ACADEMIC CURRICULA 2019 - 2021

MASTER'S DEGREE PROGRAMME

M. Tech in Mechanical Engineering

Curricula & Syllabi

Kalinga Institute of Industrial Technology (KIIT)
Bhubaneswar, Odisha, India
Deemed to be University U/S 3 of UGC Act, 1956

ACADEMIC CURRICULA
2019 - 2021

M. TECH
MECHANICAL ENGINEERING

Course Structure and Detailed Syllabi
for students admitted in
2019 - 21
Academic Session

Kalinga Institute of Industrial Technology (KIIT)
Deemed to be University U/S 3 of UGC Act, 1956
Bhubaneswar, Odisha, India

Program: M. Tech in Mechanical Engineering

Programme Educational Objectives (PEOs)

PEO- I Acquire in-depth knowledge in the domain of manufacturing process, thermal engineering and machine design and pursue successful career in academia and industry.

PEO- II Carry out research in the field of mechanical engineering and its interdisciplinary areas and engage themselves in lifelong learning to continuously evolving technological and global challenges in their field of expertise.

PEO- III Develop ability to work with others and demonstrate social and ethical responsibility as an individual.

Program Outcomes (POs)

PO 1: Ability to independently carry out research/ investigation and developmental work to solve practical problems.

PO 2: Ability to write and present a substantial technical report/document.

PO 3: Ability to demonstrate a degree of mastery in the area of Mechanical Engineering. The mastery should be a level higher than the requirements in the appropriate bachelor program.

PO 4: Ability to apply advanced knowledge, techniques, skills and modern tools in the area of Mechanical Engineering.

Specialization Specific Outcomes (Manufacturing Processes & Systems)

SSO 1: Acquire knowledge of advanced manufacturing techniques and concepts for effective utilization in suitable areas of manufacturing domain.

SSO 2: Apply creativity in designing manufacturing systems, components and processes.

Specialization Specific Outcomes (Thermal Engineering)

SSO 1: Demonstrate research skills to critically analyze complex thermal engineering problem for synthesizing new and existing information for their solutions.

SSO 2: Conceptualize designs of thermal system or component and evaluate them to select optimal feasible solution considering safety, environment and other realistic constraints.

Specialization Specific Outcomes (Machine Design)

SSO 1: Choose appropriate mechanisms to build machines and perform kinematic and dynamic analysis.

SSO 2: Perform detailed design calculations for designing mechanical elements, equipment, machines and systems used in different domains of engineering.

SCHOOL OF MECHANICAL ENGINEERING
M. Tech in Mechanical Engineering

Specialization in MANUFACTURING PROCESSES AND SYSTEMS

		1st semester				
Sl. No.	Subject Code	Subject	**Teaching Hours**			**Credit**
		Theory	L	T	P	
1		University Level Common Subject	3	0	3	3
2	ME 6113	Metal Forming & Metal Casting	3	0	3	3
3	ME 6115	Metal Cutting Technology	3	0	3	3
4	ME 6117	Advanced Manufacturing and Fabrication Processes	3	0	3	3
5		Dept. Elective-I	3	0	3	3
		Total Theory			15	15
		Practical				
6	ME 6191	Manufacturing Processes and Precision Engineering Lab	0	0	3	2
7	ME 6193	CIM Lab-I	0	0	3	2
		Total Practical			**6**	**4**
		Sessional				
8	ME 6181	Seminar-I	0	0	2	1
		Total			**23**	**20**

		2nd Semester				
Sl. No.	Subject Code	Subject	**Teaching Hours**			**Credit**
		Theory	L	T	P	
1		School Level Common Subject	3	0	3	3
2	ME 6112	CNC and Adaptive Control	3	0	3	3
3	ME 6118	Project Planning and Control	3	0	3	3
4		Dept. Elective-II	3	0	3	3
5		Dept. Elective-III	3	0	3	3
		Total Theory			15	15
		Practical				
6	ME 6192	Modelling and Simulation Lab	0	0	3	2
7	ME 6194	CIM Lab-II	0	0	3	2
		Total Practical			6	4
		Sessional				
8	ME 6182	Seminar-II	0	0	2	1
9	ME 6184	Comprehensive Viva-Voce		-		2
		Semester Total			**23**	**22**

		3rd Semester				
1	ME 6185	Thesis Part-I		-		14
		Total				14

		4th Semester				
1	ME 6186	Thesis Part-II		-		16
		Total M. Tech. credit				**72**

Specialization in THERMAL ENGINEERING

		1st semester				
Sl. No.	Subject Code	Subject	**Teaching Hours**			**Credit**
		Theory	L	T	P	
1		University Level Common Subject	3	0	3	3
2	ME 6211	Advanced Fluid Mechanics	3	0	3	3
3	ME 6213	Advanced Thermodynamics	3	0	3	3
4	ME 6215	Advanced Heat and Mass Transfer	3	0	3	3
5		Dept. Elective-I	3	0	3	3
		Total Theory			15	15
		Practical				
6	ME 6291	Thermal Engineering Lab. - I	0	0	3	2
7	ME 6293	Engineering Software Lab. - I	0	0	3	2
		Total Practical			**6**	**4**
		Sessional				
8	ME 6281	Seminar-I	0	0	2	1
		Total				**20**

		2nd Semester				
Sl. No.	Subject Code	Subject	**Teaching Hours**			**Credit**
		Theory	L	T	P	
1		School Level Common Subject	3	0	3	3
2	ME 6216	Computational Heat and Fluid Flow	3	0	3	3
3	ME 6218	Theory of Combustion and Emission	3	0	3	3
4		Dept. Elective-II	3	0	3	3
5		Dept. Elective-III	3	0	3	3
		Total Theory	15		15	15
		Practical				
6	ME 6292	Thermal Engineering Lab. - II	0	0	3	2
7	ME 6294	Engineering Software Lab. - II	0	0	3	2
		Total Practical			6	4
		Sessional				
8	ME 6282	Seminar-II	0	0	2	1
9	ME 6284	Comprehensive Viva-Voce		-		2

		Semester Total	**23**	**22**

		3rd Semester		
1	ME 6285	Thesis Part-I	-	14
		Total		14

4th Semester

1	ME 6286	Thesis Part-II	-	16
		Total M. Tech. credit		**72**

Specialization in MACHINE DESIGN						
		1st semester				
Sl. No.	Subject Code	Subject	**Teaching Hours**			**Credit**
		Theory	L	T	P	
1		University Level Common Subject	3	0	3	3
2	ME6313	Advanced Mechanics of Solids and Structures	3	0	3	3
3	ME6315	Noise and Vibration control Engineering	3	0	3	3
4	ME6317	Advanced Machines Mechanisms and Robot kinematics	3	0	3	3
5		Dept. Elective-I	3	0	3	3
		Total Theory			15	15
		Practical				
6	ME6391	Numerical Simulation Lab	0	0	3	2
7	ME6393	Advanced Mech. Design Lab - I	0	0	3	2
		Total Practical			**6**	**4**
		Sessional				
8	ME 6381	Seminar-I	0	0	2	1
		Total			**23**	**20**

		2nd Semester				
Sl. No.	Subject Code	Subject	**Teaching Hours**			**Credit**
		Theory	L	T	P	
1		School Level Common Subject	3	0	3	3
2	ME6310	Theory of Elasticity and Plasticity				
3	ME6312	Finite Element Method	3	0	3	3
4		Dept. Elective-II	3	0	3	3
5		Dept. Elective-III	3	0	3	3
		Total Theory			15	15
		Practical				

6	ME6392	Advanced Mech. Design Lab - II	0	0	3	2
		Total Practical			3	2
		Sessional				
7	ME6380	Mechanical System Design Project	0	0	3	2
8	ME6382	Seminar-II	0	0	2	1
9	ME6384	Comprehensive Viva-Voce		-		2
		Semester Total			**23**	**22**

		3rd Semester		
1	ME 6385	Thesis Part-I	-	14
		Total		14
		4th Semester		
1	ME 6386	Thesis Part-II	-	16
		Total M. Tech. credit		**72**

Sl. No.	Corse Code	Subject Name	Credit
		University Level Common Subject	
	RS6001	Fundamentals of Research Methodology	3
		School level Common Subject across all Specialization in School of Mechanical Engineering	
	ME 6116	Optimization Techniques	3
		Electives for Specialization in Manufacturing Processes and Systems	
		Dept. Elective - I	
1	ME 6119	Robotics and Robot Applications	3
2	ME 6122	Finite Element Analysis	3
3	ME 6124	Rapid Response Manufacturing	3
4	ME 6126	Flexible Manufacturing Systems	3
5	ME 6166	Manufacturing Planning and Control	3
		Dept. Elective-II	
1	ME 6142	Quality Engineering and Management	3
2	ME 6144	Advanced Materials and Processing	3
3	ME 6150	Microforming	3
4	ME 6152	Materials Management	3
5	ME 6168	Lean Manufacturing	3
		Dept. Elective-III	
1	ME 6114	Metrology and Quality Control	3
2	ME 6134	Production System Design & Control	3
3	ME 6136	Competitive Manufacturing Strategies	3

4	ME 6154	Mechatronics	3
5	ME 6164	Manufacturing Systems Engineering	3
Electives for Specialization in Thermal Engineering			
		Dept. Elective - I	
1	ME 6243	Alternative Fuels for IC Engines	3
2	ME 6245	Cryogenic Engineering	3
3	ME 6247	Theory of Nano-Technology	3
4	ME 6249	Microfluidics	3
5	ME 6251	Finite Element Analysis of Heat and Fluid Flow	3
		Dept. Elective-II	
1	ME 6244	Experimental Methods in Thermal Engineering	3
2	ME 6246	Heat Exchanger Analysis and Design	3
3	ME 6248	Bio Heat Transfer	3
4	ME 6250	Advanced Turbo machinery	3
5	ME 6252	Advanced Power Plant Engineering	
		Dept. Elective-III	
1	ME 6254	Advanced Refrigeration and Air Conditioning	3
2	ME 6256	Non-Conventional Energy Sources	3
3	ME 6258	Gas Turbines and Jet Propulsion	3
4	ME 6260	Compressible Flows	3
5	ME 6262	Theory of Turbulence	3
Electives for Specialization in Machine Design			
		Dept. Elective - I	
1	ME6319	Fracture and Fatigue based Design	3
2	ME6341	Experimental Stress Analysis	3
3	ME6343	Simulation of Dynamic Systems	3
4	ME6345	Soft Computing and Optimization Techniques	3
		Dept. Elective - II	
1	ME6314	Theory of Plates and Shells	3
2	ME6316	Machinery Fault Analysis and Reliability Engineering	3
3	ME6318	Design Optimization	3
4	ME6320	Analysis of Functionally Graded Materials	3
5	ME6342	MEMS and NEMS	3
		Dept. Elective - III	
1	ME6344	Dynamics of Rotors	3
2	ME6346	Theory of Non-linear Vibration and Shock	3
3	ME6347	Engineering Tribology	3
4	ME6348	Advanced Control Theory	3
5	ME6349	Analysis and Performance of Composite Materials	3

School of Mechanical Engineering
M. Tech in Mechanical Engineering
Specialization: Manufacturing Processes and Systems

ME 6112 CNC AND ADAPTIVE CONTROL Cr-03

Course Outcomes: At the end of the course, the students will be able to:

CO1. understand the latest developments and the main elements in computer integrated manufacturing systems.
CO2. create awareness about the implementation techniques for GT and CAPP.
CO3. classify and distinguish NC, CNC and DNC systems.
CO4. develop manual and APT part programs for 2D complex profiles, automated tool paths and G-codes for machining components and test the programs through simulation.
CO5. apply modern computational, analytical, simulation tools and techniques to face the challenges in manufacturing.

Introduction to Numerical Control in Computer Aided Manufacturing – Components of CNC system – Types of CNC systems – Open loop and Closed loop control systems
Drives and Controls – Interpolators for CNC machine tools – Principal types of CNC machine tools and their constructional features.
Design consideration – Tooling for CNC – Sensors for Adaptive Control of CNC machine tools.

SMART manufacturing
CNC part programming – Manual and computer assisted part programming – Post processors – CNC part programming with CAD/CAM systems.
Programmable Logic Controllers (PLC) - Hardware, Ladder logic programming of PLCs using basic functions-Timers and counters-Advanced programming with control and arithmetic instructions.

Text Books:

1. *Mastering CAD/CAM*, Ibrahim Zeid, Academic Publishers, 3rd edition, 1999

Reference Books:

1. *CAD/CAM/CIM,* P. Radhakrishna, S. Subramanuam, V.Raju, Edition, 3. Publisher, New Age International (P) Limited, 2008
2. *Advances in adaptive control,* K.S. Narendra, PERGAMON PRESS,1994
3. *PLC & Industrial automation,* Madhuchhanda Mitra & Samarjit Sengupta, Penram International Publishing (India) Pvt. Ltd., 2009, ISBN-978-81-87972-17-4

ME6113 METAL FORMING AND METAL CASTING Cr-03

Course outcome: At the end of the course, student will be able to:

CO1. explain the plastic deformation of metals on industrial scale and analyze the behaviour of materials during forming processes.
CO2. explain different types of metal forming process utilized in manufacturing industries.
CO3. understand the concept of technological procedures in industrial manufacturing processes related to pressure shaping of metals and estimate the forming loads and power requirement for different forming processes.
CO4. explain the essence of each technological operation employed in industrial pressure shaping of metals.
CO5. understand the industrial limitations and application of casting.
CO6. integrate knowledge gained in design of gating system in casting.

Forming: Classification of metal forming processes; basic metal working concepts and plasticity. Elements of theory of plasticity: Stress-Strain / strain rate, strain rate, analysis of strain, Yield stress, yield conditions (Mises/Tresca), anisotropy in yielding, flow behavior of the material and determination of flow stress, instability, workability, residual stresses.
Analysis of metal flow in metal forming processes: slip line field theory, Upper bound solution, application to extrusion and indentation problems, Slab methods; Mechanics of rolling, forging, drawing, extrusion. Friction and surface integrity: formability, friction and lubrication in metal working; theories of friction and lubrication, measurement of friction in metal forming, powder forming.

Formability of sheet metals: Principle, process parameters, deep drawing, forces in circular cup drawing forming limit criteria, drawability of sheet metal, anisotropy in sheet metal, forming limit diagram (FLD), stretch forming, plate bending, press brake forming, spinning.
Casting: Survey and scope, Solidification and pure metals and alloys, Solidification of actual casting, Risering, Riser design, Risering curves, NRL methods, Feeding distance, Risering of complex casting, Gating, System and their characteristics.

Gating design: Types of gates and design considerations, pattern design considerations and testing, various moulding processes, gases in metals, fluidity of metals, casting defects and casting quality measurement and improvement techniques.

Text Books:

1. *Technology of Metal Forming Processes,* S. Kumar, PHI Ltd, 2008
2. *Metal Forming: Fundamentals and Applications,* T. Altan, S.Oh & H.L. Gegel, American Society for Metals, 1983

Reference Books:

1. *Metal forming and the Finite-Element Method,* S. Kobayashi, S. Oh, T. Altan, Oxford University Press, USA, 09-Mar-1989
2. *Casting Technology and Cast Alloys,* A.K. Chakrabarti, PHI Ltd., 2005
3. *Manufacturing Technology,* Vol. – I, P.N. Rao, Tata McGraw Hill, 2007 reprint
4. *Plasticity for Mechanical Engineers,* W. Johnson & P.B. Mellor, London, Princeton, N.J., Van Nostrand [1962]
5. *Principle of Metal Working,* G.W. Rowe, ISBN: 8123904282

ME6114 METROLOGY AND QUALITY CONTROL Cr-03

Course outcome: At the end of the course, student will be able to:

CO1. demonstrate different measurement techniques.
CO2. reproduce the fundamental knowledge on metrology techniques.
CO3. apply statistical process control and acceptance sampling procedures in a manufacturing environment to improve quality of processes / products.
CO4. identify suitable metrological methods for measuring the components.
CO5. explain the acceptance test for machines.
CO6. outline the working of various optical measuring instruments.

Metrological concepts: Needs of high precision inspection, Precision & Accuracy, Errors-Abbe's alignment principle & Airy's support effect, problems associated with high precision measurements.

Standards for measurement – Material standards, Wavelength standards, standards traceability and their calibration.
Limit, Fit & Gauges- Limits, Various tolerances and their specifications, Principle of gauge design**,** Limit gauges for tapers. Selective assembly & interchangeability.
Gear and Thread Measurements: Screw Thread terminology, Errors in Threads, Pitch errors,

Measurement in various elements of a thread. Gear terminology, Spur gear measurements- run out, pitch, concentritivity, profile, lead, alignment, backlash, chordal thickness method, Parkinson's gear tester.

Surface & Form Metrology: Measurement of straightness, flatness, waviness, roughness, roundness (Talyround instrument), & The Taylor –Hobson Talysurf.
Laser Metrology: Application of Laser in precision measurements, Laser interferometer, specle measurements, Laser scanners.
Machine Tool Metrology: Alignment tests on Lathe, Milling Machines, Drilling Machines, Acceptance tests for Shapers & Planers.
Co-ordinate measuring machines: Types of CMM, Computer controlled co-ordinate measuring machines. Electronic inspection & measuring machines, Multidimensional Auto-gauging & Sorting machines.
Quality Assurance: Statistical Quality Control, Control Charts, Sampling distributions, Process Control Charts for Attributes & Variables. Acceptance Sampling, OC Curve, Sampling plans, AOQL, AQL, and Selection of Sampling Plans.
Total Quality Management: T.Q.M. Philosophy, Deming's approach to TQM, Quality Circle, Total Quality Control, Juran's ten steps to Quality Improvement, Kaizen System, ISO-9000& TQM, Taguchi methods, orthogonal arrays & Quality Audit.

Text Books:
1. *Engineering Metrology,* R.K. Jain, Khanna publishers, 1997
Reference Books:

1. *Statistical Quality Control,* E.C. Gantt, McGraw Hill, 2001
2. *Statistical Quality Control,* M.S. Mahajan, Dhanpat Rai & Sons., 2012

ME6115 METAL CUTTING TECHNOLOGY Cr-03

Course outcome: At the end of the course, student will be able to:

CO1. comprehend the tool geometry, represent and correlate in different reference systems.

CO2. conceptualize tool material characteristics and analyze mechanism of chip formation

CO3. compute machining forces from analytical and experimental methods

CO4. develop the machining performance in context of thermal phenomena, contact phenomena and vibrations

CO5. derive and develop appropriate tools towards predicting tool life, surface characteristics and integrity, tool wear and machinability

CO6. evaluate economic indices relating to metal machining.

Steriometry of cutting tools: Basic shape of cutting tools: The wedge, concept of rake & clearance angle & its advantages & disadvantages, systems of description of tool geometry & nomenclature, Tool-in-hand system. Machine Reference system (ASA) & its planes & axes. Tool Reference system (ORS & NRS) & its planes & axes. Interrelation between different systems of rake angle, Conversion of tool angles from one system to another-Master line method.

Tool Materials: Requirements of cutting tool materials, Tool material properties, Major classes of tool materials, carbon tool steels, medium alloy steels, high speed steels, cast alloy steels, cemented carbide tools, cermet tools, ceramic tools, CBN tool, and polycrystalline diamond tools. Development of tool materials: coated carbides. CVD & PVD, Indexable inserts, groove geometry, edge preparations, wiper geometry, insert clamping methods, High speed machining, hard machining and comparison with grinding operations, technological processes including hard machining, equipment & tooling for hard machining, characterization of hard machining processes.

Mechanism of chip formation: Mechanism of chip formation in machining. Levy lodes theorem, Classification of chips & factors involved in chip formation. Brief description on orthogonal & oblique cutting. Causes & amount of chip flow deviation. Free & Restricted cutting. Geometry & characteristics of chip forms (chip reduction coefficient or cutting ratio, shear angle), Dynamic shear strain in chip formation. Velocity relationship, kronenberg relationship, BUE formation. Effect of cutting variables on chip reduction coefficient. Criticism of single shear plane theory. Chip formation in drilling & milling.

Mechanics of Metal cutting: Benefit of knowing & purpose of determining cutting forces. Cutting force components & their significances. Stablers rule, Merchant's circle diagram (MCD): Assumptions & its use. Frictional & shear plane force systems. Advantageous use of MCD & some limitations of use of MCD. Development of cutting forces under orthogonal & oblique cutting, Stress in conventional shear plane & Energy of cutting process. Ernst-Merchant angle relationship & Lee-shaffers relationship. Obliquity effects in restricted cutting, Effect of wear land on force system, computation of cutting forces & empirical relations, Merchants second solution & machining constant, Bridgeman effect, Design requirements of dynamometer, Dynamometer for turning process, drilling. Design of single point & high production cutting tools, Tool tips, optimization of tool shape & chip breakers.

Contact phenomena: Nature of contact between chip & tool, Determination of natural contact length, Hahns & Zorev analysis, stagnant phenomena at contact surfaces, Formation of BUE & contact phenomena, Kinetic coefficient of friction & stresses at chip tool interface.

Thermal aspects & cutting fluids: Heat generation in metal cutting, shear plane temperature, average chip tool interface temperature, theory of cutting fluid action at the chip tool interface & techniques of application, hot machining, Dry machining & minimum quantity lubrication (MQL).

Tool wear, tool life & machinability: Mechanism of plastic failure, form stability, progressive tool wear & causes, flank & crater wear, Taylors tool life equation, Tool life (Definition in R&D, industries or shop floor), factors affecting tool life, derivation of Taylors tool life equation, woxens tool life equation, experimental techniques for evaluating Taylor exponent, wear measurement methods. Machinability criteria, tests & indices, factors affecting machinability. Role of variation of machining parameters or factors on machinability of work materials. Possible ways of improving machinability of work materials, Dynamic characterstics of the cutting processes & machine tool, stability analysis, chatter & vibration in machine tools.

Surface finish & surface integrity: Numerical assessment of the surface, Effects of parameters on surface finish, measures of surface roughness, expressions for surface roughness in machining with single point tool, surface integrity**,** methods of improvement.

Text Books:

1. *Metal cutting (Theory & practice),* A. Bhattacharya, Central Pub.,1984
2. *Fundamental of machining & machine tools*, Boothroyd & Knight, Taylor & Francis Pub., 2006

Reference Books:

1. *Metal cutting (Theory & practice),* David A.Stephenson & J.S.Agapiou, Taylor & Francis Pub.2006
2. *Metal cutting principles*, M.C. Shaw, Oxford Pub., 2005
3. *Metal cutting,* Trent & Wright, Elsevier Pub.,4th edition, 2000
4. *Metal cutting & tool design,* V. Arsinov, MIR Pub., 3rd edition, 1996.

ME6116 OPTIMIZATION TECHNIQUES Cr-03

Course outcome: At the end of the course, student will be able to:

CO1. understand importance of optimization of industrial process management.

CO2. apply basic concepts of mathematics to formulate an optimization problem and solve it by simulation.
CO3. analyse and appreciate variety of performance measures for various problems like game theory
CO4. define and Use Optimization Terminology and some multi-criteria decision making (AHP and ANP).
CO5. apply unconstrained & constrained search methods for optimization theory for continuous problems, including the necessary and sufficient optimality condition.
CO6. apply constrained optimization theory for continuous problems, including the Karush-Kuhn-Tucker conditions and algorithms such as: quadratic & separable programming

Introduction to optimization: Design vector, design constraints, constraint surface, objective function, classification of optimization problems
LPP: Mathematical Formulations of the problem, general linear programming problem, canonical and standard forms Fundamental properties of solution to L.P.P. Computational procedure. Simplex method, Artificial variable techniques, Big-M & Two phase method, Problem of Degeneracy.
Concept of Dualities: Fundamental properties of duality, Fundamental theorem of Duality and simplex Method, Dual Simplex algorithm.
Sensitivities Analysis: Discrete changes in cost vector and requirement vector.
IPP: Importance, Gomory's cutting plane method, Branch and Bound Technique.
NLPP: Problem of constrained maximum and minimum Kuhn Tucker conditions, quadratic programming, Wolfe's & Beale's Method. Goal programming.
Statistics & design of experiments: Frequency Distribution & Histograms, Probability & its Distribution, Measures of Central Tendency & Distribution, Presentation of Statistical Data. Confidence intervals, Hypothesis Testing, Correlation, Liner & Multiple Repression Analysis, Signification Testing. Full & fractional factorial experiments, analysis of variance, Latin squares, response surface methodology, Taguchi techniques.
Neural Networks: Machine Learning Using Neural Network - Adaptive Networks – Feed forward Networks – Supervised Learning Neural Networks – Radial Basis Function Networks - Reinforcement Learning – Unsupervised Learning Neural Networks – Adaptive Resonance architectures – Advances in Neural networks.
Fuzzy Logic: Fuzzy Sets – Operations on Fuzzy Sets – Fuzzy Relations – Membership Functions- Fuzzy Rules and Fuzzy Reasoning – Fuzzy Inference Systems – Fuzzy Expert Systems – Fuzzy Decision Making.
Neuro-Fuzzy Modeling: Adaptive Neuro-Fuzzy Inference Systems – Coactive Neuro-Fuzzy Modelling – Classification and Regression Trees – Data Clustering Algorithms – Rule base Structure Identification – Neuro-Fuzzy Control – Case studies.
Genetic Algorithms: Introduction to Genetic Algorithms – Applications of GA in Machine Learning - Machine Learning Approach to Knowledge Acquisition – Reproduction – Crossover – Mutation.

Text Books:
1. Engineering Optimization: Theory and Practice, S. S. Rao, New Age International (P) Ltd, 3rd Edition
2. Soft Computing by D.K. Pratihar, Narosa Publications

Reference Books:
1. Design & Analysis of Experiments, M.C. Montgomery, John Wiley & Sons, 2006
2. Quality & Robust Engineering, M.S. Phadke, Prentice Hall; 1 edition (May 22, 1989)
3. Taguchi Techniques in Quality Engineering, Phillip J. Ross, McGraw-Hill Professional; 2 editions (August 1, 1995)
4. Engineering Optimization, Ravindran and Phillips, McGraw Hill.

ME6117 ADVANCED MANUFACTURING AND FABRICATION PROCESSES Cr-03

Course outcome: At the end of the course, student will be able to:

CO1. conceptualize the principle, applications, advantages and limitations of non-conventional Manufacturing processes.
CO2. prepare process plan in context of adaptability of the non-conventional manufacturing processes.

CO3. develop mathematical model and compute material removal rate on different non-conventional manufacturing processes.
CO4. comprehend and apply the science of welding to improve welding process performance.
CO5. evaluate strategies towards mitigating the challenges in non-traditional forming processes.
CO6. select materials and fabrication processes in context of weldability.

Need of non-conventional manufacturing processes, Considerations in process selection. Overview of non-traditional machining processes.

Principle, applications, advantages and limitations of non-conventional machining processes (Ultrasonic Machining, Abrasive jet machining, abrasive-water jet machining, ECM, EDM, Wire-EDM, EBM, LBM)

Mechanics of material removal in above processes, Development of mathematical model for computing MRR, Process parameters and their effect on MRR, accuracy and surface integrity

Principle and applications of explosive forming, electro-hydraulic and electro-magnetic forming, fundamentals of contour roll forming and stress forming techniques.

Mechanism and types of metal transfer in welding. Heat flow in welding, residual stress measurement, distortion prevention; Weldability of plane carbon, Stainless steel and Aluminium, Cast iron.

Principle and applications of TIG, MIG, MMAW, CO_2 welding, SAW, Resistance, friction, diffusion, Ultrasonic, electron beam and laser welding process and Ultrasonic welding processes

Text Books:

1. *Modern machining process,* P.C. Pandey, H.S. Shan, TMH, 33rd reprint, 2008
2. *Non-conventional machining,* P.C. Mishra, Narosa publishing house, 3rd reprint, 2005

Reference Books:

1. *Manufacturing science,* A. Ghose & A.K. Mallik, East-west press, 2001
2. *Welding & Welding technology,* R. Little, TMH, 2004
3. *Welding Engineering & Welding Technology,* R. S. Parmar, Khanna Publisher, 1997

ME6118 PROJECT PLANNING AND CONTROL Cr-03

Course outcome: At the end of the course, student will be able to:
CO1. develop plans with relevant people to achieve the project's goals
CO2. break work down into tasks and determine handover procedures
CO3. identifies links and dependencies, and schedule to achieve deliverables
CO4. estimate and cost the human and physical resources required, and make plans to obtain the necessary resources
CO5. allocate roles with clear lines of responsibility and accountability.
CO6. understand the roles of project manager and selection of project.

Project Management Concepts and Needs Identification

Attributes of a Project, Project Life Cycle, The Project management Process, Global Project Management, Benefits of Project Management, Needs Identification, Project Selection, Preparing a Request for Proposal, Soliciting Proposals, Project organization, the project as part of the functional organization, pure project organization, the matrix organization, mixed organizational systems.

Project Planning and Scheduling

Design of project management system; project work system; work breakdown structure, project execution plan, work packaging plan, project procedure manual; project scheduling; bar charts, line of balance (LOB) and Network Techniques (PERT / CPM), Crashing.

Project Monitoring and Control and Project Performance

Planning, Monitoring and Control; Role of Production, Planning & Control (PPC), New Product Development & Process Design, Aggregate Planning: Relevant cost; Evaluation of strategic alternatives (Level, Chase and mixed, types of capacity, Economics and Diseconomies of scale, Developing capacity alternatives Project Audit; Project Audit Life Cycle.

The Project Manager

Responsibilities of the Project Manager, Skills of the Project Manager, Developing the Skills needed to be a Project Manager, Delegation Managing Change, Developing a Winning Proposal, Proposal Preparation, Proposal Contents, Pricing Considerations, Proposal Submissions and Follow-Up, Customer Evaluation of Proposals.

Text Books:

1. *Project Management,* James P. Clements & Jack Gido, Cengage Learning, 5th edition, 2012

Reference Books:

1. *Project Management: A Managerial Approach*, Jack R. *Meredith*, Samuel J. *Mantel*, Jr., 8th Edition, *Wiley Publications,* August 2011

ME6119 ROBOTICS AND ROBOT APPLICATIONS Cr -03

Course Outcomes: At the end of the course, the students will be able to:

CO1. understand the use of robots and design the robotic path generation
CO2. understand the kinematics and dynamics of robotic manipulator
CO3. use the different drive systems for different robot application and analyze the sensing and vision of a robot
CO4. understand the robotic programming languages and their application
CO5. understand the need of flexible manufacturing and application of robot in it
CO6. select appropriate tooling for manufacturing the part in integrated environment.

Robot Introduction – Definition – Classification and Specification. Work envelops and other basic parameters of Robots.
Mechanics: Kinematic Parameters and Modeling- Direct and Inverse Kinematics - Differential motion and jacobians – Introduction to Dynamics Path planning – Trajectory Planning and Control – Slew, Joint interpolated and straight line motion.
Hardware: Drives: Electric, Hydraulic, Pneumatic and their relative merits.
Sensors, And-effectors: Tool handling and work handling and special devices like harmonic drives, servo valves etc.
Vision: Low level and higher level vision – fundamentals, image acquisition, recognition, interpretation – a few basic examples in Robotics.
Robot Applications
Robot Programming concepts – Off-line programming and simulation – work cell application development: requirements; modeling, work cell calibration; layout planning, Case studies in assembly, machine loading / unloading, palletizing, deburring etc.

Text Books:

1. *Robotics Technology & Flexible Automation,* S.R. Deb & S. Deb, Tata McGraw Hill, 2010

Reference Books:

1. *Robot Dynamics & Control,* M.W. Spong & M.Vidyasagar, Wiley, 1989
2. *Robotic Systems: Advanced Techniques & Applications,* S.G. Tzafestas, Kluwer, Academic publisher, 1992

ME6122 FINITE ELEMENT ANALYSIS Cr -03

Course Outcomes: At the end of the course, the students will be able to:

CO1. obtain an understanding of the fundamental theory of the Finite Element Analysis (FEA).
CO2. generate the governing finite element equations for systems governed by partial differential equations.
CO3. formulate and solve various complicated beam problems using Galerkin's Technique.
CO4. understand the use of the basic finite elements to solve the bar and truss problems.
CO5. understand the application and use of the one-dimensional and two-dimensional problems.
CO6. solve complicated engineering problems using FEM software.

Introduction: Overview of FEM, General description of FEM, Engineering Application of FEM.

Basic Procedure: Discritization of domain, interpolation models, simplex, complex and multiplex elements, selection of the order of the interpolation, convergence requirements, linear interpolation polynomialsin Global and local co-ordinate system.
Higher Order and Isoparametric Elements: Higher order elements in terms of Natural co-ordinate system, one dimensional elements using classical interpolation polynomials, two dimensional elements using classical interpolation polynomials, Isoparametric elements, numerical integration.
Derivation of Element Matrices and Vectors: Direct Approach, Variatonal approach, derivation of Finite Element equations using Rayleigh-Ritz and Galerkin Method, Solution of eigenvalue problems using weighted Residual approach.
Assembly of Element Matrices and Derivation of System Equations: Co-ordinate transformations, Assemblage of Element equations, Incorporation of boundary conditions.
Application to Solid Mechanics and Heat Transfer Problems: Formulation of solid and structural mechanics, formulation of FE equations (Static Analysis), application to (Truss Elements, Beam Elements, Triangular Elements, Tetrahedral Elements)

Text Books:

1. *The Finite Element Method in Engineering,* S.S. Rao, Elsevier Publications, 2011

Reference Books:

1. *Concept and Application of FEM,* R.D. Cook & D.S. Malkus, Wiley, 3rd edition, 1989

ME6124 RAPID RESPONSE MANUFACTURING Cr-03

Course Outcomes: At the end of the course, the students will be able to:

CO1. understand the concept of additive manufacturing, its benefits and applications
CO2. know the various liquid, powder and solid material based technologies in Rapid Prototyping and Rapid Tooling.
CO3. design solid models and converting it to STL file format required for part generation.
CO4. focus on the various errors in the RP parts
CO5. develop rapid tooling techniques.
CO6. apply reverse engineering for generating RP parts.

Definition & concept of Rapid Prototyping processes, Need of RP in context of batch production, Lead time reduction in design; Concurrent engineering: concepts, tools and techniques; Basic principles of RP, Steps in RP, Process chain in RP in integrated CAD-CAM environment, Advantages of RP.
Classifications of different RP techniques based on raw material, layering technique (2D or 3D) and energy sources.

Process Technology, Basic concept & process detail of RP process like Stereo-lithography (SL), Solid foil polymerization, Selective laser sintering, Selective powder binding, Ballistic particle manufacturing both 2D and 3D, Fused Deposition Modeling, Shape Melting, Laminated Object Manufacturing, Solid Ground Curing, Repetitive Masking and deposition, Beam Inference Solidification, Holographic Interference Solidification.
Special Topic on RP using metallic alloys Solid ground curing laminated object manufacturing, fused deposition modeling, three dimensional printing, ballistic particle manufacturing & vacuum casting, their advantages applications & limitation.
Programming in RP, Modeling, Slicing, Internal Hatching, Surface Skin Fills, Support Structure

Technology for Rapid Prototyping: Selection of materials, Development of 3D model & transforming it to the RP machine, Supporting techniques & development of the workpiece, Post processing part removal, part cleaning, post curing, part finishing, machine accuracy & part accuracy.
Some case studies & application of Auto industry, die-making industry, medical appliances, etc.

Text Books:

1. *Rapid prototyping & Manufacturing Fundamental of Stereo-lithography,* Paul F. Jacobs, SME Publications,1992

Reference Books:

1. *Rapid Prototyping,* Amitabha Ghosh, East West Press Pvt. Ltd, 1997
2. *Rapid Prototyping, Principles and Application,* C.K. Chua, K.F. Leong and C.S. Lim, World scientific publishing Co. Pvt. Ltd., Singapore, 2005

ME6126 FLEXIBLE MANUFACTURING SYSTEMS Cr-03

Course Outcomes: At the end of the course, the students will be able to:

CO1. understand the use of robots and design the robotic path generation
CO2. understand the kinematics and dynamics of robotic manipulator
CO3. use the different drive systems for different robot application and analyze the sensing and vision of a robot
CO4. understand the robotic programming languages and their application
CO5. understand the need of flexible manufacturing and application of robot in it
CO6. select appropriate tooling for manufacturing the part in integrated environment.

Definition and broad characteristics of flexible Manufacturing Cells, Systems, Islands and Flexible transfer lines.
Place of flexible manufacturing systems in CIM – The FMS relational: Economics and technological justification for FMS
Design and Planning: the role of associated technologies such as GT, JIT and simulation Installation, Operation and evaluation – Scheduling problems
FMS hardware CNC machines tools, robots, AGVs, ASRs, Inspection and Cleaning stations – Control aspects of FMS-DNC of machine tools, cutting tools, robots, quality control and inventories.
Personnel and infrastructural aspects – Flexible machining cells and islands – Flexible assembly Systems, structure, control and applications – FMS in action: Typical case studies. Future prospects.

Text Books:

1. *Flexible manufacturing systems: current issues and models,* F.Choobineh, R. Suri, Industrial Engineering and Management Press, Institute of Industrial Engineers, 1986

Reference Books:

1. *Modeling, simulation, and control of flexible manufacturing systems: a Petri net approach,* Vol 6 of Series in Intelligent Control and Intelligent Automation, M.C.Zhou, K.Venkatesh, World Scientific, 1999
2. *Automation, production systems, and computer-integrated manufacturing*, M.P.Groover, Prentice Hall, 2007

3. *Flexible manufacturing systems: the technology and management*, R.A.Maleki, Prentice Hall, 1991

ME6134 PRODUCTION SYSTEM DESIGN AND CONTROL Cr-03

Basic concepts of systems and concerning chaos / problems; System design and decision support / making system for management; System design approach; Evolution of production systems; Elements of production systems and their interaction; Types and classifications of production systems; Recent manufacturing strategies; Dynamics and performance evaluation of production systems; Basic concept of production system modeling, evaluation, optimization and simulation; Introduction to concurrent engineering and its applicability to production system design
Production levels and modes; Design requirements of production system; Architecture and methodologies of production system; Group technology: process and machine characteristics; JIT and Kankan; Automation systems for production; Layout designs: flexible, computer aided and computer integrated layouts; Concept of computer-aided design (CAD) and computer aided process planning (CAPP), Computerized layout planning

Production control strategies; Demand forecasting; Capacity and aggregate production planning; Inventory Management; Logistic planning; Production scheduling; Shop floor control; Process planning: alternative solutions and computer aided techniques; Assessing cost effectiveness; Importance of optimization in production; Global optimization methods;

Concept of artificial intelligence and its application for optimization
Framework of production systems and supply management; Performance measurement and tools of production systems; Simulation and modeling of production systems
Design of information system for manufacturing, machining, etc; Parts oriented production information system; Information networking for strategic information system for production; Development of knowledge based production system, Concept of on-line and off-line production control systems, Role of computer in production management systems.

Social production modes; Human centered production system; Basic concept of KANSI and its role in production system; Social system for production system, Concepts and approaches to manufacturing excellence
Case studies of production support system, machinery manufacturer and replacement of production machine.

Text Books:

1. Manufacturing Systems Engineering, K. Hitomi, Viva Books, New Delhi, 2008

Reference Books:

1. Re-Engineering the Manufacturing System: Theory and Applications, Robert E. Stein, Marcel Dekker, New York, 2005
2. Computer Integrated Manufacturing Technology and Systems, U. Rembold, C. Blume & R. Dillmann, Marcel Dekker, New York, 2004
3. Manufacturing System Redesign-Creating the Integrated Manufacturing Environment, David O'Sullivan, Prentice Hall, New Jersey, 2002

ME6136 COMPETITIVE MANUFACTURING STRATEGIES Cr-03

Introduction to the Competitive Environment in Market, WTO Agreement and its Effect on Indian Industries, Manufacturing as a Competitive Strategy, Competitive Advantages and Disadvantages

Manufacturing Challenges, Manufacturing Audit, Product Variety, Modular Design, Introduction to DFX Methodologies, Design for Manufacturing, Simulation as Tools for Competitive Manufacturing

Selection of Manufacturing Strategies / Systems for Different Manufacturing Scenarios, Dedicated Manufacturing Systems, Flexible Manufacturing Systems (FMS), Cellular Manufacturing Systems (CMS), Re-Configurable Manufacturing System (RMS), Computer Integrated Manufacturing (CIM)

MRP-I, MRP-II, TQM, TPM, Six Sigma, Agile Manufacturing, JIT Manufacturing, Kanban System, Rapid Response Manufacturing, World-Class Manufacturing, Molecular Manufacturing, Value Analysis / Engineering and Cost Reduction, Product Life Cycle Management (PLM), Lean Principles and their impact on Manufacturing Cycle Time, Lean Manufacturing, Lean Six Sigma, Core Process Reengineering, Kaizen

Effect of Industrial Activity on Environment, Basic Concepts of Clean Technologies and Eco Friendly Manufacturing; Design, Planning and Implementation of Clean Production, Type of Wastes in Manufacturing Industries, Causes of Waste Generation and its Elimination Strategies, Resource Recovery and Recycling, Product Reengineering / Remanufacturing and Demanufacturing.

Dynamic Customer, Supply Chain Management, Vendor Development and Rating, Evolution, Characteristics and Features of ERP, Network Based Manufacturing, Intelligent and Innovative Manufacturing, E-Manufacturing, Factories of Future (FOF)

Text Books:

1. Manufacturing Excellence in Global Markets, W. Euershelm, Chapman & Hall, 1996

Reference Books:

1. Manufacturing Systems Design and Analysis: Context and Techniques, B. Wu, Springer, 1994
2. Intelligent Manufacturing Planning, P. Gu, Chapman & Hall, 1995
3. Fast Track to Waste Free Manufacturing, J.W. Davis, Productivity Press, USA, 1999
4. Clean Production: Environment & Economic Perspective, K.B. Misra, Springer - Verlog, 1996
5. Techniques of Value Analysis & Engineering, L.D. Miles, McGraw-Hill, 1972

ME6142 QUALITY ENGINEERING AND MANAGEMENT Cr-03

Course outcomes: At the end of the course, student will be able to:

CO1. compare and appreciate the contributions of Quality Gurus
CO2. understand quality engineering methods and tools
CO3. apply SQC methods to improve quality of products and services
CO4. gain the knowledge regarding sampling plans
CO5. understand the concept of acceptance sampling and OC Curve
CO6. have a working knowledge of the techniques of reliability engineering.

Attributes of quality, Evolution of philosophy of Quality Management, Economics of quality and measurement of cost of quality, Data presentation techniques for quality analysis, Statistical process control, Use of control charts and process engineering techniques for implementing quality plan, Machine and process capability analysis, statistical tolerance analysis.
Acceptance sampling: Single, double and multiple sampling plans, Acceptance sampling for variables Reliability analysis and predictions, Bath-Tub Curve, Exponential and Weibull distribution in modelling reliability, System reliability

Experimental designs and factorial experiments: Concepts of randomization, Blocking and Confounding Single factor randomized design, ANOVA, 2 k factorial experiments Taguchi philosophy; Loss function; Signal to noise ratio, Orthogonal arrays for parameter and tolerance design.

Fundamentals of TQM: Customer orientation, Continuous improvement, Total participation; Some important philosophies and their impact on quality (Deming, Juran, Crossby), QC Tools, Components of Total Quality System (TQS), Quality audit, Introduction to ISO 9000 and 14000 standards.

Text Books:
1 Quality and Process Improvement, Mark A. Fryman, Delmar Thomson Learning, 2002
2. Quality Planning and Analysis, Juran J M and Gryna F M, Tata McGraw Hill, 2001

ME6144 ADVANCED MATERIALS AND PROCESSING Cr-03

Polymers and polymerization: structure and properties of thermoplastics and thermosets, engineering applications, property modifications -mechanical, thermal behaviour, Processing of polymers

Advanced Composite Materials and their Applications: Introduction, Fibers, Matrix materials, Material forms and fabrication methods, Current applications, fabrication of composites.

Concepts of composite mechanics: Macro-mechanics Material symmetry, Engineering constants, Coordinate transformations, Thermal effects, Moisture effects
Concepts of Micromechanics: Effective properties, Survey and model comparison from strength of materials approximations, continuum mechanics approaches.
Laminate analysis: Stress-strain relationship for an orthotropic lamina, Orthotropic properties in plane stress, Deformation due to extension and bending, A, B, D matrices, Hygro-thermal behavior, Average stress-strain properties
Concepts of failure of laminates: Tensile failure of fiber composites, Compressive failure of fiber composites, Effect of multi-axial stresses (failure criteria by Tsai-Wu, Hashin, etc.)

Glasses, glass ceramics, fabrication methods, metal matrix and ceramic matrix composites, Processing of ceramics: thermal spraying, ion beam machining, laser and electron beam processing, super-plastic forming, Thin films and their deposition, diamond coating techniques, Tribological applications.

Text Books:
1. Elements of Material Science & Engineering, V. Vlack, Pearson Education, 2008

Reference Books:

1. Materials science and engineering: An introduction, W.D. Callister, John Wiley & Sons, 2007
2. Materials Science and Engineering: A First Course, V. Raghavan, PHI Learning Pvt. Ltd., 2004
3. Fundamentals of composites manufacturing: materials, methods and applications, A.B. Strong, Society of Manufacturing Engineers, 2008
4. Carbon fiber composites, Deborah D.L. Chung, Butterworth-Heinemann, 1994

ME6150 MICROFORMING Cr-03

Course Outcome: At the end of the course, the students will be able to:

CO1. understand the difference between Bulk forming and Micro forming processes.
CO2. identify the suitable micro forming processes for different metal and applications.
CO3. understand the importance of material and machine handling during Micro forming processes.
CO4. analyze and model the forming operations at micro scale.
CO5. understand microfabrication of semiconductor
CO6. know the various application of micro forming in industry.

Basics of Micro-manufacturing, Size effects, Microstructural effects, Mechanics of micro-forming, Mechanical property at micron-scale, Micro-forming processes Micro-Rolling, Micro-Extrusion, Micro-Drawing, Micro-stamping, micro- Punching, Electromagnetic forming, Micro-laser forming, Micro-forming machines, tooling and handling, Quality, inspection and process control; Modelling and analysis at micro-scale, Simulation of Micro-forming processes, Micro fabrication in semiconductor industry, , Micro-forming of Polymers, Applications of micro forming.

Text book:

1. Micro Metal Forming; Editor: Vollertsen, Frank; Springer Publication; 2013; ISBN 978-3-642-30915-1
2. Micro-Manufacturing: Design and Manufacturing of Micro-Products; Editor(s): Muammer Ko303247 and Tuğrul 303226zel; Willy publication; 2011; ISBN: 978-0-470-55644-3

Reference book:

1. Advanced Methods in Metal Forming, D. Banabic, Springer Publication; 2007; ISBN 978-3-540-69845-6
2. Metal Forming- Mechanics and Metallurgy; William F. Hosford and Robert m. Caddell; Cambridge Univ. Press; 2007; 978-0-521-88121-0

ME6152 MATERIALS MANAGEMENT Cr-03

Introduction to materials, productivity and role of materials management, techniques of improved material productivity, cost reduction and value improvement. Role of purchasing in cost reduction.

Value analysis for right choice and rationalization of materials. Purchasing research identification of right sources of right suppliers. Vendor rating.
Standardization and variety reduction, negotiation and purchase. Price analysis. Organization of purchasing functions. Product explosion. Materials requirement planning, make or Buy decisions. Incoming materials control, acceptance sampling, inspection. Vendor satisfaction plans. Vendor and supplier reliability.

Inventory management. ABC-VED analysis. Various inventory models. Inventory models with quantity discounts. Exchange curve concept and coverage analysis. JIT. Information systems for inventory management. Stores management and ware housing. Optimal stocking, issuing policies. Inventory management of perishable commodities. Surplus management. Design of inventory distribution systems. Monitoring MM effectiveness, Case studies.

Text Books:

1. Materials management: procedures, text and cases, A.K. Datta, PHI, 2004

Reference Books:

1. Materials management: an integrated approach, P. Gopalakrishnan, M. Sundaresan, PHI, 2004
2. Materials management: a systems approach, G.K. Beekman-Love, L. Nieger, Martinus Nijhoff Social Sciences Division, 1978
3. Materials Management: Text and Cases, A.K. Chitale, R.C. Gupta, PHI, 2007

ME6154 MECHATRONICS Cr-03

Course Outcomes: At the end of the course, the students will be able to:

CO1. select and apply the knowledge, techniques, skills and modern tools in mechatronics engineering technology.

CO2. apply concepts of circuit analysis, analog and digital electronics, automation and controls, motors, electric drives, power systems, instrumentation, and computers to aid in the design, characterization, analysis, and troubleshooting of mechatronics systems used in industries as well as home appliances.

CO3. apply the different drive systems for actuation of various parts and components of a system.

CO4. understand the different controllers used in industries, machines and industrial robots.

CO5. understand the concept of CNC machining

CO6. develop the G code for part programming

Introduction – Definition of Mechanical Systems, Philosophy and Approach. Embedded Microprocessor Systems – Hardware Structure, Software Design and Communication. Programmable Logic Devices, Application Specific ICs, Automatic Control and Real time Control Systems, Fuzzy Logic Control. Systems and Design, Modeling, Analysis and Simulation, Man-Machine Interface.

Sensors and Transducers – Classification, Development in Transducer Technology-Semiconductors, Thick film and Thin film Elements, Signal Processing, Opt-electronics – Shaft Encoders, CD Sensors, Optical probe for Metrology, Vision System, etc.
Drives and Actuators – Hydraulic and Pneumatic Drives, Electrical Actuators such as Servo Motor and Stepper Motor – Drive circuits, Open and Closed loop control, Piezoelectric and Magnetostrictive Actuators
Materials, Static and Dynamic characteristics, Illustrative examples for Positioning, Vibration Isolation etc.
Micromechatronic Systems – Microsensors, Microactuators, Smart Instrumentation, Micro-fabrication techniques
Lithography, etching, Microjoining etc; Application Examples. Case studies – Examples of Mechatronic Systems from Robotics, Manufacturing, machine Diagnosis, Road Vehicles and Medical Technology.

Text Books:

1. *Mechatronics*, N.P. Mahalik, Tata McGraw-Hill, 2003

Reference Books:

1. *Mechatronics, Infinity Science Series, Engineering Series*, G. Hegde & G.S. Hegde, Jones & Bartlett Learning, 2010
2. *Mechatronics: an introduction*, R.H. Bishop, Taylor & Francis, 2006
3. Mechatronics, M.D. Singh & J.G. Joshi, PHI Learning Pvt. Ltd., 2006
4. Mechatronics: principles and applications, G.C. Onwubolu, Butterworth-Heinemann, 2005
5. Mechatronic systems: Fundamentals, R. Isermann, Birkhäuser, 2005
6. System Dynamics: Modeling and Simulation of Mechatronic Systems, Karnopp, Wiley-Interscience, 2000

ME6164 MANUFACTURING SYSTEMS ENGINEERING Cr-03

Types of manufacturing – product variety vs production volume; Manufacturing decisions, strategies & priorities; Manufacturing system paradigm; Characteristics and types of manufacturing systems; Factors and tools for system development; Advent of advanced manufacturing technologies & systems; Product manufacturing cycle; Stages & phases of system development life cycle (SDLC); Problem definition & system modeling; System reliability & its assessment; Considerations of reliability & maintainability in product design; FMECA & criticality analysis; Fault tree analysis; Design for reliability (DFR)

Components of manufacturing system; Manufacturing system classification; Facility layout; Modified manufacturing cells; Single system manufacturing cells; Group technology (GT) & creation of part families; GT machine cell design; Basic concept of flexibility; Types of manufacturing flexibility; Flexible manufacturing systems (FMS); Computer integrated manufacturing systems (CIMS)

Product components & new product; Importance & stages of new product development (NPD); Designing a product for customer; Basic concept of design for manufacturing (DFM) & design for assembly (DFA); Sequential engineering vs concurrent engineering (CE); Fundamentals, essence & techniques of CE; Major elements & building blocks of CE; Designing a CE environment

Parametric design & quality control during manufacturing; Introduction to design of experiment (DOE) & Taguchi technique for manufacturing system design; Introduction to material requirement planning (MPR) and manufacturing resource planning (MPR-II), Just-in-time (JIT) production system; Theory of constraints (TOC); Synchronous manufacturing; Basics of demand forecasting techniques & inventory management system; Lot sizing & operation scheduling
Introduction to world class manufacturing system (WCMS); Waste reduction; Toyota production system & the Toyota way; Basic concept of integrated logistics & supply chain management (SCM); Tapping human resources & building a learning environment; Introduction to knowledge management system (KMS)

Case study of automation in manufacturing unit, productivity in Japan & India, failure of refrigerators in GE Company and implementation of simultaneous engineering at Cadillac Automobile Company (division of General Motors)

Text Books:

1. Manufacturing systems engineering, B. Bhadury, Macmillan India, 2009

Reference Books:

2. Mechanical system design, R.C. Mishra & Simant, PHI, 2009
3. Mechanical system design, W.E.Eder & W.Gosling, Pergamon Press, 1965
4. Mechanical system design, S.Patil, Jaico Publishing House, 2008
5. Mechanical system design, K.U.Siddiqui, M.K.Singh & M.A.Faruqi, New Age International (P) Ltd., Publishers, 2007

ME6166 MANUFACTURING PLANNING AND CONTROL Cr-03

Course outcomes: At the end of the course, students will be able to:

CO1. take the decisions in conversion process, manufacturing strategy, product planning and forecasting product demand
CO2. take the decisions in process planning and design, performance measures, capacity planning
CO3. take the decisions in selection of facilities location and design the facilities layout
CO4. generate the aggregate plans, master schedules, short-term schedules
CO5. generate material requirements planning and strategies for manufacturing excellence

Manufacturing operations and manufacturing strategy for competitive advantage, product planning, forecasting product demand, facilities location, process selection and design, capacity planning, layout of facilities, job design and work measurement, aggregate planning, master manufacturing schedules, material requirement planning for dependent demand, short term schedules and shop floor control, independent demand inventory systems, strategies for manufacturing excellence.

Text Book:
1: Heizer Jay and Render Barry "Operations Management", 11th Edition, 2013, Pearson.

Reference Books:
1. Stevenson William J, “Operations Management”, 12th Edition, 2017, McGraw Hill
2. Mahadevan, B. (2010), “Operations Management: Theory and Practice”, 2nd Edition, Pearson Education, New Delhi

ME6168 Lean Manufacturing Cr-03

Course outcomes: At the end of the course, students will be able to:

CO1. understand the necessary for lean production and basic image of lean production
CO2. practice the concept of stability: 5S System and TPM
CO3. practice standardized work and lean thinking
CO4. implement Just-in-Time production, Jidoka, Kaizen circle activity, Hoshin planning and culture of lean production
CO5. create value through value stream mapping process
CO6. implement the concepts of “The Toyota Way” (14 Management principles)

Birth of lean production, lean production system, stability, standardized work, just-in-time, jidoka, involvement, hoshin planning, the culture, value stream mapping process, the 14 principles of Toyota way.

Text books

1. Pascal Dennis, "Lean Production Simplified", 2nd Edition, Productivity Press, 2007.
2. Jeffrey K. Liker, “The Toyota Way”, MaGraw-Hill Edition, New Delhi, 2004.
3. Don Tapping, Tom Luyster and Tom Shuker, “Value Stream Management”, Productivity Press, New York, 2002

Reference books

1. Mike Rother, “Learning to See: Value Stream Mapping to Create Value & Eliminate MUDA”, Lean Enterprise Institute, 2003.
2. Jeffrey K Liker and Divid Meier, “The Toyota Way Field Book: A Practical Guide for Implementing Toyota’s 4Ps”, Tata MaGraw-Hill Edition, 2006.
3. John Allen, Charles Robinson and David Stewart, “Lean Manufacturing: A Plant Floor Guide”, Society of Manufacturing Engineers, Michigan, 2001.
4. Mike Rother, “Toyota Kata: Managing People for Improvement, Adaptiveness, and Superior Results”, Tata MaGraw-Hill Edition, 2010.

Specialization: Thermal Engineering

ME 6211 ADVANCED FLUID MECHANICS Cr-3

Course outcomes: At the end of the course, students will be able to:
CO1: Gain a knowledge of different fluid forces causing the fluid flow and understand the stress tensor
CO2: Understand the continuity and momentum equation in fluid motion
explain the conservation equations in different fluid flow problems
CO3: Understand the concepts of boundary layer and its estimation in different flows
CO4: Analyze the flow over different geometries
CO5: Develop the skill to apply analytical and numerical methods used to solve fluid dynamics problems.
CO6: Interpret the stability of fluid flow

Fluid Forces: body forces, surface forces- stress tensor and concept of pressure.

Description of Fluid motion: Eulerian and Lagrangian description; substantial derivative, Reynolds' transport theorem; Rates of linear and angular strain; Rotation, Decomposition of Velocity gradient matrix into symmetric and anti-symmetric part; normal and shear stresses; Navier–Stokes' equation. Transport theorems, constitutive equations, derivation of Navier Stokes equations for compressible flow.

Applications of Navier Stokes equations: plane Poiseuille flow and Couette flow, Hagen-Poiseuille flow, flow between two concentric rotating cylinders, Stoke's first and second problem, and Hiemenz flow.

Slow Viscous flow: Stokes and Oseen's approximation, Boundary layer: derivation, exact solutions, Blasius, Falkner Skan, series solution and numerical solutions, Approximate methods, Momentum integral method.

Two–dimensional potential flow: Conformal transformation technique; Flow round a sharp edge; Joukowski transformation; Flow around an ellipse; Kutta condition and flow over thin air foil; Schwarz–Christoffel transformation.

Singular Perturbation Technique in fluid mechanics: Flow past a sphere; Linear stability theory; physical description of fluid instabilities; Klein–Helmholtz and Rayleigh–Taylor instabilities; Orr–Sommerfeld equation; Rayleigh's equation; stability; Stability curves; Squire's theorem for an inviscid flow.

Text Books:

1. Fluid Mechanics, R.N. Fox and A.T McDonald, John Wiley & Sons, 4th Ed., 1994.
2. Introduction to Fluid Mechanics, Shaughnessy, Oxford University Press, 4th Ed. 2004.

Reference Books:

1. Fundamentals of Fluid Mechanics, Schlitching, Springer Links, 2000
2. Fluid Dynamics, V.L. Streeter, Mc Graw-Hill, 1971
3. The dynamics and thermodynamics of compressible fluid flow, Vol. I & II, A.H. Shapin, The Ronald Press Co., 1955.
4. Foundations of Fluid Mechanics, S.W. Yuan, Prentice Hall of India, 1976.
5. Advanced Engineering Fluid Mechanics, Muralidhar & Biswas, Alpha Science International Ltd, 2005.
6. Principles of Fluid Mechanics and Fluid Machines, N.Pillai and C.R.Ramakrishnan, University Press, Hyderabad, 2006.
7. Fluid Dynamics, 3rd revised Ed., Dr. J.K Goyal & K.P. Gupta., Pragathi Prakasan, Meerut, 1989.
8. Hydrodynamics Theory & Application, Robertson, Prentice Hall of India, 1965.
9. Fluid Mechanics, P.K. Kundu, I.M. Kohen& D.R. Dowling, Academic Press, 2011

ME 6213 ADVANCED THERMODYNAMICS Cr-3

Course outcomes: At the end of the course, students will be able to:
CO1: Understand the laws of thermodynamics
CO2: Evaluate the useful and non-recovered work of a system during different processes
CO3: Determine the different thermodynamic properties of systems
CO4: Analyze the basic postulates in irreversible thermodynamics
CO5: Aware of molecular-level understanding of key thermodynamic quantities such as heat, work, free energy and entropy
CO6: Explain the availability analysis of different thermodynamic processes

Review of Fundamentals: Zeroth, first and second laws of thermodynamics; Concept of entropy generation.

Thermodynamic Relations: Exergy concept; Physical and Chemical Exergy; Helm Holtz function, Gibb's function, Reciprocity relation, Availability analysis for processes and cycles, Thermodynamic relations, Maxwell's relations, T-ds equations, specific heat relations, energy equation, Joule Thomson effect, Clausius-Claperyon Equation, Criteria for Equilibrium, Gibb's phase rule, The third law of thermodynamics.
Thermodynamics of Mixtures: Thermodynamic properties of homogeneous mixture and multiphase, multi-component systems; Chemical availability.
Irreversible Thermodynamics: Stability; Phase transition; Critical phenomena; Nernst postulate; General systems; Classical irreversible thermodynamics.
Statistical Thermodynamics: Thermodynamics probability, Maxwell statistics, Fermi Dirac and Bose – Einstein statistics, Entropy and probability, Degeneracy of energy levels, Partition functions.

Text Books:

1. Fundamentals of Classical Thermodynamics, G.J. Van Wylen & R.E. Sonntag, Willy Eastern Ltd. 1989 (Chapters: I, II & III)
2. Principles of Thermodynamics, J. Hsieg, McGraw Hill, 1978.

Reference Books:

1. Thermodynamic for Engineers, A.S. Michael, Prentice Hall, 1972.
2. Engineering Thermodynamics, 2nd Ed., P.K. Nag, McGraw Hill, 1995.
3. Thermodynamics, 4th Ed., J.P. Holman., McGraw Hill, 1988.
4. Statistical Thermodynamics, Lee and Sears, Addition Wesley, 1976.
5. Thermodynamics for Chemists, V. Nastrand & S. Glasstne, 1974.
6. Engg Thermodynamics for Engineers, M.D. Burghardt, Harper & Row, NY, 1987.
7. Advanced Thermodynamics for Engineers, K. Wark, McGraw Hill, NY, 1987.
8. Introduction to Chemical Engineering Thermodynamics, K. Smith & H.C. Van Ness, McGraw Hill, 1987.

ME 6215 ADVANCED HEAT & MASS TRANSFER Cr-3

Course outcomes: At the end of the course, students will be able to:
CO1: Understand the application of heat conduction in different heat transfer problems like anisotropic, inverse heat transfer problems, phase change problems, Non-Fourier problems.
CO2: Aware of the boundary layer theory; Be able to solve the external and internal laminar boundary flow and heat transfer.
CO3: Understanding of Natural convection and its applications
CO4: Understand the basics of radiative heat transfer
CO5: Understand the different solution methods of radiative heat transfer problems
CO6: Aware of basic principle of mass transfer process and its applications

Conduction: Review of heat transfer modes; Heat conduction in anisotropic media, Inverse heat conduction problems, Probability methods in heat conduction, Heat conduction in porous media, Phase change problems, Ablation, Moving heat source problems, Non-Fourier conduction problems.

Convection: Derivation of boundary layer equations by order of magnitude analysis; Solution of boundary layer equations by similarity variable and integral methods; Natural convection in boundary layers; Integral method, Boussinesq approximation and scaling analysis, Transport equations with discontinuous property variation. Conservation laws for interface phenomena, Concept of hydrodynamic and thermal stability, Rayleigh-Benard convection, Turbulent heat transfer, and Turbulent Prandtl number.

Radiation: Basic definitions, surface properties, view factors; Radiation exchange in black and grey enclosure; Radiosity matrix; Interaction of surface radiation with other mode of heat transfer. Radiative properties of real surface; Equation of radiative transfer in participating media; Radiative properties of molecular gases; Exact solution for one dimensional grey media; Approximate solution methods; Pn and Sn approximate methods; Zonal method; Monte Carlo method for thermal radiation; Experimental techniques on radiation heat transfer.

Mass Transfer: Basic definitions; Fick's law of diffusion; Species conservation equation; Solution of one dimensional mass transfer problem, Associated illustrations.

Text Books:

1. Fundamentals of Heat and Mass Transfer, F.P. Incropera and D. P. Dewit, John Wiley & Sons, 1998.
2. Heat and Mass Transfer, J.P. Holman, Tata McGraw Hill, 1989.

Reference Books:

1. Heat and Mass Transfer, Y.A.Cengel, Tata McGraw Hill, 2003
2. Convective Heat Transfer, L.C. Burmister, John Willey and Sons, 1983.
3. Fundamentals of Heat and Mass Transfer, C. P. Kothandaraman, New Age International, 1997.
4. Extended Surface Heat Transfer, D. D. Kern, New Age International Ltd., 1985.
5. Analysis of Heat and Mass Transfer, E. R. D. Eckert and R.M. Drake, McGraw Hill, 1980.
6. Convective Heat and Mass Transfer, W.M. Kays and W. Crawford, McGraw Hill Inc., 1993.
7. Fundamentals of Heat Transfer, Krith, Taylor & Francis, 2007.
8. Radiation Heat Transfer, E.M Sparrow, R.D Cess, 2009
9. Conduction Heat Transfer, V.S Arpaci, Ginn Press, 1991.

ME6216 COMPUTATIONAL HEAT AND FLUID FLOW Cr-3

Course outcomes: At the end of the course, students will be able to:
CO1: develop mathematical models for heat and fluid flow problems
CO2: choose appropriate boundary conditions to solve the numerical problems
CO3: Evaluate the accuracy of the numerical results
CO4: Understand the solution techniques for different numerical problems
CO5: analyze the numerical methods for solving problems in fluid dynamics
CO6: solve computational fluid flow and heat transfer problems

Brief Overview of the Transport Equations: Solution of linear and non-linear Ordinary Differential Equations (ODE) applicable in Thermal and Fluids Engineering.

Partial Differential Equations: Classification, Introduction to Finite Difference, Finite Volume and Integral Methods. Solution of Steady and Transient Heat Conduction Problems, Solution of Laplace and Poisson type PDEs.

Error Analysis: Introduction of Explicit and Implicit Schemes. Stability and Consistency of Numerical Methods. Numerical Errors, Fourier Stability Analysis of typical Solution Algorithms. Alternate Direction Implicit (ADI) method.

Solution of Simultaneous Algebraic Equations: Tri-Diagonal-Matrix Algorithm (Thomas Algorithm), Gauss-Siedel and Gauss-Jordon Methods. Strongly Implicit Procedures (SIP Solvers – Stone's Algorithm) for two and three dimensional problems.

Vorticity Problems: Vorticity Transport Equation in Two Dimensions, Solution of Fluid Flow Problems by Stream-function Vorticity Method. Examples of Derived Boundary Conditions for Stream Function and Vorticity. Derivation of Pressure Poisson Equation and Their Solution.

Navier Stokes Equation: Integration of Navier Stokes equation in primitive variables and Scalar Transport Equation. Various Schemes of Discretisation – First and Second Order Upwind Schemes, QUICK, Hybrid, Exact and Exponential Differencing Schemes.

Solution of Navier Stokes and Scalar Transport Equations: Introduction to Staggered Grid Layout. Solution by SIMPLE, SIMPLER and SIMPLEC Algorithms.

Text Books:

1. *Numerical heat transfer fluid flow*, S.V. Patankar, Hemisphere Publishing Corporation, 1980.
2. *Computational Fluid Flow and Heat Transfer*, K. Muralidhar and T. Sundararajan, Narosa Publishing House, New Delhi, 1995.

Reference Books:

1. *Computer Simulation of flow and heat transfer*, P.S., Ghoshdasdidar, Tata McGraw-Hill Publishing Company Ltd., 1998.
2. *Computational Fluid Mechanics and Heat Transfer*, D.A. Anderson, I.I. Tannehill, and R.H. Pletcher, Hemishphere Publishing Corporation, New York, USA, 1984.
3. *Computational Techniques for Fluid Dynamics Fundamental and General Techniques*, C.A.J. Fletcher, Springer-Verlag, 1987.
4. *Numerical Fluid Dynamics*, T.K. Bose, Narosa Publishing House, 1997.
5. *Introduction to Computational Fluid Dynamics*, P. Niyogi, S.K. Chakrabartty and M.K. Laha, Pearson Edu., 2005
6. *Fundamentals of Fluid Dynamics*, T.K. Sengupta, University Press, Hyderabad, 2004.
7. *Computational Fluid Dynamics*, Versteeg and Malasekharan, Prentice Hall, 2007.

ME6218 THEORY OF COMBUSTION AND EMISSION Cr-3

Course outcomes: At the end of the course, students will be able to:
CO1: Define and classify the combustion phenomena with applications
CO2: Understand and apply the thermodynamic rules to combustion system
CO3: Elaborate the chemical kinetics of combustion system
CO4: Interpret the combustion systems with different conservation equations
CO5: Predict the flame temperature and to estimate the mass fraction in the combustion flame
CO6: Develop the model for droplet evaporation in a combustion system and understand the pollution methods

Introduction: Definition, need, application, classification etc. of combustion systems, Energy sources.

Combustion and Thermochemistry: Review of property relations, Equation of state, calorific equations of state, ideal gas mixtures, Thermodynamics (1st & 2nd law for pure, non-reacting (mixture) and reacting systems); stoichiometry, absolute enthalpy and enthalpy of formation, enthalpy of combustion and heating values, adiabatic flame temperatures.

Conservation Equations: (Continuity, momentum, total & thermal energy and species); Fluid Mechanics; Heat Transfer & Mass Transfer, mass transfer rate laws, species conservation, applications of mass transfer: Stefan problem and droplet evaporation.

Chemical Kinetics: Global versus elementary reactions, elementary reaction rates, unimolecular, bimolecular and termolecular reactions, Collision theory; reaction rate and its functional dependence; Arrhenius equation; order of reaction, steric factor, collision frequency, activation energy etc.
Rates of reaction for multistep mechanisms: relation between rate coefficients and equilibrium constants, chain and chain branching reactions, chemical time scales.

Laminar premixed flame: Definition, principal characteristics; Simplified Analysis: assumptions, conservation (mass, species & energy) equations with boundary conditions and their solutions to find out temperature & mass-fraction distribution; Factors affecting flame velocity and thickness, Correlations of flame velocity & thickness; quenching; flammability & ignition, flame stabilization.

Laminar diffusion flame: Laminar Jet, Jet flame physical description, simplified theoretical descriptions, Burke-Schumann solution: assumptions, simplification and solution of mass, species, momentum & energy equation with the boundary conditions; determination of temperature & mass-fraction distribution as well as flame height, soot formation and destruction.

Droplet evaporation & combustion: Applications, Simple model of droplet evaporation, assumptions, solution of mass, species & energy equation with the boundary conditions; determination of temperature & mass-fraction distribution, mass evaporation rate, flame stand-off ratio, flame temperature, expression for transfer numbers, evaporation/burning rate constant, droplet life-time etc.

Pollutant emissions: Effects of pollutants, quantification of emissions, emission indices, various specific emission measures, emissions from premixed combustion, emissions from non-premixed combustion.

ME6243 ALTERNATIVE FUELS FOR IC ENGINES Cr-3

Course outcomes: At the end of the course, students will be able to:
CO1: Identify the different alternative fuels and estimate their reserve
CO2: Understand the combustion and emission characteristic of SI engines and suggest the modifications in the engines
CO3: Explain the use of CNG and LPG and analyse the performance in the SI and CI engines
CO4: Estimate the performance of SI and CI engines by using the vegetable oils
CO5: Understand the preparation of vegetable oils and study its emission characteristics by using it SI and CI engines
CO6: Summarize the use of electric vehicle and to understand its electronic control systems

Estimation of Petroleum Reserve: Need for alternate fuel - Availability and properties of alternate fuels – general use of alcohols - LPG - Hydrogen - Ammonia, CNG and LNG - Vegetable oils and Biogas – Solar - Merits and demerits of various alternate fuels

Fuel Properties: Alcohols and gasoline blends, performance in SI engine, Methanol and gasoline blends, Combustion characteristics in engines, emission characteristics, Engine modifications.

CNG and LPG: Availability of CNG, properties, modification required to use in engines - performance and emission characteristics of CNG using LPG in SI & CI engines, Performance and emission for LPG, Hydrogen Storage and handling, performance and safety aspects.

Vegetable oils for engines: Single and dual fuel use, Engine modifications, SVO, Esterification, Performance in engines, Performance and emission characteristics.

Layout of an electric vehicle: Advantage and limitations, Specifications, System component, Electronic control system, High energy and power density batteries, Hybrid vehicle, Solar powered vehicles.

Text Book:

1. Alternative Fuels, Sharma, M., McGraw Hill, 1987.

Reference Books:

1. Energy Today & Tomorrow, M. Dayal, I & B Horishr, India, 1982.

2. Power Plant Engineering, Nagpal, Khanna Publishers, 1991.

3. The properties and performance of modern alternate fuels, SAE Paper No.841210. SAE Handbook

4. Automotive Fuels Guide Book, Richard L. Bechtold, SAE Publications, 1997.

ME6244 EXPERIMENTAL METHODS IN THERMAL ENGINEERING Cr-3

Course outcomes: At the end of the course, students will be able to:
CO1: Compare between the computational and experimental techniques in thermal engineering
CO2: Identify the controlling parameters of experiments

CO3: Explain appropriate and efficient design of experiment
CO4: Understand the basic principles related to measuring systems, measurement uncertainty
CO5: Know about different measuring instruments and sensors
CO6: Predict and diagnose various errors and evaluate accuracy and precision of measurements

Introduction: Theoretical, computational and experimental research methodologies, objectives of experiments, monitoring, control and research.

System and variable Identifications for mechanical systems, planning of instrumentation, Design of Experiments (DOE).

Basic Concepts in Measurements: Generalized description of measurement system, operational description of a general measurement system and elimination methods of interfering inputs to the desired inputs.

Measurement Methods: Null and deflection methods of measurements, analog and digital measurements, static and dynamic measurements, accuracy, precision, sources of errors in measurements, and uncertainty analysis.

Performance Characteristics, Order of Instruments and Calibration.

Sensors and Transducers: Data sampling, signal conditioning and acquisition, examples of transducer for mechanical measurements, working demonstration, pressure measurement, flow measurement, temperature and heat flux measurement**.**

Text Book:

1. Experimental Methods for Engineers, Holman, J. P., Tata McGraw Hill Book Company, New Delhi, 2010.

Reference Books:

2. Mechanical Measurements, Thomas G. Beckwith and Lewis Buck, Narosa Publishing House, 2009.

3. Measurement Systems - Applications and Design, Ernest, O. D., Tata McGraw Hill Book Company,

New Delhi, 2011.

ME6245 CRYOGENIC ENGINEERING Cr-3

Course outcomes: At the end of the course, students will be able to:
CO1: Explain the behaviour of material at low temperature
CO2: Identify the applications of cryogenics
CO3: Compare gas liquefaction and purification systems/methods
CO5: Analyze system parameters and performance
CO6: Design of storage vessel with appropriate insulation for storing cryogens

Cryogenic Systems: Properties of Cryogenic fluids, Material properties at Cryogenic Temperatures. Carnot Liquefaction Cycle, F.O.M. and Yield of Liquefaction Cycles. Inversion Curve - Joule Thomson Effect.
Liquefaction Cycles: Linde Hampson Cycle, Precooled Linde Hampson Cycle, Claudes Cycle, Collins Cycle, Dual Pressure Cycle, Helium Regrigerated Hydrogen Liquefaction Systems. Critical components in Liquefaction Systems, Introduction to air separation.

Cryogenic Refrigerators: J.T. Cryocoolers, Stirling Cycle Refrigerators, G.M. Cryocoolers, Pulse Tube Refrigerators, Regenerators used in Cryogenic Refrigerators, Magnetic Refrigerators

Storage and transfer of Cryogenic liquids, Design of storage vessels.

Cryogenic Insulation, Multi-layer insulation, Vacuum insulation etc**.**

Applications: Applications of Cryogenics in Space Programmes, Superconductivity, Cryo Metallurgy, Medical applications**.**

Text Book:
1. K. D.Timmerhaus and T.M. Flynn, Cryogenic Process Engineering, Plenum Press, 1989.

Reference Books:
1. R. F. Barron, Cryogenic Systems, McGraw Hill, 1985.
2. R.B.Scott, Cryogenic Engineering, Van Nostrand and Co., 1962.
3. H. Weinstock, Cryogenic Technology, 1969.
4. R.W. Vance, Cryogenic Technology, John Wiley & Sons, Inc., New York, London, 1963.

ME6246 HEAT EXCHANGER ANALYSIS AND DESIGN Cr-3

Course outcomes: At the end of the course, students will be able to:
CO1: Understand the fundamentals of various types of heat exchangers
CO2: Evaluate the performance of different heat exchangers by using method of log mean temperature difference
CO3: Analyze the flow distribution of heat exchangers by calculating friction factor, pressure losses etc.
CO4: Design the heat exchanger by calculation of different stresses
CO5: Analyze heat exchanger performance by using the method of heat exchanger effectiveness
CO6: Understand the different industrial applications of heat exchangers

Constructional Details: Types, fluid flow arrangements, parallel, counter and cross flow, shell and tube heat exchanger, regenerators and recuperator, condensers – Industrial applications.
Heat Transfer: Modes of heat transfer, overall heat transfer coefficient, thermal resistance, efficiency, temperature distribution and its implications, LMTD, effectiveness.

Flow Distribution: Effect of turbulence, friction factor, pressure loss, orifice, flow nozzle, diffusers, bends, baffles, effect of channel divergence, and manifolds.

Stress in Tubes, Headers Sets and Pressure Vessels: Differential Thermal Expansion, Thermal stresses, Shear stresses, Thermal sleeves, Vibration, Noise, types of failures.

Design Aspects: Heat transfer and pressure loss flow configuration effect of baffles, effect of deviations from ideality, design of typical liquid-liquid, gas-gas-liquid heat exchangers, design of cooling towers.

Text Book:

1. Heat Exchanger Design, A. P. Frass and M. N. Ozisik, John Wiley and Sons Inc., 1965.

Reference Books:

1. Compact Heat Exchangers, W. M. Kays and A. L. London, 3rd Ed., McGraw Hill, 1984.

2. Industrial Heat Exchangers- A basic guide, G. Walker, McGraw Hill V Book Co., 1980.

3. Process Heat Transfer, D. Q. Kern, McGraw Hill Book Co., 1984.

4. Heat Exchangers, E. A. D. Saunders, Longman Scientific and Technical, New York, 1988.

ME6247 THEORY OF NANO-TECHNOLOGY Cr-3

Course outcomes: At the end of the course, students will be able to:
CO1: Understand the characteristic scale for quantum phenomena
CO2: Explain the properties of nano tubes
CO3: Elaborate the determination of physical structure of nano materials
CO4: Analyse the principles of nano fluidics

CO5: Examine the hydro dynamic boundary conditions
CO6: Interpret the electro kinetic affects

Characteristic scale for quantum phenomena, nanoparticles, nano-clusters, nanotubes, nanowires and nanodots

Transport, optical, thermal and mechanical properties of nano tubes, synthesis of nano-materials using chemical techniques, application of nano materials, micro and nano electromechanical systems.

Characterization of materials, resistivity probing, hall mobility, optical mapping, auto radiography, electron micrography, phase identification, chemical assessment, spectrophotometry, differential thermo analysis.

Determination of physical structure, optical methods of structure determination, optical microscopy, electron microscopy (SEM, TEM, AFM etc.).

Nanofluidics and surfaces: liquid structure near solid-liquid interfaces (simple liquids; layering electrolytes: Poisson-Boltzmann equation; Debye Hückel approx.)

Hydrodynamic boundary condition: slip vs. non-slip, electro kinetic effects (electrophoresis, electro osmotic effect, electro viscous effect), surface reconstruction, dangling bonds and surface states.

Text Book:

1. Introduction to Nano Technology: Charles P. Poole Jr. & F.J. Owens, Springer, 2003

Reference Books:

1. Experimental Techniques of Surface Science, Woodruff and Delchar, Cambridge Univ. Press

(Cambridge, 1994)

2. Advances in Nano Science & Tech., Sharma Ashutosh, Jayesh, CSIR (New Delhi), 2004

ME6248 BIO HEAT TRANSER Cr-3

Course outcomes: At the end of the course, students will be able to:
CO1: Analyse the heat transfer involved in the human body
CO2: Understand the basic equations of heat transfer in biological tissues
CO3: Identify the different causes of heat generation involved in the human body
CO4: Develop different mathematical models of heat transfer in biological tissues
CO5: Interpret the causes of human comfort and establish appropriate relations with the heat transfer
CO6: Enhance the student's ability to know the international standard for human comfort

Introduction: Basic parameters and heat balance equation for the human body, Human thermal physiology and thermoregulation
Psychological responses: models, thermal sensation, and thermoreception, Clothing thermal properties
Bioheat Modeling: Circulation heat transfer model of the human artery and vein system, Blood perfusion heat transfer in tissues models using analytical equations, Thermoregulatory control of heat transfer of the following modes,
Vaso-constriction/dilation of arteries and veins, Surface sweating rate and spatial control, Local control of shivering heat generation in tissue, Metabolic control, Respiration heat transfer model, Clothing heat transfer and water transport models by conduction through the clothing layers
Thermal comfort, Heat stress, Cold stress, Human comfort and ventilation, Thermal comfort and radiation asymmetry

Thermal environment interference with activities, performance, and productivity, International standards: ASHRAE, ISO and European Standards for thermal comfort.

Text Book:

1. Charny, C. K. 1992. Mathematical models of bio-heat transfer. Advances in Heat Transfer 22:19-153.

Reference Books:

1. Fanger, P. O. 1972. Thermal Comfort: Analysis and Applications in Environmental Engineering. McGraw-Hill, New York, NY.
2. ASHRAE Handbook of Fundamentals (2005), Chapter 8.
3. Fournier, R. L. 1998. Basic Transport Phenomena in Biomedical Engineering. Taylor & Francis, Philadelphia, Pennsylvania.
4. Yang, W. 1989. Biothermal-Fluid Sciences. Hemisphere Publishing Corporation, New York.
5. Weiss, T. F. 1996. Cellular Biophysics. Volume 1: Transport. The MIT Press, Cambridge, Massachusetts.

ME6249 MICROFLUIDICS Cr-3

Course outcomes: At the end of the course, students will be able to:
CO1: Understand the fundamentals of micro fluidic phenomena.
CO2: Identify dominant forces and their effects in micro scale fluid systems.
CO3: Extend the understanding to micro-fabrication, flow controls and measurements.
CO4: Explore new possible micro fluidic applications in the emerging fields of thermal sciences.
CO5: Understand the constitutive relations of flow in a micro channel
CO6: Design the micro fluidic devices

Introduction - Origin, Definition, Benefits, Challenges, Commercial activities, Physics of miniaturization, Scaling laws.
Basic Principles-Intermolecular forces, States of matter, Continuum assumption, Governing equations, Constitutive relations. Gas and liquid flows, Boundary conditions, Slip theory, Transition to turbulence, Low Re flows, Entrance effects. Exact solutions, Couette flow, Poiseuille flow, Stokes drag on a sphere, Time-dependent flows, Two-phase flows, Thermal transfer in microchannels. Hydraulic resistance and Circuit analysis, Straight channel of different cross-sections, Channels in series and parallel**.**
Capillary flow analysis- Surface tension and interfacial energy, Young-Laplace equation, Contact angle, Capillary length and capillary rise, Interfacial boundary conditions, Marangoni effect. Active microfluidics - Electro-hydrodynamics. Electro-osmosis, Debye layer, Ideal electro-osmotic flow, Ideal electro-osmotic with back pressure, Cascade electro-osmotic micro pump, EOF of power-law fluids. Electrophoresis of particles, Electrophoretic mobility, Electrophoretic velocity dependence on particle size. Dielectrophoresis, Induced polarization and DEP, Point dipole in a dielectric fluid, DEP force on a dielectric sphere, DEP particle trapping, AC DEP force on a dielectric sphere
Micro-fabrication Techniques - Materials, Clean room, Silicon crystallography, Miller indices. Oxidation, photolithography- mask, spin coating, exposure and development, Etching, Bulk and Surface micromachining, Wafer bonding. Polymer micro-fabrication, PMMA/COC/PDMS substrates, micromolding, hot embossing, fluidic interconnections. Experimental flow characterization – Overview of µPIV
Components of Micro fluidic devices –micro pumps, micro valves, micro flow sensors, micro mixers, droplet generators, micro particle separator, micro reactors
Applications- Medical Analysis and Diagnosis, Applications in Drug Delivery, Microchips for cell signalling and Cancer Research

Text Book:

1. N. T. Nguyen and S. T. Werely, Fundamentals and applications of Microfluidics, 2nd Edition, Artech house Inc., 2006.

Reference Books:

1. P. Tabeling, Introduction to microfluidics, Oxford University Press Inc., 2005.
2. M. J. Madou, Fundamentals of Microfabrication, CRC press, 2002.
3. B. J. Kirby, Micro- and Nanoscale Fluid Mechanics: Transport in Microfluidic Devices, Cambridge University Press, 2010 5. H. Bruus, Theoretical Microfluidics, Oxford University Press Inc., 2008
4. Colin,S., Microfluidics, John Wiley & Sons, 2009.

ME 6250 ADVANCED TURBO-MACHINERY Cr-3

Course outcomes: At the end of the course, students will be able to:
CO1: Define the principle of turbo machinery
CO2: Identify the different non dimensional numbers by writing the energy transfer equation
CO3: Understand the different types of turbo machinery and estimate the thermodynamic efficiency
CO4: Analyse and study the importance of different thermodynamic terms and their roles in different turbo machines
CO5: Estimate the losses in the thermodynamic processes in the turbo machines
CO6: Understand the principles and mechanisms of working of different turbo machines

Introduction, Classification of turbo machinery. Application of TT – theorem in turbo machinery.

Incompressible fluid in turbo machines – Effects of Reynolds Number and Mach number. Energy transfer between a fluid and a rotor - Euler turbine equation – components of energy transfer impulse and Reaction – Efficiencies.

Radial flow pumps and compressors – head capacity relationship – Axial flow pumps and compressors – Degree of reaction dimensionless parameters – Efficiency and utilization factor in Turbo Machinery.

Thermodynamics of Turbo machine processes – Compression and expansion efficiencies – Stage efficiency – Infinitesimal stage and finite stage efficiencies.

Flow of fluids in Turbo machines – flow and pressure distribution over an airfoil section – Effect of compressibility cavitations – Blade terminology- Cascades of blades – fluid deviation – Energy transfer of blades – Degree of reaction and blade spacing – Radial pressure gradient – Free vortex flow – losses in turbo machines.

Centrifugal pumps and compressors – Inlet section – Cavitation – flow in the impeller channel – flow in the discharge casing pump and compressor characteristic**.**

Radial flow turbines – inward flow turbines for compressible fluids – inward flow hydraulic – velocity and flow coefficients – gas turbine blading – Kaplan turbine – Pelton wheels.

Text Book:

1. Lee, Theory and Design of Steam and Gas Turbine, McGraw Hill, 1954.

Reference Books:

1. Yahya, Turbines, Compressions & Fans', Tata McGraw Hill, 1983.

2. D.G. Stephard, Principles of Turbo machines', Macmillan Co., 1984.
3. W.J Kerten, Steam Turbine Theory and Practice', CBS Publisher & Distributors, 1988.
4. C. Rogers, S Muttoo, Gas Turbine Theory ', Long man, 1988.
5. W N.Bathe, Fundamentals of Gas Turbines', Willey & Sons, 1994.

ME6251 FINITE ELEMENT ANALYSIS OF HEAT AND FLUID FLOW Cr-3

Course Outcomes: At the end of the course, the students will be able to:
CO1. understand the basic finite element formulation techniques.
CO2. derive equations in finite element methods for 1D, 2D and 3D problems.
CO3. develop element characteristic equations and generation of global equation.
CO4. apply suitable boundary conditions to a global equation for plane walls, axi-symmetric problems and solve them for temperature distribution and heat transfer.
CO5. develop element characteristic equations for transient heat conduction problems.
CO6. Formulate for ideal flow and incompressible viscous flow.

Introduction: Numerical techniques to solve boundary value problems, General procedure for FEA, Elements and shape functions, Interpolation functions for C0-continuity and C1-continuity. Finite Element Formulation, Method of weighted residuals, Galerkin method, Laws of Heat Transfer, Boundary and initial conditions.
Steady State Heat Conduction in One Dimension: Plane walls, radial heat flow in a cylinder, conduction-convection systems. A one dimensional Problem solved using a single element – Linear element, Quadratic element, the use of numerical integration. A one dimensional problem solved using an assembly of elements.
Steady State Heat Conduction in Multi Dimensions: Two dimensional plane problems, linear and quadratic triangular and rectangular elements, Three dimensional problems, Axisymmetric problems, Finite Element formulation for axisymmetric problems.
Transient Heat Conduction Analysis: Lumped heat capacity system, Galerkin method for transient problems, One-dimensional transient heat conduction problems, Time discretization using FDM, Time discretization using FEM, stability criteria, multi dimension transient heat conduction.
Convection Heat Transfer: Navier-Stokes equations, Non-dimensional form the governing equations for forced, free and mixed convection, Formulation for ideal flow (Stream function and velocity potential function in 2-D flow, Formulation for incompressible viscous flow (Stokes flow and viscous flow with inertia).

Text Books:
1. Fundamentals of the Finite Element Method for Heat and Fluid Flow, Roland W. Lewis, P. Nithiarasu and K.N. Seetharamu, Wiley; 1st edition, 2004.
2. Fundamentals of the Finite Element Analysis, David V. Hutton, Mc Graw Hill, 1st edition.
Reference Books:
1. The Finite Element Method in Heat Transfer Analysis, H. R. Thomas, K. N. Seetharamu, Ken Morgan, R. W. Lewis, John Wiley & Sons Inc, 1996.
2. The Finite Element Method in Heat Transfer and Fluid Dynamics, J.N. Reddy and D.K. Gartling, CRC; 2nd edition, 2000.

ME6252 ADVANCED POWER PLANT ENGINEERING Cr-3

Course outcomes: At the end of the course, students will be able to:
CO1: Recall the trend of modern power plant and their limitations
CO2: Compare the power plants according to their, efficiency, environmental issues and economic considerations
CO3: Apply the basic principles to improving the efficiency with minimum consumption of water, coal and other resources
CO4: Analyze the fuel cell integrated systems and nuclear power plants in terms of various thermal, environmental and economic parameters
CO5: Explain energy scenario of the country and globe
CO6: Design the solar collector to maximize its efficiency

Review of Conventional Power Plants: Limitations, trends of modern power generation, environmental issues, combined power plants

Coal Gasification: Plants with coal gasification, high temperature fuel cells, fuel cell integrated systems, other plants, parametric analysis, performance estimation, retrofitting of old plants, case studies.

Nuclear Power Engineering: Basic concepts of reactor physics, radioactivity, neutron scattering, thermal and fast reactors, nuclear cross-sections, neutron flux and reaction rates, moderator criteria.

Reactor Core Design: Conversion and breeding, types of reactors, characteristics of boiling water, pressurized water, pressurized heavy water, gas cooled and liquid metal cooled reactors.
Heavy Water Management: Containment system for nuclear reactor, reactor safety radiation shields, waste management, Indian nuclear power programme.

Solar Power Engineering: Fundamental principles of solar radiation, handling of solar radiation data, thermal analysis of flat plate collectors, performance test of flat plate collectors, concentrating collectors.

System Sizing by F-chart: Utilizability method, economics of solar energy, application of solar thermal energy to cooling, drying and distillation, storage of solar energy, solar ponds.

Text Books:

1. Nuclear Power Engineering, M. M. EI. Wakil, McGraw Hill Book Company, New York, 1987.

Reference Books:

1. Nuclear Reactors Engineering, S. Glasstone and A. Setonske., 3rd Ed., CBS Publishers and Distributors, 1992.
2. Nuclear Power Plants, Loftness, D. Van Nostrand Company Inc, Princeton, 1964.
3. Physics of Nuclear Reactors, S. Sarg et al., Tata McGraw Hill Publishing Company Ltd., 1985.
4. Fundamentals of Nuclear Energy, T. J. Connoly., John Wiley, 1978.

ME 6254 ADVANCED REFRIGERATION & AIR-CONDITIONING Cr-3

Course outcomes: At the end of the course, students will be able to:
CO1: Understand the concept of vapour compression refrigeration system
CO2: Analyse the vapour absorption system
CO3: Identify the different refrigeration equipment
CO4: Evaluate the cooling load requirement for efficient air conditioning system
CO5: Formulate and evaluate the low temperature refrigeration system
CO6: Design of the air conditioning equipment with different applications

Vapour Compression Refrigeration: Analysis of vapour compression refrigeration system (theoretical and actual); Effect of various factors on the performance of vapour compression refrigeration system; Multiple evaporator systems; Compound vapour compression systems; Low temperature and multi-temperature systems, Cascade System.

Vapour Absorption Refrigeration: Analysis of vapour absorption refrigeration system (theoretical and actual); LiBr-H2O system; Electrolux systems; Binary mixtures; Analysis of absorption systems using analysis and rectification columns.

Refrigeration Equipment: Compressors (reciprocating and centrifugal); Expansion devices; Condensers; Evaporators; Controls used in refrigeration systems. Properties of refrigerants; Their development and applications; Principles of various other refrigeration systems.

Psychometry: Definitions and processes, Advanced psychometric calculations, Cooling load calculations – Determination of U factor –short method calculation; Human comfort; Comfort chart; Sol-Air temperature air-conditioning system.

Low Temperature Refrigeration: Joule Thompson coefficient – liquefaction of air – hydrogen –helium - Applications of cryogenics.

Room Air Distribution: Friction losses in ducts - Duct design, Air filters clean rooms – Air curtain.

Air-Conditioning: Different types of air conditioning plants and air conditioning equipment.

ME6256 NON-CONVENTIONAL ENERGY SOURCES Cr-3

Course outcomes: At the end of the course, students will be able to:
CO1: Estimate the solar radiation energy
CO2: Understand the storage of the solar energy
CO3: Explain the use of wind energy
CO4: Understand the availability and use of geothermal energy
CO5: Identify the scope of use of tidal energy
CO6: Determine the importance of use of biomass energy

Solar Radiation: Solar thermal process, heat transfer devices, solar radiation measurement, estimation of average solar radiation.
Solar energy storage: stratified storage, well mixed storage, comparison, Hot water system, practical consideration, solar ponds, Non-convective solar pond, extraction of thermal energy and application of solar ponds. Wind energy: The nature of wind. Wind energy resources and modeling.
Geothermal energy: Origin and types of geothermal energy and utilization.
OTEC: Ocean temperature differences. OTEC systems. Recent OTEC developments.
Wave energy: Fundamentals. Availability Wave-energy conversion systems.
Tidal energy: Fundamentals. Availability Tidal-energy conversion systems.
Energy from biomass: Photosynthesis; Biomass resource; Utilization of biomass.

Text Book:

1. S.P.Sukhatme, Solar Energy Principle of Thermal Collection and Storage', Tata McGraw Hill, 1990.

Reference Books:

1. G.L. Johnson, Wind energy systems, Prentice Hall Inc., New Jersey, 2002.
2. J.M.Kriender, Principles of Solar Engineering', McGraw Hill, 1987.
3. V.S. Mangal, Solar Engineering', Tata McGraw Hill, 1992.
4. N.K.Bansal, Renewable Energy Source and Conversion Technology', Tata McGraw Hill, 1989.
5. P.J. Lunde., Solar Thermal Engineering', John Willey & Sons, New York, 1988.

ME6258 GAS TURBINES AND JET PROPULSION Cr-3

Course outcomes: At the end of the course, students will be able to:
CO1: Define the compressible flow inside a duct
CO2: Identify different parameters effecting the characteristics of compressor, blower and fan
CO3: Analyze the performance characteristics of axial flow fan and compressors
CO4: Understand the concept of combustion system of a gas turbine
CO5: Explain principle of working of axial flow turbine
CO6: Evaluate the performance of gas turbine
Introduction: application, shaft power gas dynamics – Compressibility effect, steady one dimensional compressible flow of a perfect gas in a duct, isentropic flow in a constant area duct with friction, normal shock waves, oblique shock wave, isentropic two dimensional, supersonic expansion and compression

Centrifugal fans Blowers and Compressors: Principle of operations, work done and pressure rise, slip factor, diffusers, compressibility effects, non-dimensional qualities for plotting compressor characteristics. Bray ton cycle, regeneration and reheating cycle analysis.

Axial Flow Fans and Compressors: Elementary theory, degree of reaction, three dimensional flow, simple design methods, blade design, calculation of stage performance, overall performance, and compressibility effects. Performance characteristics.

Combustion System: Form of combustion, important factors affecting combustion chamber design, combustion processes, combustion chamber performance, and practical problem

Axial Flow Turbines: elementary theory, vortex theory, choice of blade profile, pitch and chord; estimation of stage performance, he cooled turbine

Prediction of performance of simple gas turbines: component characteristic, off design shaft gas turbine, equilibrium running gas generators, off design o free turbine and jet engine, methods of displacing the equilibrium, running line, incorporation of variable pressure losses, methods of improving part load performance, matching procedure for twin spool engines, behavior of gas turbine, Gas turbine rotors and stresses.

Text Book:

1. Theory and Design of Stream and Gas Turbine, J.F. Lee, McGraw-Hill, 1954.

Reference Books:

1. Gas Turbine Theory, H. Cohen & G.F.C. Rogers, Longmans, Green, 1951.

2. Gas and Steam Turbine Theory, R. Yadav, Central Publishing House, 1998.

ME6260 COMPRESSIBLE FLOWS Cr-3

Course outcomes: At the end of the course, students will be able to:
CO1: Understand the fundamentals of the compressible flow
CO2: Simplify the complex compressible flow problems
CO3: Apply numerical methods to solve compressible flow problems
CO4: Understand the various applications of compressible flow
CO5: Apply the fundamental concepts of compressible flow practically
CO6: Define the governing equations and apply different methods to solve the compressible fluid flow problems

Basic concepts: Introduction to compressible flow, A brief review of thermodynamics and fluid mechanics, Integral forms of conservation equations, Differential conservation equations, Continuum Postulates, Acoustic speed and Mach number, Governing equations for compressible flows.
One-dimensional compressible flow: One dimensional flow concept, Isentropic flows, Stagnation/Total conditions, Characteristics speeds of gas dynamics, Dynamic pressure and pressure coefficients, Normal shock waves, Rankine-Hugonoit equations, Rayleigh flow, Fanno flow, Crocco's theorem.
Two-dimensional flows: Oblique shock wave and its governing equations, θ-B-M relations, The Hodograph and Shock Polar, Supersonic flow over wedges and cones, Mach line, Attached and Detached shock, Reflections and interaction of oblique shock waves, Expansion waves, Prandtl-Meyer flow and its governing equations, Supersonic flow over convex and concave corners,
Quasi-one dimensional flows: Governing equations, Area velocity relations, Isentropic flow through variable-area ducts, Convergent-divergent (or De Laval) nozzles, Over-expanded and under-expanded nozzles, Diffusers.
Unsteady wave motions: Moving normal shock waves, Reflected shock waves, Physical features of wave propagation, Elements of acoustic theory, Incident and reflected waves, Shock tube relations, Piston analogy, Incident and reflected expansion waves, Finite compression waves, Shock tube relations.

Introduction to experimental facilities: Subsonic wind tunnels, Supersonic wind tunnels, Shock tunnels, Free-piston shock tunnel, Detonation-driven shock tunnels, and Expansion tubes.

Text Book:

1. John D. Anderson Jr (1990), Modern Compressible Flow with Historical Perspective, McGraw-Hill, Singapore.

Reference Books:

1. Liepmann HW and Roshko A (1957), Elements of Gas Dynamics, John Wiley & Sons, Inc., New York.
2. Shapiro A (1954) The Dynamics and Thermodynamics of Compressible Flow, Ronald Press, London.

ME6262 THEORY OF TURBULENCE Cr-3

Course outcomes: At the end of the course, students will be able to:
CO1: Understand the fundamental concepts of the turbulent flow
CO2: Familiarize the students of modelling the turbulent flows
CO3: Understand the different mathematical equations to simplify the complex flow problems
CO4: Exposure to understand the different statistical theories of turbulence
CO5: Analyse the different applications of turbulent flow
CO6: Develop mathematical models and predict the nature of the turbulence

Introduction: Properties of laminar flow, Properties of turbulent flow, Boundary Layer, Swirling Structure, Mean Motion and Fluctuations, Consequences of Turbulence, Homogeneous Isotropic Turbulence.
Correlation Functions and Intensity: Correlation Functions, Ideas about eddy size, Intensity of Turbulence or Degree of Turbulence, Kolmogorov Universal Law for the Fine Structure, Energy Cascade, Kolmogorov Length Scale, Kolmogorov's First Hypothesis, Kolmogorov's Second Hypothesis. Probability Density Functions and Averaging: Introduction, Probability density function, Averaging used in the analysis of turbulent flows.
Reynolds' Averaged Navier-Stokes Equations: Reynolds' Decomposition, Examples of Turbulent Fluctuations, Measurements on Fluctuating Components, Shear Stress due to the Fluctuations, The boundary layer measurements of Klebanoff, Turbulent Boundary Layer Equations for a two dimensional flow, The Boussinesq or eddy viscosity model, Eddy viscosity.
Vorticity Dynamics: Introduction, Vorticity and the equations of motion, Reynolds stress and vorticity. Vortex Stretching: Vortex Stretching, Kinetic Energy of the Mean Flow, Kinetic Energy of Fluctuations, Some Scaling Relations.
The Law of the Wall for Wall Bounded Flows: The Law of the Wall for Wall Bounded Flows, The Universal Velocity Profile, Free Shear Flows, Turbulent Jets, Uniform Eddy Viscosity model, Spectral Dynamics
RANS Equations and Eddy Viscosity: Reynolds Averaged Navier-Stokes (RANS) Equations, k - ω Model, SST (Shear Stress Transport) Turbulence Model. RNG k - ε Model and Kato-Launder Model, Reynolds Stress Models (RSM), Large Eddy Simulation (LES), Direct Numerical Simulation.

Text Book:

1. H. Tennekes and J.L. Lumley, 1987, A First Course in Turbulence, The MIT Press, Cambridge, Massachusetts, and London, England.

Reference Books:

1. P.K. Kundu and I.M. Cohen, 2002, Fluid Mechanics, Academic Press (An Imprint of Elsevier Science, USA.
2. S.B. Pope, Turbulent Flows, 2000, Cambridge University Press, UK.
3. G. Biswas and V. Eswaran, 2002, Turbulent Flows: Fundamentals, Experiments and Modeling, Narosa Publishing House, New Delhi, India.

Specialization: Machine Design

ME6310 THEORY OF ELASTICITY AND PLASTICITY Cr-3

Course Outcome: At the end of the course, the students will be able to

CO1. explain stress and strain at a point and its components in Cartesian and Polar co-ordinates
CO2. solve compatibility equations and boundary conditions in 2-D and 3-D cases.
CO3. understand airy's stress function in 2-D problems of elasticity in Cartesian/Polar coordinates.
CO4. understand the theories of torsion of prismatic bars of various cross sections and can solve the problems of torsion.
CO5. understand various theories of failures and analyze the structures using plasticity.

Elasticity-I: Introduction, Definition of stress and strain at a point, components of stress and strain at a point in Cartesian and polar co-ordinates, constitutive relations, equilibrium equations, compatibility equations and boundary conditions in 2-D and 3-D cases. Plain stress and plain strain: Airy's stress function approach to 2-D problems of elasticity, Solution of axi-symmetric problems, stress concentration due to the presence of a circular hole in planes.
Elasticity-II: Elementary problems of elasticity in three dimensions, stretching of a prismatical bar by its own weight, twist of circular shafts, torsion of non-circular sections

Plasticity-I: Stress-strain diagram in simple tension, perfectly elastic, Rigid - Perfectly plastic, Linear work - hardening, Elastic Perfectly plastic, Elastic Linear work hardening materials, Failure theories.

Plasticity-II: Plastic stress-strain relations, Saint Venant's Theory of Plastic flow, Elastic plastic Deformations, Prandtl's stress equations, Levy - Mises equation, Reuss theory of elastic - plastic deformation, Hencky's theory of small plastic deformations.

Text Books:
1. Timoshenko and Goodier, Theory of elasticity, McGraw Hill Book Company, III Edition, 1983.
2. J. Chakrabarthy, Theory of Plasticity, McGraw Hill, 1987.

References:
1. W. Johnson and P. B. Mellor, Plasticity for Mechanical Engineers, D.Van Nostrand Co. Ltd., 1962.
2. Oscar Haffman and George Sachs, Introduction to the Theory of Plasticity for Engineers, Mc, Graw Hill
3. C. N. Massonnet, Plastic Analysis and Design of Plates, Shells and Discs, North Holland Publishing Co.
4. M. Kachanov, Theory of Plasticity, Mir publishers, Moscow.

ME6312 FINITE ELEMENT METHOD Cr-3

Course Outcome: At the end of the course, the students will be able to

CO1. obtain an understanding the fundamental theory of Finite Element Method (FEM).
CO2. generate the governing finite element equations for systems governed by partial differential equations.
CO3. formulate and solve various complicated beam problems using Galerkin's Technique and applying polynomial Shape Functions.
CO4. understand the use of the basic finite elements to solve the bar and truss problems.
CO5. understand the application and use of the one-dimensional, two-dimensional, and three-dimensional problems.
CO6. expertise to solve complicated engineering problems using FEM software.

Introduction: Concept of FEM, History, Packages, Range of applications, Steps in FEM, Approaches of FEM, Development of Elemental Equations for simple systems, Two DOF problems- Plane Trusses and

Frame structures; Assembly Procedure, Application of Boundary Conditions; Solver Technology: Linear direct solver, Iterative solvers, Eigen solver, Non-linear equation solver.

One dimensional problems: Governing Equation and Boundary Conditions for Solid Mechanics-Bar extension and Beam bending; Weak Formulation and Functional, Polynomial Approximation, Standard 1-D Shape Functions of continuity elements, Derivation of Element Matrices and Vectors, Assembly, Imposition of Boundary Conditions and Nodal Solution; Co-ordinate Transformation and Numerical Integration.

Two dimensional problems: Governing Equation and Boundary Conditions-Solid mechanics-Rod Torsion, Fluid Dynamics-Stream function, Weak Formulation and Functional, Polynomial Approximation, Standard 2-D Shape Functions of continuity elements, Derivation of Element Matrices and Vectors, Assembly, Imposition of Boundary Conditions and Nodal Solution; Mapping and Numerical Integration; Transient and Eigen Value Problems.

Three dimensional problems: Governing equation and Boundary Conditions, Weak Formulation and Functional, Polynomial Approximation, Standard 3-D Shape Functions of Continuity Elements, Derivation of Element Matrices and Vectors, Assembly, Imposition of boundary conditions and Nodal Solution; Mapping and Numerical Integration.

Text Books:

1. Finite Element Methods -S.S. Rao, Elesevier
2. P. Sheshu, Text book of finite element analysis, PHI, 2005.

References:

1. O. C. Zienkiewicz, The Finite Element Method in Engg Science, Ed, Wiley & Sons.
2. S. Lary, Applied Finite Element Analysis, John Wiley, 2008.

ME6313 ADVANCED MECHANICS OF SOLIDS AND STRUCTURES Cr-3

Course Outcome: At the end of the course, the students will be able to

- CO1. understand the behaviour of material under stress and evaluate principal stresses, their directions and stress invariants.
- CO2. draw the Mohr's circle for three dimensional state of stress.
- CO3. determine the strain invariants, principal strains and their associated directions.
- CO4. understand the generalized Hooke's law.
- CO5. analyze theories of failure and their application in designing the machine components.
- CO6. expertise to solve engineering problems like shear stresses in curved beams, axisymmetric bodies.

Analysis of Stresses and Strains in rectangular and polar coordinates: Cauchy's formula, Principal stresses and principal strains, 3D Mohr's Circle, Octahedral Stresses, Hydrostatic and deviatoric stress.

Stress-strain relations for linearly elastic solids: Differential equations of equilibrium, Plane stress and plane strain, compatibility conditions. Introduction to curvilinear coordinates. Generalized Hooke's law and theories of failure.

Bending of straight/curved beams and shear centre: Effect of shear stresses, Curved beams, Unsymmetrical bending, Shear center and shear flow, thick curved bars.

Axisymmetric Problems: Thick and thin walled cylinders, Rotating disks and cylinders. Euler's buckling load, Beam Column equations. Strain measurement techniques using strain gages, characteristics, instrumentations, principles of photo-elasticity.

Text Books:
1. A. P. Boresi, R. J. Schmidt, Advanced Mechanics of Materials, 5th Edition, John Willey and Sons Inc, 1993.
2. L. S. Srinath, Advanced Mechanics of Solids, 2nd Edition, TMH Publishing Co. Ltd., New Delhi, 2003.

References:
1. R. G. Budynas, Advanced Strength and Applied Stress Analysis, 2nd Edition, McGraw Hill Publishing Co, 1999.
2. A. P. Boresi, R. J. Schmidt, Advanced Mechanics of Materials, 5th Edition, John Willey and Sons Inc, 1993.
3. S. P. Timoshenko, J. N. Goodier, Theory of Elasticity, 3rd Edition, McGraw Hill Publishing Co. 1970.
4. P. Raymond, Solid Mechanics for Engineering, 1st Edition, John Willey & Sons, 2001.

ME6314 THEORY OF PLATE AND SHELLS Cr-3

Course Outcome: At the end of the course, the students will be able to
CO1. understanding the basic behaviour of plates and shells.
CO2. analyzing the bending of thin plates under several loads.
CO3. evaluating the strain energies of plates under various loading conditions.
CO4. analyzing buckling of plates under various edge conditions.
CO5. understanding the bending behaviour of thin shells.
CO6. investigating the symmetrical buckling behaviour of cylindrical shells.

Introduction: Plate and Shell Structures in Aerospace Vehicles. Flexural rigidity of plates. Flexural rigidity of shells. Introduction to bending and buckling of plates and shells. Reinforced plates. Eccentrically compressed shells.
Bending of Thin Plates –Stresses: Pure bending of plates. Isotropic and orthotropic flat plates. Flexural rigidity of plate. Bending of plates by distributed lateral load. Combined bending and tension or compression. Bending and twisting moments. Shear stress.
Bending of Thin Plates - Strain Energy: Slopes of deflection of surface. Different edge conditions: - built in edge, simply supported edge and, free edge. Combined bending and tension or compression of plates. Strain energy by: – bending of plates, bending by lateral loads, combined bending and tension or compression of plates.
Buckling of Thin Plates: Method of calculation of critical loads. Buckling of simply supported rectangular plates uniformly compressed in one direction. Buckling of uniformly compressed rectangular plates simply supported along two opposite sides perpendicular to the direction of compression and having various edge conditions along the other two sides. Critical values of compressive stress.
Buckling of Reinforced Plates: Stability of plates reinforced by ribs. Simply supported rectangular plates with longitudinal ribs. General equation for critical compressive stress. Critical compressive stress for a plate stiffened by one rib. Study of the experimental value of buckling of plates.
Bending of Thin Shells: Deformation of an element of a shell. Expression for components of normal stresses. Flexural rigidity of shell. Case of deformation with presence of shearing stresses.
Strain Energy of Deformation of Shells: Strain energy of deformation of shell:-bending and stretching of middle surface. Symmetrical deformation of a circular cylindrical shell. Differential equation for bending of strip.
Buckling of Shells: Symmetrical buckling of cylindrical shell under the action of uniform axial compression: -differential equation, critical stress. Symmetrical buckling of cylindrical shell under the action of uniform axial pressure. Study of the experimental values of cylindrical shells in axial compression. Bent or eccentrically compressed shells.

Text book:
1. Theory of plates and Shells by S. Timoshenko, S.W. Krieger, McGraw Hill Publications.

Reference Book:
1.Theory and analysis of elastic plates and shells, J.N. Reddy,. CRC press.

2. Dynamics of Plates by J.S. Rao, Narosa.

ME6315 NOISE AND VIBRATION CONTROL ENGINEERING Cr-3

Course Outcome: At the end of the course, the students will be able to
CO1. model a two degrees of freedom dynamic systems.
CO2. find out natural frequencies and mode shapes.
CO3. design a dynamic vibration absorber.
CO4. measure noise source and calculate the combined effects.
CO5. select the best noise control method.
CO6: find out phycologycal effects of noise and vibration level in humans.

Multi degrees of freedom systems: Generalised co-ordinates, constraints, virtual work; Hamilton's principle, Lagrange's equations; Discrete and continuous system; Vibration absorbers; Response of discrete systems - SDOF & MDOF: Free-vibration, periodic excitation and Fourier series, impulse and step response, convolution integral.
Continuous systems: Modal analysis: undamped and damped non-gyroscopic, undamped gyroscopic and general dynamical systems. Effect of damping; Vibration of strings, beams, bars, membranes and plates, free and forced vibrations; Raleigh-Ritz and Galerkin's methods. Measurement techniques.
Basics of noise engineering: Principles of sound generation and propagation, sound attenuation, sound absorption, sources of industrial noise, effects of noise, noise measurement units and instruments, identification of source of noise.
Noise Control: Noise evaluation procedures, acoustical enclosures, design of reactive and absorptive mufflers, active noise control, designing for quieter machines and processes, case studies.

Texts Books:

1. Vibration and Acoustics by C. Sujatha, TMH

References:
1. F S Tse, I E Morse and R T Hinkle, Mechanical Vibrations, CBS Publ., 1983.
2. J S Rao and K Gupta, Theory and Practice of Mechanical Vibrations, New Age Publication, 1995
3. Harold Lord, Gatley and Eversen, Noise Control for Engineers, McGraw-Hill
4. R. H. Lyon, Machinery Noise and Diagnostics, Butterworths, 1987. 5. J. W. Dally and W.

ME6316 MACHINERY FAULTANALYSIS AND RELIABILITY ENGINEERING Cr-3

Course Outcome: At the end of the course, the students will be able to
CO1. decide and apply the best maintenance principle.
CO2. find out MTTR and machine availability.
CO3. conduct FMEC and RCF analysis.
CO4. select sensors for machine condition monitoring and fault diagnostics.
CO5. find root cause and fault diagnostics of rotating machinery using vibration and noise signatures.
CO6. use WADA, Thermography and NDT techniques to find out fault in machineries.

Maintenance Principles, Maintainability, MTTR, Availability, Reliability Centered Maintenance(RCM), Failure Modes Effects and Critical Analysis(FMECA) and Root Cause Failure Analysis(RCFA).

Basics of Machine Vibration, Signal Analysis, Computer aided data acquisition, Time Domain Signal Analysis, Frequency Domain Signal Analysis, Fault Detection Transducers.

Vibration Monitoring, Field Balancing of Rotors, Condition Monitoring of Rotating Machines, Noise Monitoring.

Wear and Debris Analysis(WADA), Thermography, Electric Motor Current Signature Analysis, Ultrasonics testing and other NDT Techniques for Condition Monitoring.

Industrial Case studies.

Text Books:

1. Machinery Condition Monitoring Principles and Practices by A.R. Mohanty, CRC Press

Reference Books:

1.Maintenance Engineering by Er. Sushil Kumar Srivastava, S.Chand

2.Machinery Analysis and Monitoring by John S. Mitchell, Penn Well Publishing Company

3.Maintenance Engineering and Management by K. Venkataraman, PHI

4.Plant Maintenance and Reliability Engineering by N.V.S. Raju, CENGAGE Learning

ME6317 ADVANCED MACHINE MECHANISMS AND ROBOTKINEMATICS Cr-3

Course Outcome: At the end of the course, the students will be able to

CO1. know the concept fundamental to the synthesis and analysis of mechanisms.
CO2. explore synthesis techniques to create potential linkage design solutions for some typical kinematic applications.
CO3. synthesize linkages for specified ouput positions analytically.
CO4. solve the synthesis of spatial mechanism by using different technique.
CO5. know the control systems and components of Robot.
CO6. solve mathematical models of active mechanism by using computer aided methods.

Review of Kinematic synthesis: Kinematics fundamentals, Graphical and analytical methods, two and three precision point synthesis. Quick-return Mechanisms, Function, Path and motion generation by 4-bar linkage: four and five precision point synthesis. Coupler-curves, straight-line mechanisms, Dwell mechanisms, Constant velocity piston motion, remote center circular motion.

Synthesis of planer mechanisms: position analysis, two-position and three position motion generation by analytical synthesis, Analytical synthesis of a four-bar function generator. Geared linkages, path and motion generation by Watt and Stephenson's six- bar chain, precision point synthesis Vis a vis optimization method. Newton-Raphson solution Method for fourbar linkage.

Synthesis of spatial mechanisms: displacement analysis, matrix method of analysis, Synthesis of 4 – revolute spherical mechanisms, synthesis of 2- revolute 2 spheric- pair mechanisms.

Application to robotics: Manipulator Dynamics and Controls, Robot end effctors,Sensors and intelligent robots,Computer-Aided Methods for setting and solving Mathematical models of active mechanisms.

Text Books:

1. Norton, R.L., 1999, "Design of Machinery: An Introduction to the Synthesis and Analysis of Mechanisms and machines", 2nd Ed., WCB McGraw-Hill.

References:

1. Hartenberg, R.S., Denavit, J., 1964, "Kinaematic Synthesis of Linkages", McGraw-Hill, New York.
2. Sandor, G.N., Erdman, A.G., 1984"Advanced Mechanism Design Analysis and Synthesis", Vol. - 1, Prentice-Hall, New Jersey.
3.

ME6318 DESIGN OPTIMIZATION Cr-3

Course Outcome: At the end of the course, the students will be able to

CO1. model and formulate optimization problems.
CO2. draw the optimality of a solution.
CO3. write the code to determine the optimal solution for optimization problem of single variables.
CO4. determine the optimal solution for optimization problem of multiple variables.
CO5. solve linear optimization problems graphically.
CO6. fit the curves to discrete data to obtain intermediate estimates.

Introduction: Morphology of design with a flow chart, Discussion on market analysis, profit, time value of money, an example of discounted cash flow technique, Concept of workable design, practical example on workable system and optimal design.

System Simulation: Classification, Successive substitution method – examples, Newton Raphson method - one unknown – examples, Newton Raphson method - multiple unknowns – examples, Gauss Seidel method – examples, Rudiments of finite difference method for partial differential equations, with an example.

Regression and Curve Fitting: Need for regression in simulation and optimization, Concept of best fit and exact fit, Exact fit - Lagrange interpolation, Newton's divided difference – examples, Least square regression - theory, examples from linear regression with one and more unknowns – examples, Power law forms – examples, Gauss Newton method for non-linear least squares regression – examples.

Optimization: Introduction, Formulation of optimization problems – examples, Calculus techniques – Lagrange multiplier method – proof, examples, Search methods – Concept of interval of uncertainty, reduction ratio, reduction ratios of simple search techniques like exhaustive search, dichotomous search, Fibonacci search and Golden section search – numerical examples, Method of steepest ascent/ steepest descent, conjugate gradient method – examples, Geometric programming – examples, Dynamic programming – examples, Linear programming – two variable problem –graphical solution, New generation optimization techniques – Genetic algorithm and simulated annealing – examples, Introduction to Bayesian framework for optimization- examples.

Text Books:

1- Engineering Optimization, S.S. Rao, New Age Publications.

References:

1. Design and optimization of thermal systems, Y.Jaluria, Mc Graw Hill, 1998.
2. Elements of thermal fluid system design, L.C.Burmeister, Prentice Hall, 1998.
3. Design of thermal systems, W.F.Stoecker, Mc Graw Hill, 1989.
4. Introduction to optimum design, J.S.Arora, Mc Graw Hill, 1989.

ME6319 FATIGUE AND FRACTURE BASED DESIGN Cr-3

Course Outcome: At the end of the course, the students will have the knowledge of

CO1. modes of failure and energy release rate of DCB specimen.
CO2. crack tip deformation.
CO3. linear elastic fracture mechanics (LEFM).
CO4. plasticity at crack tip & Irwin principle.
CO5. elastic plastic analysis & J-integral.
CO6. factors influencing fatigue strength.

Modes of failure: Types of failure, Brittle and ductile fracture, Modes of fracture failure, Griffith's theory of brittle fracture, Energy release rate, Energy release rate of DCB specimen.

Linear elastic analysis of cracked bodies: Deformation at crack tip, Crack resistance, Stable and unstable crack growth, R-curves for brittle cracks, critical energy release rate.

Linear elastic fracture mechanics (LEFM): Stress intensity factor, Fracture toughness, Stress distribution at crack tip, Plane stress and plane strain cases.

Crack tip plasticity: plastic zone size due to Irwin, plastic zone size due to Dugdale, plastic zone shape using classical yield criteria plane strain fracture toughness.

Elastic plastic analysis: Introduction, the J-integral, path independence of J-integral.

Fatigue crack growth: Types of fatigue loading, Fatigue test methods, Endurance limit and S-N diagram, Factors influencing fatigue strength, Influence of stress concentration, Crack initiation and propagation, effect of an overload, Crack closure, Fatigue life calculations, methods of increasing fatigue life, Test methods to determine K_{Ic}.

Text Books:
1. T L Anderson, Fracture Mechanics: Fundamentals and Applications, CRC Press.
2. S Suresh, Fatigue of Materials, Cambridge University Press.

Reference Books:
1. P. Kumar, Elements of Fracture Mechanics, Wheeler Publishing.
2. K. Hellan, Introduction to Fracture Mechanics, McGraw-Hill.

ME6320 ANALYSIS OF FUNCTIONALLY GRADED MATERIALS Cr-3

Course Outcome: At the end of the course, the students will be able to

CO1. understand about the different functionally graded materials, structures, plates, and shells.
CO2. expertise to solve complicated problems of functionally graded material and structure using Higher Order Shear Deformation Plate Theory and Generalized Kármán-Type Nonlinear Equations.
CO3. analyze the elastic properties and understand the mechanical performance like nonlinear bending, buckling, and thermal stresses of functionally graded material plates.
CO4. calculate the nonlinear vibration of functionally graded material plates in thermal environments.
CO5. analyze problems on bending and buckling of functionally graded material cylindrical shells.
CO6. determine the axial compression, torsional, and thermal behavior of functionally graded material cylindrical shells.

Modeling of Functionally Graded Materials and Structures: Effective Material Properties of FGMs, Reddy's Higher Order Shear Deformation Plate Theory, Generalized Kármán-Type Nonlinear Equations

Nonlinear Bending of Shear Deformable FGM Plates: Nonlinear Bending of FGM Plates under Mechanical Loads in Thermal Environments, Nonlinear Thermal Bending of FGM Plates due to Heat Conduction

Postbuckling of Shear Deformable FGM Plates: Postbuckling of FGM Plates with Piezoele ctric Actuators under Thermoelectromechanical Loads, Thermal Postbuckling Behavior of FGM Plates with

Piezoelectric Actuators, Postbuckling of Sandwich Plates with FGM Face Sheets in Thermal Environments.

Nonlinear Vibration of Shear Deformable FGM Plates: Nonlinear Vibration of FGM Plates in Thermal Environments, Nonlinear Vibration of FGM Plates with Piezoelectric Actuators in Thermal Environments, Vibration of Postbuckled Sandwich Plates with FGM Face Sheets in Thermal Environments

Postbuckling of Shear Deformable FGM Shells: Boundary Layer Theory for the Buckling of FGM Cylindrical Shells, Postbuckling Behavior of FGM Cylindrical Shells under Axial Compression, Postbuckling Behavior of FGM Cylindrical Shells under External Pressure, Postbuckling Behavior of FGM Cylindrical Shells under Torsion, Thermal Postbuckling Behavior of FGM Cylindrical Shells

Text Book:
1. Functionally Graded Materials by J.N. Reddy

Reference Book:
1. Functionally Graded Materials: Non linear Analysis of Plates and Shells
 Hui-Sen Sen, Publisher: CRC Press (2009)

ME6341 EXPERIMENTAL STRESS ANALYSIS Cr-3

Course Outcome: At the end of the course, the students will be able to

CO1. describe variety of strain gauges and strain gauge circuits.
CO2. calculate the strain using strain gauge rosettes.
CO3. explain the nature of light and process of polarization.
CO4. understand different methods of 2-D photo elasticity, effects of stressed model in polariscope..
CO5. explain different types of coatings, test strain data using brittle coating and detect cracks.
CO6. understand load time relation and its influence on strain effects of a biaxial stress field.

Theory of Photo-elasticity: The stress optic law in two dimensions at normal incidence, Effects of a stressed model in a plane polariscope, Effects of a plane model in a circular polariscope with dark and light field arrangements.
Analysis Techniques: Isochromatic fringe patterns, Isoclinic fringe patterns, Compensation techniques, separation techniques, Sealing model to prototype stresses.

Strain Measurement Methods: Basic characteristics of a strain gauge, Types of strain gauge, Moire method of strain analysis, Grid method of strain analysis.

Electrical Resistance Strain Gauge: Factors influencing strain sensitivity in metallic alloys, Gauge construction temperature compensation, Factors-influencing gauge section gauge sensitivity and gauge factor, Correction for transverse strain effects, Semiconductor strain gauges. Rosette analysis – three element rectangular rosette. The delta rosette, the four elements. The delta rosette, the strain gauge, Strain circuits, Potentiometer circuits, the Wheatstone bridge.
Brittle Coating Method: Coating stresses, Failure theories of brittle coating crack patterns due to direct loading, Brittle-coating crack patterns produced by refrigeration techniques, Brittle coating crack pattern produced by releasing the load, Double crack pattern, Crack detection, Load-time relation and its influence on the threshold strain effects of a biaxial stress field.

Text Books:

1. J.W. Dally and W.F. Riley, Experimental Stress Analysis, 2nd eEd. McGraw Hill.

2. K. Ramesh, Published by IIT Madras, India, Experimental Stress Analysis, 2009.

Reference Books:

1. A Mubin, Khanna Publications, Experimental Stress Analysis, 2003.

2. Sadhu Singh, Khanna Publishers, Experimental Stress Analysis,1982.

3. Srinath , An Introduction to Experimental Stress Analysis - MGH

ME6342 MEMS AND NEMS Cr-3

Course Outcome: At the end of the course, the students will be able to

CO1. understand the basics of various Micro and Nano Electromechanical Systems.
CO2. ability to analyze the working principles of Micro and Nano Electromechanical Systems (MEMS/NEMS) and microsystems.
CO3. acquire the knowledge of the different micro-sensors (optical, acoustic, and thermal, chemical, etc.) and micro-actuators/pumps.
CO4. expertise to use MEMS and NEMS in the automotive industry, aerospace industrial, biomedical, and telecommunications, etc.
CO5. describe the techniques for building micro devices in silicon, polymer, metal and other materials.
CO6. understand the fabrication methods used in designing and constructing MEMS and NEMS.

Introduction: Various components of MEMS, applications and standards, micromachining, basic process tools- epitaxy, sputtering, chemical vapor deposition and spin on methods, oxidation, evaporation, lithography and etching, advanced process tools, sol gel process, EFAB. Silicon, Silicon oxide and nitride, thin metal films, Polymers, Other materials and substrates, polycrystalline materials, mechanics of Microsystems, static bending, mechanical vibrations, thermo mechanics, fracture mechanism, fatigue, and stress and strain, young's modulus and modulus of rigidity, scaling laws in miniaturization.

Sensor and Scaling: Micro sensors (acoustic wave sensors, biomedical, chemical, optical, capacitive, pressure, thermal), micro actuators (thermal, piezoelectric, electrostatic, micrometers, micro valves & pumps, accelerometer, micro fluidics and devices), design consideration, process design and mechanical design. Mechanical system, Thermal system, Fluidic system, Electrical system scaling. Packaging of MEMS and NEMS and its design considerations.

Application: Automotive industry – health care – aerospace industrial product consumer products – lab on chip – molecular machines – data storage devices – micro reactor – telecommunications, Servo systems.

Text Book:

1. MEMS and NEMS: Systems, Devices and Structures by Sergey Edward Lyshevski, CRC Press, 2012.

Reference Book:

1. Modeling MEMS and NEMS by John A. Pelesko , David H. Bernstein, CRC Press, 2002.

ME6343 SIMULATION OF DYNAMIC SYSTEMS CR-3

Course Outcome: At the end of the course, the students will be able to

CO1. demonstrate a basic understanding of differential equations and stochastic processes and their role in engineering simulation.
CO2. explain the fundamental practical limitations of numerical simulation of dynamical systems and know how to recognize them.

CO3. know the main principles of dynamic systems modeling and simulation, and understand the process from basic laws of physics via mathematical models to simulation and analysis.

CO4. have basic knowledge using different tools and methods in a unified approach to perform dynamic simulations of multi-domain systems: mechanical handling system, Robot, hydraulic and thermal systems.

CO5. do simple simulation and model-based design, but also do advanced simulation.

CO6. make design recommendations for simple mechatronic systems based on dynamics simulation data.

Introduction: An invariant nature of power exchange, representation of junction elements, power direction and physical system coordinates, notion of causality.

Creation of System Equation: selection of system states, bond graph with transfer element, system with differential causality, algebraic loops, creation of system bond graph.

Use of Noninertial Coordinate: principle of material objective, dynamics of rigid bodies, system with nonpotential fields.

Simulation: structural members, multi-body system, mechanical handling system, robot, thermal system, hydraulic system.

Control systems: control strategy, modelling of electronics circuit, fault detection and isolations.

Text Book:

1. Bond Graph in Modeling, Simulation and Fault Indentification by A Mukherjee, R. Karmakar, A.K. Samantaray, I.K. International Publications.

Reference Book:

1. Modeling and identification of dynamic systems by Peter Lindskog, Torkel Glad, Lennart Ljung, Jacob Roll.

ME6344 DYNAMICS OF ROTOR Cr-3

Course Outcome: At end of this course, students will be able to

CO1. obtain the equations of motion of a rigid rotor in the absolute and rotating coordinate systems.

CO2. explain the critical speed of revolution and the self-balancing effect.

CO3. explain the external damping, and internal damping and their effects.

CO4. explain the change of a critical speed in the case that the gyro effect is considered.

CO5. explain the real time analysis and expert system of vibration.

CO6. understand balancing of reciprocating and rotary masses of Rotors.

Torsional Vibration in Rotating Systems: Modelling of rotating systems, Equivalent discreet system, branched system and gear system.

Bending Critical Speeds of Simple Shafts: Whirling of unbalanced elastic rotor, simple shaft with several disks, and Transfer matrix analysis of bending critical speeds.Out of balance response of rotors with rigid supports.

Gyroscopic Effects in Rotor system: Effect of spinning disk, synchronous whirl of an overhang rotor, Non synchronous whirl, Rotor with couplings and whirl speed analysis.

Rotor mounted on fluid film bearings: Simple rotor in fluid film bearings, Dual rotor system analysis, Optimum design for minimum unbalance Instability of rotors.

Balancing of Rotors: Rigid rotor balancing criteria and balancing of flexible rotors.

Condition Monitoring: Vibration Measurements, Vibration generating mechanism, vibration spectrum real time analysis and expert system.

Text Book:

1. Rotor Dynamics by J. S. Rao, New Age Int.

Reference Book:

1. Rotor Dynamics by Agnieszka Muszynska, CRC Press

ME6345 SOFTCOMPUTING AND OPTIMIZATION TECHNIQUE SYLLABUS CR-3

Course Outcome: At end of this course, students will be able to

CO1. understand the fundamentals of soft computing
CO2. knowledge of Fuzzy Logic & its application
CO3. knowledge of ANN & its application
CO4. knowledge of Adaptive Neuro Fuzzy system & its application
CO5. knowledge of GA & its application
CO6. knowledge of unconstrained and constrained optimization

Introduction: Evolution of Computing - Soft Computing Constituents – Conventional AI to Computational Intelligence - Machine Learning Basics.

Neural Networks: Machine Learning Using Neural Network - Adaptive Networks – Feed forward Networks – Supervised Learning Neural Networks – Radial Basis Function Networks - Reinforcement Learning – Unsupervised Learning Neural Networks – Adaptive Resonance architectures – Advances in Neural networks.

Fuzzy Logic: Fuzzy Sets – Operations on Fuzzy Sets – Fuzzy Relations – Membership Functions- Fuzzy Rules and Fuzzy Reasoning – Fuzzy Inference Systems – Fuzzy Expert Systems – Fuzzy Decision Making.

Neuro-Fuzzy Modeling: Adaptive Neuro-Fuzzy Inference Systems – Coactive Neuro-Fuzzy Modelling – Classification and Regression Trees – Data Clustering Algorithms – Rule base Structure Identification – Neuro-Fuzzy Control – Case studies.

Genetic Algorithms: Introduction to Genetic Algorithms – Applications of GA in Machine Learning - Machine Learning Approach to Knowledge Acquisition – Reproduction – Crossover – Mutation.

Unconstrained Optimization: Optimizing Single-Variable Functions, conditions for Local Minimum and Maximum, Optimizing Multi-Variable Functions.

Constrained Optimization: Optimizing Multivariable Functions with Equality Constraint: Direct Search Method, Lagrange Multipliers Method, Constrained Multivariable Optimization with inequality constrained: Kuhn-Tucker Necessary conditions.

Text Book:

1. Soft Computing by D.K. Pratihar, Narosa Publications

Reference Books:

1. Soft computing by K. Vinoth Kumar, S.K. Kataria and Sons

2. Neural Network- A class room approach by Satish kumar, McGraw Hill.

ME6346 THEORY OF NON-LINEAR VIBRATION AND SHOCK Cr-3

Course Outcome: At end of this course, students will be able to

CO1. know the basics of nonlinear dynamics with a specific emphasis on second order systems representing vibration problems.
CO2. explain Linear stability analysis and local phase space.
CO3. explain Various sources and type of nonlinearities in mechanical systems
CO4. know Numerical approaches to get branches of solutions (continuation.)
CO5. explain Forced vibration of the van der Pol equation showing entrainment.
CO6. analyse the Detailed study of the logistic map illustrating chaos and the concept of Lyapunov exponents.

Introduction: Mechanical vibration: Linear nonlinear systems, types of forces and responses, Conservative and non-conservative systems, equilibrium points, qualitative analysis, potential well, centre, focus, saddle-point, cusp point, commonly observed nonlinear phenomena: multiple response, bifurcations, and jump phenomena.

Development of nonlinear governing equation of motion: Force and moment based approach, Lagrange Principle, Extended Hamilton's principle, Multi body approach, Linearization techniques, Development of temporal equation using Galerkin's method for continuous system, Ordering techniques, scaling parameters, book-keeping parameter. Commonly used nonlinear equations: Duffing equation, Van der Pol's oscillator, Mathieu's and Hill's equations.

Approximate solution method: Harmonic balance, perturbation techniques (Linstedt-Poincare', method of Multiple Scales, Averaging – Krylov-Bogoliubov-Mitropolsky), incremental harmonic balance, modified Lindstedt Poincare' techniques.

Stability and bifurcation analysis: static and dynamic bifurcations of fixed point and periodic response, different routes to chaotic response (period doubling, torus break down, attractor merging etc.), crisis.

Numerical techniques: time response, phase portrait, FFT, Poincare' maps, point attractors, limit cycles and their numerical computation, strange attractors and chaos; Lyapunov exponents and their determination, basin of attraction: point to point mapping and cell to cell mapping, fractal dimension.

Application: Single degree of freedom systems: Free vibration-Duffing's oscillator; primary-, secondary- and multiple- resonances; Forced oscillations: Van der Pol's oscillator; parametric excitation: Mathieu's and Hill's equations, Floquet theory; effects of damping and nonlinearity. Multi degree of freedom and continuous systems.

Text Books:

1. J S Rao and K Gupta, Theory and Practice of Mechanical Vibrations, New Age Publication, 1995

Reference Books:

1. Nayfeh, A. H., and Mook, D. T., Nonlinear Oscillations, Wiley-Interscience, 1979.
2. Hayashi, C. Nonlinear Oscillations in Physical Systems, McGraw-Hill, 1964.

3. Evan-Ivanowski, R. M., Resonance Oscillations in Mechanical Systems, Elsevier, 1976.
4. Nayfeh, A. H., and Balachandran, B., Applied Nonlinear Dynamics, Wiley, 1995.
5. Seydel, R., From Equilibrium to Chaos: Practical Bifurcation and Stability Analysis, Elsevier, 1988.
6. Moon, F. C., Chaotic & Fractal Dynamics: An Introduction for Applied Scientists and Engineers, Wiley, 1992.

ME6347 ENGINEERING TRIBOLOLGY Cr-3

Course Outcome: At the end of the course, the students will be able to

CO1. understand tribology and its broad classification, application areas as well as different terminologies related to tribology.
CO2. explain friction, wear and lubrication as well as their classification.
CO3. understand bearing and bearing lubrication.
CO4. explain bearing deign and its various parameters as well as Sommerfeld number, Petroff's equation.
CO5. understand hydrostatic and elasto-hydrodynamic lubrication as well as its various principles and applications.
CO6: explain principle of Hertz's Theory, Ertel-Grubin equation.

Introduction: Defining Tribology, Tribology in Design - Mechanical design of oil seals and gasket - Tribological design of oil seals and gasket, Tribology in Industry (Maintenance), Defining Lubrication, Basic Modes of Lubrication, Properties of Lubricants, Lubricant Additives, Defining Bearing Terminology - Sliding contact bearings - Rolling contact bearings, Comparison between Sliding and Rolling Contact Bearings.

Friction & Wear: Laws of friction - Friction classification - Causes of friction, Theories of Dry Friction, Friction Measurement, Stick-Slip Motion and Friction Instabilities, Wear - Wear classification - Wear between solids - Wear between solid and liquid - Factors affecting wear - Measurement of wear, Theories of Wear, Approaches to Friction Control and Wear Prevention, Boundary Lubrication.

Bearing Lubrication: Mechanics of Fluid Flow, Theory of hydrodynamic lubrication, Mechanism of pressure development in oil film, Two Dimensional Reynolds's Equation and its Limitations, Designing Journal Bearing, Sommerfeld number, Raimondi and Boyd method, Petroff's Solution, Parameters of bearing design, Unit pressure, Temperature rise, Length to diameter ratio, Radial clearance, Minimum oil-film thickness.
Hydrostatic Lubrication: - Basic concept - Advantages and limitations - Viscous flow through rectangular slot - Load carrying capacity and flow requirement - Energy losses - Optimum design, Squeeze Film Lubrication - Basic concept - Squeeze action between circular and rectangular plates - Squeeze action under variable and alternating loads, Application to journal bearings, Piston Pin Lubrications.

Elasto-Hydrodynamic Lubrication: Principles and Applications, Pressure viscosity term in Reynolds's equation, Hertz's Theory, Ertel-Grubin equation, Lubrication of spheres, Gear teeth bearings, Rolling element bearings.

Text Books:
1. Engineering Tribology, by G. Stachowiak and A.W. Batchelor.
2. B C Majumdar, 1999, "Introduction to Tribology of Bearings", A. H. Wheeler & Co. Ltd., New Delhi.

References:

1. Pinkus, O. and Sternlicht, B., 1961, Theory of hydrodynamic lubrication", Mc Graw Hill Book Co. Inc., New York.
2. A Cameron and C.M. Mc Ettles, 1987, Basic Lubrication Theory, Wiley Eastern Ltd., New Delhi.

ME6348 ADVANCED CONTROL THEORY Cr-3

Course Outcome: At the end of the course, the students will be able to

CO1. determine open and closed loop control system and Formulate mathematical model for physical systems.
CO2. modify complex systems using reduction techniques.
CO3. use standard test signals to set performance characteristics of first and second order systems.
CO4. apply root locus technique for stability analysis.
CO5. study performance characteristics of system using Frequency response methods.
CO6. determine response of system and able to design Lead, Lag and Lead – lag compensator.
CO7. solve optimal control problem and analyse the nonlinear system problem.

Introduction to control problems: Industrial Control examples. Transfer function models of mechanical, electrical, thermal and hydraulic systems. System with dead-time. System response. Control hardware and their models: potentiometers, synchro, LVDT, dc and ac servomotors, techno generators, electro hydraulic valves, hydraulic servomotors, electro pneumatic valves, pneumatic actuators. Closed-loop systems. Block diagram and signal flow graph analysis, transfer function.

Basic characteristics of feedback control systems: Stability, steady-state accuracy, transient accuracy, disturbance rejection, insensitivity and robustness. Basic modes of feedback control: proportional, integral and derivative. Feed-forward and multi-loop control configurations, stability concept, relative stability, Routh stability criterion. Time response of second-order systems, steady-state errors and error constants. Performance specifications in time-domain. Root locus method of design. Lead and lag compensation.

Frequency-response analysis: Relationship between time & frequency response, Polar plots, Bode's plot, stability in frequency domain, Nyquist plots. Nyquist stability criterion. Performance specifications in frequency-domain. Frequency-domain methods of design, Compensation & their realization in time & frequency domain. Lead and Lag compensation. Op-amp based and digital implementation of compensators. Tuning of process controllers. State variable formulation and solution.

State variable Analysis: Concepts of state, state variable, state model, state models for linear continuous time functions, diagonalization of transfer function, solution of state equations, concept of controllability &observability.

Introduction to Optimal control & Nonlinear control Optimal Control problem, Regulator problem, Output regulator, treking problem. Nonlinear system – Basic concept & analysis.

Text Books:

1. Gopal. M., "Control Systems: Principles and Design", Tata McGraw-Hill, 1997

Reference Books:

1. Kuo, B.C., "Automatic Control System", Prentice Hall, sixth edition, 1993.

2. Ogata, K., "Modern Control Engineering", Prentice Hall, second edition, 1991.3. Nagrath & Gopal, "Modern Control Engineering", New Ages International.

ME6349 ANALYSIS & PERFORMANCE OF COMPOSITE MATERIALS Cr-3

Course Outcome: At the end of the course, the students will be able to

CO1. understand the basics of fibers, matrices and composites and its manufacturing processes.
CO2. develop general stress-strain relation for different materials.
CO3. predict and calculating the elastic modulii and various strengths of orthotropic lamina.
CO4. evaluate the ultimate strengths of unidirectional lamina using micromechanics.
CO5. analyse macro mechanical behaviour of laminates.
CO6. uunderstandd different types of laminates, their failure modes and some design issues.

Introduction: Fibers, Matrices, Classifications, Particulate and Fabrication of composites, matrix materials.

Behavior of Unidirectional composites: Longitudinal behavior of unidirectional composites, transverse stiffness and strength, prediction of shear modulus, prediction of Poission's ratio, failure modes, expansion coefficients and transport properties.

Analyses of Orthotropic Lamina: Stress-strain relations and engineering constants, Hooke's Law and stiffness and compliance matrices, strength of an orthotropic lamina.

Analyses of Laminated composites:_ Laminate strains, laminate description system, determination of laminate stresses and strains, analysis of laminates after initial failure.

Performance of Fibre Composites: Fatigue damage, factors influencing fatigue behavior of composites, impact, energy absorbing mechanisms and failure models, effect of materials and testing variables on impact properties, hybrid composites and their impact strength, environmental-interaction effects.

Experimental characterization of Composites: Measurement of physical properties, Measurement of mechanical properties, inter-laminar shear strength and fracture toughness.

Text book:
Mechanics of Composite Materials, Autar K. Kaw, Taylor & Francis.

Reference Book:
1. Mechanics of Composite Materials, Autar K. Kaw, Taylor & Francis.
2. Engineering Mechanics of Composite Materials-I.M.Daniel and Ori Ishai, Oxford University press.