2) Rober M. Jones, "Mechanics of Composite Materials", Taylor & Francis, 1998.

18UMEE833	Modeling and Simulation of Dynamic 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. Basic concepts related to modeling and simulation
2. Bond graph according to causality conflicts, and from a given bond graph
3. Find dynamic response and transfer function using various tools for system modeling.
4. Modeling and simulation of mechanical and electrical systems using computer tools

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 related to modeling and simulation	-	1,2	-
CO-2	Analyze the bond graph according to causality conflicts, and from a given bond graph	1,2	-	-
CO-3	Use conservation laws and constitutive relationships to model mechanical, electrical and flow systems, and combinations of these.	-	1,2	-
CO-4	Find dynamic response and transfer function using various tools for system modeling.	-	1,2	-
CO-5	Model and simulate mechanical and electrical systems using softwares	1,2	-	-

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

Prerequisites: Nil

Contents:

Unit - I

Introduction to modeling and simulation: Introduction to modeling, Examples of models, modeling of dynamic system, Introduction to simulation, MATLAB as a simulation tool, Bond graph modeling, causality, generation of system equations. **8 Hrs**

Unit - II

Random-Number Generation, Random-Variate Generation: Properties of random numbers; Generation of pseudo-random numbers; Techniques for generating random numbers; Tests for Random Numbers Random-Variate Generation: Inverse transform technique; Acceptance Rejection technique; Special properties. **7 Hrs**

Unit - III

Input Modeling: Data Collection; Identifying the distribution with data; Parameter estimation; Goodness of Fit Tests; Fitting a non-stationary Poisson process; Selecting input models without data; Multivariate and Time-Series input models.

System models of combined systems: Linearity and non linearity in systems combined rotary and translatory system, electro mechanical system, hydromechanical system. **8 Hrs**

Unit - IV

Dynamic Response and System Transfer Function: Dynamic response of 1st order system and 2nd order system, performance measures for 2nd order system, system transfer function, transfer function of 1st and 2nd order system Block diagram algebra, signal flow diagram, state variable formulation, frequency response and bode plots. **8 Hrs**

Unit - V

Types of simulations with respect to output analysis: Stochastic nature of output data; Absolute measures of performance and their estimation; Output analysis for terminating simulations; Output analysis for steady-state simulations.

Verification, Calibration, and Validation; Optimization: Model building, verification and validation; Verification of simulation models; Calibration and validation of models, optimization via Simulation **8 Hrs**

Reference Books:

1) Gordon, G., “System Simulation”, 2nd edition, Prentice-Hall 1978.
2) Close, C.M., and Frederick, D.K., “Modeling and Analysis of Dynamic Systems”, 2nd edition, John Wiley & Sons 1995.
3) Bhonsle, S. R., and Weinmann, K. J., “Mathematical Modeling for Design of Machine Components”, Prentice-Hall 1998.
4) D’Souza, A. F., and Garg, V. K., “Advanced Dynamics: Modeling and Analysis”, 2nd edition, Prentice-Hall 1984.

18UMEE834	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.

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.

18UMEE835	Failure Analysis	(3-0-0) 3

Contact Hours: 39

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

1. Role of failure in materials for better sustainability of materials and prevent failure of materials by testing under various loads.
2. The importance failure modes in 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	Discuss failure criteria and different modes of mechanical failures.	-	1,2	-
CO-2	Apply damage theories to determine failure criteria	1	2	3
CO-3	Use statistics in fatigue analysis	1	2	3
CO-4	Explain concepts of creep, stress rupture and fatigue	-	1,2	-
CO-5	Explain concepts of fretting, wear, and other failure modes	-	1,2	-

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

Pre requisites: Nil.

Contents:

Unit - I

The role of Failure Prevention Analysis in Mechanical Design: Introduction, Definition of Design, Some Design objectives, Modes of Mechanical failure, definition of failure mode, failure modes observed in practice.

High Cycle fatigue: The nature of fatigue, Fatigue loading, Laboratory fatigue testing, The S-N-P curves-A basic design tool, factors that affect S-N-P curves, The influence of nonzero mean stress, multiaxial fatigue stresses. **8 Hrs**

Unit - II

Concepts of cumulative damage, life prediction, and fracture control: The linear damage theory, Cumulative Damage Theories: Henry Cumulative Damage theory, Gatts Cumulative Damage theory, Martin Cumulative Damage theory, Damage tolerance and fracture control **8 Hrs**

Unit - III

Use of Statistics in Fatigue analysis: Definitions, Population Distributions, Sampling Distributions, Statistical Hypotheses, confidence limits, Properties of good estimators, sample size for desired confidence, probability paper.

Fatigue testing Procedures and statistical interpretation of data: Standard method, Constant stress level testing, response or survival method, Prot method, extreme value method. **8 Hrs**

Unit - IV

Low cycle fatigue: The strain cycling concept, the strain life cycle curve and low cycle fatigue relationships, the influence of nonzero mean strain and nonzero mean stress, cumulative damage in low cycle fatigue, Influence of multiaxial states of stress, Relationship of thermal fatigue to low cycle fatigue. **7 Hrs**

Unit - V

Creep, stress rupture and fatigue: Prediction of long term creep behavior, Theories for predicting creep behavior, cumulative creep concepts.

Fretting, Fretting fatigue, and Fretting wear: Variables of importance in the Fretting process, Fretting Fatigue, Fretting wear, Fretting Corrosion, minimizing or preventing Fretting damage. Wear, corrosion and other important failure modes. **8 Hrs**

Text Book:

1) Jack A. Collins, “Failure of Materials in Mechanical Design: Analysis, Prediction”, Prevention, 2nd Edition, John Wiley & Sons, 1983.

Reference Books:

1) Richard M Christensen, “Theory of Materials Failure”, Oxford University Press, 2013.
2) Ashok Choudhury, “Failure Analysis of Engineering Materials”, Charles R. Brooks, McGraw Hill Professional, 2002.

18UMEE836	Surface Engineering	(3-0-0) 3

Contact Hours: 39

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

1. Surface structure and surface engineering basics
2. Basics of wear and corrosion problems
3. The contrasts between different group of surface engineering processes
4. Industrial applications of different surface engineering technique

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 concepts of friction, wear, corrosion of materials and their types	-	-	1,2
CO-2	Describe the principles of different Surface treatments and coating techniques based on the applications	-	1,2	-
CO-3	Explain different coating techniques and their properties.	-	-	1,2,3
CO-4	Discuss different surface treatment techniques.	-	1,2	3
CO-5	Explain new trends in coating technology and quality testing of coatings	-	-	1,2,3

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

Prerequisites: Nil

Contents:

Unit - I

Introduction to Surface engineering: Philosophy of surface, general applications and requirements. Scope of surface engineering for different

engineering materials, Surface Preparation methods such as Chemical, Electrochemical, Mechanical: Sand Blasting, Shot peening, Shot blasting, Hydro-blasting, Vapor Phase Degreasing etc.,
Coatings: Classification, Properties and applications of Various Coatings.
8 Hrs

Unit - II

Mechanisms of Wear and Metal Cleaning: Basic Mechanisms of wear-abrasive, adhesive wear, contact fatigue, Fretting corrosion, Testing of wear resistance, practical diagnosis of wear, general cleaning process for ferrous and non ferrous metals and alloys selection of cleaning processes, alkaline cleaning, emulsion cleaning, ultrasonic cleaning, pickling salt bath descaling, abrasive bath cleaning, polishing and buffing shot peening. **7 Hrs**

Unit - III

Coating: The concept of the coatings, Structure of the coating, Types of coatings: metallic and non-metallic, Classification of coatings, Potential properties of coatings, Geometrical parameters of coatings, Geometric and physic - chemical parameters of coatings, Physio - chemical parameters of coatings, Service properties of coatings: Anti-corrosion properties, Signification of development of coating. Diffusion coating. **8 Hrs**

Unit - IV

Surface Treatments: Introduction – Surface properties, Superficial layer – Changing surface metallurgy – Wear resistant coatings and Surface treatments, Thermal spray processes; Electrodeposited coatings; Physical and chemical vapour deposition techniques; Polymer coatings; Finishing of surface coatings applied by welding and thermal spraying, Laser surface hardening and alloying, Ensuring quality in surfacing, **8 Hrs**

Unit - V

Surface treatments Techniques: Applications of coatings and surface treatments in wear and friction control – Characteristics of Wear resistant coatings – New trends in coating technology – DLC – CNC – Thick coatings – Nano-engineered coatings – Other coatings, Corrosion resistant coatings.
Quality Assurance, Testing and Selection of Coatings: The quality plan, design, testing and inspection, thickness and porosity measurement, selection of coatings, industrial applications of engineering coatings **8 Hrs**

Reference Books:

1) T Burakowski and T. Wierzchon, “Surface engineering of metals”, CRC Press.
2) S. Grainger, “Engineering Coatings-design and application”, Jaico Publishing House.
3) Principles of Metals surface treatment and protection- D. R. Gabe, Pergamon.

18UMEE837	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

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 Networking

Big 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, “Al-Structures and Strategies for and Strategies for Complex Problem solving”, 4th edition, Pearson Education, 2002.