Department of Mechanical Engineering

Curriculum for M.E. CAD/CAM

Regulations 2014 - Revision 0

Semester I

Course Code	Course Title	Hours / Week			Credits	Marks
		L	T	P		
THEORY						
140CC0101	Advanced Mathematics	3	1	0	4	100
140CC0102	Computer Applications in Design	3	0	0	3	100
140CC0103	Mechanical Vibrations	3	1	0	4	100
140CC0104	CNC Machines and Robotics	3	0	0	3	100
140CC0105	Modeling and Analysis of Manufacturing Systems	3	0	0	3	100
xxx	Elective-I	3	0	0	3	100
PRACTICAL						
140CC0107	CAM Laboratory	0	0	3	2	100
TOTAL		**18**	**2**	**3**	**22**	**700**

SEMESTER II

Course Code	Course Title	Hours / Week			Credits	Marks
		L	T	P		
THEORY						
140CC0201	Finite Element Analysis	3	0	0	3	100
140CC0202	Micro Electro Mechanical Systems	3	0	0	3	100
140CC0203	Integrated Product and Processes Development	3	0	0	3	100
140CC0204	Design for Manufacture ,Assembly and Environment	3	0	0	3	100
xxx	Elective-II	3	0	0	3	100
xxx	Elective-III	3	0	0	3	100
PRACTICAL						
140CC0207	CAD and CAE laboratory	0	0	3	2	100
TOTAL		**18**	**0**	**3**	**20**	**700**

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SEMESTER III

Course Code	Course Title	Hours / Week			Credits	Marks
		L	T	P		
THEORY						
xxx	Elective-IV	3	0	0	3	100
xxx	Elective-V	3	0	0	3	100
xxx	Elective-VI	3	0	0	3	100
PRACTICAL						
140CC0307	Project Work Phase-I	0	0	12	6	200
TOTAL		**9**	**0**	**12**	**15**	**500**

SEMESTER IV

Course Code	Course Title	Hours / Week			Credits	Marks
		L	T	P		
PRACTICAL						
140CC0407	Project Work Phase-II	0	0	24	12	400
TOTAL		**0**	**0**	**24**	**12**	**400**

Total Credits: 69

LIST OF ELECTIVES

Course Code	Course Title	Hours / Week			Credits	Marks
		L	T	P		
140CC9111	Industrial Robotics and Expert Systems	3	0	0	3	100
140CC9112	Mechatronics System Design	3	0	0	3	100
140CC9113	Advanced Tool Design	3	0	0	3	100
140CC9114	Productivity Management and Re-Engineering	3	0	0	3	100
140CC9115	Applied Materials Engineering	3	0	0	3	100
140CC9116	Computer Aided Process Planning	3	0	0	3	100
140CC9117	Metrology and Non Destructive Testing	3	0	0	3	100
140CC9118	Data Communication in CAD/CAM	3	0	0	3	100
140CC9119	Computational Fluid Dynamics	3	0	0	3	100
140CC9120	Modeling of Dynamic System	3	0	0	3	100
140CC9121	Design of Automotive Systems	3	0	0	3	100
140CC9122	Design and Analysis of Thermal Systems	3	0	0	3	100
140CC9123	Design of Plastic Parts	3	0	0	3	100
140CC9124	Enterprise Resource Planning	3	0	0	3	100
140CC9125	Advanced Mechanisms Design and Simulation	3	0	0	3	100
140CC9126	Flexible Competitive Manufacturing System	3	0	0	3	100
140CC9127	Optimization Techniques in Design	3	0	0	3	100
140CC9128	Tribology in Design	3	0	0	3	100
140CC9129	Advanced Strength of Materials	3	0	0	3	100
140CC9130	Design of Material Handling Equipment	3	0	0	3	100
140CC9131	Mechanics of Composite Materials	3	0	0	3	100
140CC9132	Design of Hydraulic and Pneumatic Systems	3	0	0	3	100
140CC9133	Product Data Management	3	0	0	3	100
140CC9134	Rapid Prototyping and Tooling	3	0	0	3	100
140CC9135	Research Methodology	3	0	0	3	100
140CC9136	Engineering Fracture Mechanics	3	0	0	3	100
140CC9137	Welding Metallurgy	3	0	0	3	100
140CC9138	Combustion and Emission in engines	3	0	0	3	100

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140CC0101 **ADVANCED MATHEMATICS** **3 1 0 4**

AIM:
To develop analytical capability and to impart knowledge in Mathematical and Numerical methods and their applications in Engineering and Technology and to apply these concepts in engineering problems they would come across

OBJECTIVES:

- At the end of the course, students should be able to understand Mathematical and Numerical methods concepts and apply the concepts in solving the engineering problems.

UNIT I **SIMULTANEOUS EQUATIONS AND NUMERICAL INTEGRATION** **10+3**

Solving of set of equations, Gauss elimination method, Choleski method, Iterative methods, Relaxation method, System of non-linear equations- Newton Raphson method -Newton-Cotes integration formulas, Trapezoidal rule, Simpson's rules, Gaussian quadrature, Adaptive integration, Examples.

UNIT II **BOUNDARY VALUE AND CHARACTERISTIC VALUE PROBLEMS** **8+3**

Shooting method, solution through a set of equations, derivative boundary conditions, Rayleigh-Ritz method, characteristic value problems, solution using Characteristic polynomial method, Jacobi method, Power method and Inverse power method.

UNIT III **CALCULUS OF VARIATIONS** **6+2**

Variation and its properties –Euler's equation – Functionals dependent on first and higher order derivatives - Functionals dependent on functions of several independent variables – Rayleigh Ritz method- Galerkin method.

UNIT IV **PARTIAL DIFFERENTIAL EQUATIONS - NUMERICAL SOLUTION** **7+3**

Laplace's equations, representations as a difference equation, Iterative methods for Laplace's equations, Poisson equation, derivative boundary conditions, irregular and non-rectangular grids, Matrix patterns, Sparseness, ADI method, Applications to heat flow problems.

UNIT V **PARABOLIC PARTIAL DIFFERENTIAL EQUATIONS** **7+2**

Explicit method, Crank-Nicholson method, derivative boundary condition, stability and convergence criteria, Parabolic equations in two or more dimensions, applications to heat flow problems.

UNIT VI **HYPERBOLIC PARTIAL DIFFERENTIAL EQUATION** **7+2**

Solving wave equation by finite differences, stability of numerical method, method of characteristics, Wave equation in two space dimensions, computer programs.

Note: Assignments/Term papers using MATLAB / C / C++ to solve design problems.

L: 45, T: 15, Total: 60

REFERENCES:

1. Curtis F Gerald and Patrick O Wheatley, "Applied Numerical Analysis", Pearson Education, 2002
2. Rajasekaran S, "Numerical Methods in Science and Engineering – A Practical Approach", Wheeler Publishing, 1999, Second Edition.
3. Douglas J Faires and Riched Burden, "Numerical Methods", Brooks/Cole Publishing Company, 1998, Second Edition.
4. Steven C Chapra and Raymond P Canale, "Numerical Methods for Engineers with Software and Programming Applications", Tata McGraw Hill Edition, 2004
5. John H Mathews and Kurtis D Fink, "Numerical Methods using MATLAB", Prentice Hall, 1998.
6. Ward Cheney and David Kincaid, "Numerical Mathematics and Computing", Brooks/Cole Publishing Company, 1999, Fourth Edition.

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BoS Chairman

140CC0102 **COMPUTER APPLICATIONS IN DESIGN** **3 0 0 3**

AIM:

This programme intends to develop a new breed of Post Graduate Engineers required for the tasks of Design and Development.

OBJECTIVES:

- To give students greater breadth and depth of technical knowledge in the areas of CAD/CAM
- To synthesize and apply the concepts learnt
- To provide experience in team-based engineering design projects
- The emphasis is on mathematical modeling and the application of quantitative techniques associated with design, manufacturing, optimization, probability and statistics to the design and operation of the systems.

UNITI INTRODUCTION TO COMPUTER APPLICATIONS IN NEW PRODUCT DESIGN 9

Concept design – parametric sketching – constraints – computer graphics principles- 2D transformation, scaling, rotation – windowing, view ports – clipping – data exchange formats.

UNIT II COMPUTERS IN DESIGN 10

Solid modeling of Mechanical components – associative features – Sheet metal components, nesting and development – plastic parts with draft and shrinkage allowance – Reverse engineering of components – assembly of parts – tolerance analysis – mass property calculations

UNIT III COMPUTERS IN TOOLING DESIGN 9

Mould design – jigs and fixtures design – check for interferences – mechanism design and analysis – Rapid tooling

UNIT IV COMPUTERS IN DESIGN PRODUCTIVITY 8

Customizing various software by using visual basic, pro/program, script, LISP etc to write applications like design of shafts, gears etc.,

UNIT V MANAGING PRODUCT DESIGN DATA 9

Version control – library creation – catalog making – standardization for design – collaborative design among peer groups – Design optimization for geometry - Design check, approval and validation.

L: 45, T: 0, Total: 45

REFERENCES:

1. William M. Neumann and Robert Sproul " Principles of Computer Graphics" McGraw Hill Book Co. Singapore 1989.
2. Ibrahim Zeid "CAD/CAM – Theory and Practice" – McGraw Hill, International Edition 2010.
3. Rao. P .N. "CAD/CAM :Principles and Applications" Tata McGraw Hill , Second Edition. 2004
4. Schlechtendahl, E. G, CAD – Data transfer for Solid Models, Springer Verlag, Berlin, 1989.
5. Donald Hearn and M Pauline Baker "Computer Graphics" Prentice Hall Inc 1992

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BoS Chairman

140CC0103 **MECHANICAL VIBRATIONS** **3 1 0 4**

AIM:

To develop the theoretical basis and to derive the theories of the mechanical vibrations with sound mathematical principles and to enable students to systematically solve engineering problems regardless of difficulty

OBJECTIVES:

- To learn analytical, experimental, and numerical treatment of single and multi DOF vibration systems. Free and forced vibrations of Mechanical systems with lumped inertia, springs, and dampers are the primary emphasis.

UNIT I FUNDAMENTALS OF VIBRATION **8+3**

Introduction – Single degree freedom free vibration systems – Damped vibrations – Single degree freedom forced vibration with elastically coupled viscous dampers, System Identification from frequency response, Support motion, Duhamel's Integral – Impulse Response function – Virtual work – Lagrange's equation— Transient Vibration

UNIT II TWO DEGREE FREEDOM SYSTEM **8+3**

Free vibration of spring-coupled system – mass coupled system – Vibration of two degree freedom system – Forced vibration – Vibration Absorber – Vibration isolation.

UNIT III MULTI-DEGREE FREEDOM SYSTEM **12+3**

Normal mode of vibration – Flexibility Matrix and Stiffness matrix – Eigen values and eigen vectors – orthogonal properties – Modal matrix-Modal Analysis – Forced Vibration by matrix inversion – Modal damping in forced vibration – Numerical methods for fundamental frequencies.

UNIT IV VIBRATION OF CONTINUOUS SYSTEMS **8+3**

Systems governed by wave equations – Vibration of strings – vibration of rods – Euler Equation for Beams – Effect of Rotary inertia and shear deformation – Vibration of plates.

UNIT V EXPERIMENTAL METHODS IN VIBRATION ANALYSIS **9+3**

Vibration instruments – Vibration exciters Measuring Devices – Analysis – Vibration Tests – Free and Forced Vibration tests. Examples of Vibration tests – Industrial, case studies.

L: 45, T: 15, Total: 60

REFERENCES:

1. Benson H.Tongue, Principles of Vibration, 2nd edn., Oxford University Press, NY, 2002
2. Thomson, W.T. – "Theory of Vibration with Applications", CBS Publishers and Distributors, New Delhi, 1990.
3. Rao, J.S., & Gupta, K. – "Ind. Course on Theory and Practice Mechanical Vibration", New Age International (P) Ltd., 1984
4. Den Hartog, J.P, "Mechanical Vibrations," Dover Publications, 1990.
5. Rao, S.S.," Mechanical Vibrations,"Pearson Education , 2009

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BoS Chairman

140CC0104 **CNC MACHINES AND ROBOTICS** **3 0 0 3**

AIM:

To study the application of computers in manufacturing section and also to study the components of Industrial robotics and expert systems

OBJECTIVES:

- To introduce the numerical control machine and automation, concept of Industrial robotics,
- To learn the concepts of GI, FMS, AGV's, AS / RS systems, various planning systems and process monitoring, Control systems concepts.
- To learn the basics about robotics and robot manipulation in space, the controlling of Robots and devices system, Sensor technology, Robot programming and expert system.

UNIT I INTRODUCTION AND DESIGN FEATURES OF CNC MACHINES 9

Working principles of typical CNC lathes, turning centre, machining centre, CNC grinders, CNC gear cutting machines, wire cut EDM. Selection of CNC machine tools, structure, drive kinematics, gear box, main drive, selection of timing belts and pulleys, spindle bearings arrangement and installation. Re-circulating ball screws, linear motion guide ways, tool magazines, ATC, APC, chip conveyors tool turrets, pneumatic and hydraulic control system, Open loop and closed loop systems , microprocessor based CNC systems, description of hardware and software interpolation systems, spindle encoder

UNIT II PART PROGRAMMING OF A CNC LATHE 9

Process planning, tooling, preset and qualified tools, typical tools for turning and machining centres. Axes definition, machine and workpiece datum, turret datum, absolute and incremental programming, tape codes, ISO and EIA codes, G and M functions, tool offset information, soft jaws, tool nose radius compensation, long turning cycle, facing cycle, constant cutting velocity, threading cycle, peak drilling cycle, part programming examples.

UNIT III MANUAL PART PROGRAMMING OF A MACHINING CENTRE 9

Co-ordinate systems, cutter diameter compensation, fixed cycles, drilling cycle, tapping cycle, boring cycle, fineboring, back boring cycle, area clearance programs, macro, parametric programming, part programming examples. CAD/CAM based NC programming, features of CAM packages.

UNIT IV FUNDAMENTAL CONCEPT OF ROBOTICS AND ROBOT DRIVES 9

History, present status and future trends, robotics and automation, laws of robotics, robot definition, robotics system and robot anatomy, specification of robots, resolution, repeatability and accuracy of a manipulator. Power transmission systems and control robot drive mechanisms, mechanical transmission method, rotary-to-rotary motion conversion, rotary–to-linear motion conversion end effectors, types, gripping problem, remote-centered compliance devices, control of actuator in robot mechanisms. Sensors for robotic applications.

UNIT V TRANSFORMS AND KINEMATICS 9

Homogeneous co-ordinates, co-ordinate reference frames, homogeneous transformations for the manipulator, the forward and inverse problem of manipulator kinematics, motion generation, manipulator dynamics, robot programming.

L: 45, T: 0, Total: 45

REFERENCES

1. Radhakrishnan .P, "Computer Numerical Control CNC Machines" New central book agency, 1992
2. Richard D Klafter, Thomas A cmielewski, Michael Negin, "Robotc Engineering, AnIntegrated Approach", Eastern economy edition prentice hall Pvt. Ltd., 1989.
3. Mikell .P. Groover, Mitchell weiss, Roger N Nagel G Odrey, "Industrial Robotics", Mc-Graw Hill book co, NY, 1986.
4. Yoram Koren, "Computer Control of Manufacturing Systems", Mc-Graw Hill book co, 1986.
5. Programming instruction manuals of CNC lathes and machining centres, 2001
6. Shuman .Y .Nof, "Handbook of Industrial Robotics", John wiley and sons, New York, 1985

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BoS Chairman

140CC0105 MODELING AND ANALYSIS OF MANUFACTURING SYSTEMS

3 0 0 3

AIM:
To highlight the basic concepts and procedure for Mathematical Modeling and analysis of manufacturing systems

OBJECTIVES:

- To know the fundamentals of automation in material handling
- To understand the types and principles of manufacturing systems
- To learn the basic concepts and components of FMS
- To apply key management interfaces and activities
- To use the various optimized production techniques

UNIT I MANUFACTURING SYSTEMS AND MODELS **10**

Types and principles of manufacturing systems, types and uses of manufacturing models, physical models, mathematical models, model uses, model building.

UNIT II MATERIAL FLOW SYSTEMS **12**

Assembly lines-Reliable serial systems, approaches to line balancing, sequencing mixed models. Transfer lines and general serial systems-paced lines without buffers, unpaced lines. Shop scheduling with many products. Flexible manufacturing systems-system components, planning and control. Group technology-assigning machines to groups, assigning parts to machines. Facility layout-Quadratic assignments problem approach, graphic theoretic approach.

UNIT III SUPPORTING COMPONENTS **7**

Machine setup and operation sequencing-integrated assignment and sequencing. Material handling systems-conveyor analysis, AGV systems. Warehousing-storage and retrieval systems, order picking.

UNIT IV GENERIC MODELING APPROACHES **5**

Analytical queuing models, a single workstation, open networks, closed networks. Empirical simulation models-even models, process models, simulation system, example manufacturing system.

UNIT V SYNCHRONIZATION MANUFACTURING **5**

Synchronization Vs Optimization, defining the structure, identifying the constraint, exploitation, buffer management.

UNIT VI PETRI NETS **6**

Basic definitions-dynamics of Petri nets, transformation methods, event graphs, modeling of manufacturing systems.

L: 45, T: 0, Total: 45

REFERENCES:

1. Ronald G Askin, "Modeling and Analysis of Manufacturing Systems", John Wiley and Sons, Inc, 1993
2. Mengchu Zhou, "Modeling, Simulation, and Control of Flexible Manufacturing Ststems: A Petri Net Approach",Worls Scientific Publishing Company Pvt Ltd. 2000
3. Jean Marie Proth and Xiaolan Xie, "Petri Nets: A Tool for Design and Management of Manufacturing Systems" John Wiley and Sons, New York, 1996
4. Brandimarte. P, Villa. A, "Modeling Manufacturing Systems" Springer Verlag, Berlin, 1999.

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BoS Chairman

140CC0107 **CAM LABORATORY** **0 0 3 2**

AIM:

To equip the students with today's CAM packages

OBJECTIVES:

- To familiarize in part programming and tool path generation algorithms
- To understand the simulation concepts in CAM packages
- To provide students an extensive and intensive training in commercial CAM software

Simulation and Machining using CNC / DNC Machine Tools – Use of FEM Packages - Relational Data Base – Networking – Practice on Computer Aided Measuring Instruments - Image Processing – Software Development for Manufacturing – CNC Controllers – Use of advanced CNC Machining Packages – Business Data Processing.

Total : 45

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BoS Chairman

SEMESTER II

140CC0201 FINITE ELEMENT ANALYSIS 3 0 0 3

AIM:

To study the basic principles and applications of the Finite Element Analysis in product development

OBJECTIVES:

- To introduce Engineering Analysis tool FEA, its application in Linear static Analysis and 2D problems
- To study Finite Element modeling and simulation Techniques
- To use FEA in structural vibration and thermal Analysis
- To study and use Finite Element Software (ANSYS)

UNIT I INTRODUCTION & ONE-DIMENSIONAL PROBLEMS 10

Relevance of finite element analysis in design - Variational principles and methods – Weighted-Integral statements – Weak formulations – Ritz method – Method of weighted residuals – Applications of FEA - Finite element modeling – Co-ordinates and shape functions - Potential energy approach – Galerkin's approach – One dimensional finite element models in Solid mechanics and Heat transfer – Finite element model for beams

UNIT II TWO-DIMENSIONAL PROBLEMS 10

Poisson equation – Laplace equation – Weak form – Element matrices for triangular and rectangular elements – Evaluation of integrals – Assembly – Axi-symmetric problems – Applications – Conduction and convection heat transfer - Torsional cylindrical member – Transient analysis - Theory of elasticity – Plane strain – Plane stress – Axi-symmetric problems – Principle of virtual displacement

UNIT III ISOPARAMETRIC ELEMENTS 8

Introduction – Bilinear quadrilateral elements – Quadratic quadrilaterals – Hexahedral elements - Numerical integration – Gauss quadrature – Static condensation – Load considerations – Stress calculations – Examples of 2D and 3D applications

UNIT IV STRUCTURAL DYNAMICS APPLICATIONS 9

Dynamic equations – Mass and damping matrices – Natural frequencies and modes – Reduction of number of DOF-response history – Model methods – Ritz vectors – Component mode synthesis – Harmonic response – Direct integration techniques – Explicit and implicit methods – Analysis by response spectra – Example problems

UNIT V NON-LINEAR PROBLEMS & ERROR ESTIMATES 8

Introduction – Material non-linearity – Elasto Plasticity – Plasticity – Visco plasticity – Geometric non-linearity – Large displacement – Error norms and convergence rates – H-refinement with adaptivity – adaptive refinement

L: 45, T: 0, Total: 45

REFERENCES:

1. Reddy J.N.,"An Introduction to the Finite Element Method",McGraw Hill, International Edition,2005
2. Logan D.L, "A First Course in the Finite Element Method", Third Edition, Thomson Learning, 2002
3. Cook, Robert Davis et al "Concepts and Applications of Finite Element Analysis", Wiley, John & Sons, 1999.
4. Segerlind L.J., "Applied Finite Element Analysis", John Wiley, 1984
5. Rao. S.S., "Finite Element Analysis", 2002 Edition.
6. Zienkiewicz, O.C. and Taylor, R.L., "The Finite Element Method", Fourth Edition, Volumes 1 & 2, McGraw Hill International Edition, Physics Services, 1991
7. Bathe K.J., "Finite Element Procedures in Engineering Analysis", Prentice Hall, 1990.

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BoS Chairman

140CC0202 MICRO ELECTRO MECHANICAL SYSTEMS 3 0 0 3

AIM:
To explore the world of Micro electro mechanical devices and systems ("MEMS").

OBJECTIVES:
- To study about Micro electromechanical devices such as pressure sensors, accelerometers,
- To know about a broad range of disciplines, from micro fabrication to mechanics.

UNIT I INTRODUCTION 9

Overview-Microsystems and microelectronics - Working principle of Microsystems -micro actuation techniques-microsensors-types-microactuators-types-micropump-micromotors-micro-valves-microgrippers-scaling laws-scaling in geometry-scaling in rigid body dynamics- scaling in electrostatic forces- scaling in electricity- scaling in fluid mechanics- scaling in heat transfer.

UNIT II MATERIALS AND FABRICATION PROCESS 9

Substrates and wafer-single crystal silicon wafer formation-ideal substrates-mechanical properties-silicon compounds - Sio_2, SiC, Si_3N_4 and polycrystalline silicon - Silicon piezoresistors - Gallium aresenside, Quartz-piezoelectric crystals-polymers for MEMS -conductive polymers – Photolithography - Ion implantation - Diffusion – Oxidation –CVD - Physical vapor deposition - Deposition by epitaxy - etching process

UNIT III MICROMECHANICS 9

Introduction-static bending of thin plates-circular plates with edge fixed - rectangular plate with all edges fixed and square plate with all edges fixed – Mechanical vibration-resonant vibration- micro accelerometers-design theory and damping coefficients- thermo mechanics-thermal stresses-fracture mechanics-stress intensity factors, fracture toughness and interfacial fracture mechanics.

UNIT IV MICRO SYSTEM MANUFACTURING 9

Clean room technology-Bulk Micro manufacturing- surface micro machining –LIGA-SLIGA-Micro system packaging-materials-die level-device level-system level-packaging techniques-die preparation-surface bonding-wire bonding-sealing

UNIT V MICRO SYSTEM DESIGN 9

Design considerations-process design-mask layout design- mechanical design-applications of micro system in -automotive industry-bio medical –aero space-telecommunications.

L: 45, T: 0, Total: 45

REFERENCES:

1. Mohamed Gad-el-Hak, The MEMS Hand book, CRC press 2002
2. Julian W.Gardner,Vijay K.Varadan,Osama O.Awadel Karim,Microsensors MEMS and Smart Devices, John Wiby & sons Ltd.,2001
3. S.Fatikow,U.Rembold,Microsystem Technology and Microrobotics,Springer-Verlag Berlin Heidelberg ,1997.
4. Tai-Ran Hsu,MEMS & Microsystems Design and Manufacture,Tata McGraw-Hill,2006.
5. Francis E.H Tay and W.O Choong, Microfludics and BioMEMS Applications, Springer, 2002

BoS Chairman

140CC0203 INTEGRATED PRODUCT AND PROCESSES DEVELOPMENT

3 0 0 3

AIM:

To study the various tools and approaches available for product design and development.

OBJECTIVES:

- To give a clear insight about various aspects of product design and development
- To develop a procedural approach for the product design and development

UNIT I INTRODUCTION 9

Characteristics of Successful Product Development-Interdisciplinary activity-Duration and Costs of Product Development- Challenges of Product Development -Development Processes and Organizations-A Generic Development Process-Concept Development: The Front-End Process Adapting the Generic Product Development Process- The AMF Development Process-Product Development Organizations-The AMF Organization

UNIT II PRODUCT PLANNING 9

Product Planning Process- Identifying Opportunities- Evaluating and Prioritizing Projects- Allocating Resources and Timing- Pre-Project Planning-Reflect on the Results and the Process-Identifying Customer Needs- Raw Data from Customers- Interpreting Raw Data in Terms of Customer Needs-Organizing the Needs into a Hierarchy-Establishing the Relative Importance of the Needs-Reflecting on the Results and the Process

UNIT III PRODUCT SPECIFICATIONS **9**

Specifications - Specifications Established - Establishing Target Specifications-Setting the Final Specifications-Concept Generation-The Activity of Concept Generation-Clarify the Problem- Search Externally-Search Internally-Explore Systematically- Reflect on the Results and the Process.

UNIT IV CONCEPT SELECTION **9**

Concept Selection- Overview of Methodology-Concept Screening-Concept Testing-Define the Purpose of the Concept Test- Choose a Survey Population- Choose a Survey Format- Communicate the Concept- Measure Customer Response-Interpret the Results- Reflect on the Results and the Process

UNIT V PRODUCT ARCHITECTURE **9**

Product Architecture-Implications of the Architecture-Establishing the Architecture-Delayed Differentiation-Platform Planning-Related System-Level Design Issues

L: 45, T: 0, Total: 45

REFERENCES:

1. Product Design and Development, Karl T. Ulrich and Steven .D Epinger , McGraw-Hill International Edns. 1999.
2. Kevien Otto and Kristin Wood, "Product Design" Pearson Publication, 2004
3. Tool Design – Integrated Methods for successful Product Engineering, Stuart Pugh, Addison Wesley Publishing, Neyourk, NY, 1991, ISBN 0-202-41639-5
4. Effective Product Design and Development, Stephen Rosenthal, Business One Orwin, Homewood, 1992,ISBN, 1-55623-603-4
5. Concurrent Engg. /Integrated Product Development. Kemnneth Crow, DRM Associates, 26/3,Via Olivera, Palos Verdes, CA 90274(310) 377-569,Workshop Book

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BoS Chairman

140CC0204 DESIGN FOR MANUFACTURE, ASSEMBLY AND ENVIRONMENT

3 0 0 3

AIM:

To study how a design can be made suitable for various manufacturing and assembly process requirements.

OBJECTIVES:

- To study the various factors influencing the manufacturability of components and the use of tolerances in manufacturing.
- To apply this study to various forging, casting, welding and machining processes
- To study about the various assembly methods and processes and design for assembly guidelines

UNIT I INTRODUCTION **8**

General design principles for manufacturability - strength and mechanical factors, mechanisms selection, evaluation method, Process capability - Feature tolerances Geometric tolerances - Assembly limits -Datum features - Tolerance stacks.

UNIT II FACTORS INFLUENCING FORM DESIGN **10**

Influence of materials on form design - form design of grey iron, malleable iron, steel and aluminium castings - form design of welded members, forgings.

UNIT III COMPONENT DESIGN - MACHINING CONSIDERATION **9**

Design features to facilitate machining - drills - milling cutters - keyways - Doweling procedures, counter sunk screws - Reduction of machined area- simplification by separation - simplification by amalgamation - Design for machinability - Design for economy - Design for clampability - Design for accessibility - Design for assembly.

UNIT IV COMPONENT DESIGN - CASTING CONSIDERATION **9**

Redesign of castings based on Parting line considerations - Minimizing core requirements, machined holes, redesign of cast members to obviate cores.Identification of uneconomical design - Modifying the design - group technology - Computer Applications for DFMA

UNIT V DESIGN FOR THE ENVIRONMENT **9**

Introduction – Environmental OBJECTIVESS: – Global issues – Regional and local issues – Basic DFE methods – Design guide lines – Example application – Lifecycle assessment – Basic method – AT&T's environmentally responsible product assessment - Weighted sum assessment method – Lifecycle assessment method – Techniques to reduce environmental impact – Design to minimize material usage – Design for disassembly – Design for recyclability – Design for remanufacture – Design for energy efficiency – Design to regulations and standards.

L: 45, T: 0, Total: 45

REFERENCES:

1 Boothroyd, G, Design for Assembly Automation and Product Design, Marcel Dekker, New York., 1992.
2 Bralla, Design for Manufacture handbook, McGraw hill, 1999.
3 Boothroyd, G, Heartz and Nike, Product Design for Manufacture, Marcel Dekker, 1994
4 Dickson, John. R, and Corroda Poly, Engineering Design and Design for Manufacture and Structural Approach, Field Stone Publisher, USA, 1995
5 Fixel, J. Design for the Environment McGraw hill., 1996.
6 Graedel T. Allen By. B, Design for the Environment Angle Wood Cliff, Prentice Hall. Reason Pub., 1996.
7 Kevien Otto and Kristin Wood, Product Design. Pearson Publication, 2004

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BoS Chairman

140CC0207 **CAD AND CAE LABORATORY** **0 0 3 2**

AIM:
To learn, formulate and solve design problems using state of the art commercial CAD/CAE packages.

OBJECTIVES:

- To equip the students with fundamental theories and technologies in geometric modeling algorithms, curves and surfaces, meshing algorithms,
- To provide students an extensive and intensive practice of a leading commercial CAD/CAE software with ample in-depth projects

UNIT I **CAD (COMPUTER AIDED DRAFTING)**
Modeling and Assembly of mechanical components using parametric and feature based packages. Introduction to CAD software, Part – Assembly –Drafting model of mechanical machine components like –Flange coupling, Universal coupling, Screw jack etc.

View: Orthographic view, Isometric view, Sectional view, Exploded view.

GD&T: Standard, Part list, Bill of Material, Machining symbols, Tolerance – Fits and Geometric.

UNIT II **CAE (COMPUTER AIDED ENGINEERING)**
Analysis of mechanical machine components using analysis software.
Introduction of CAE software, STRUCTURAL Analysis: Static analysis -2D, 3D, Beam, Truss. THERMAL Analysis: 2D Conduction, 3D Convection. DYNAMICS Analysis: Modal analysis, Transient analysis.

Total: 45

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BoS Chairman

ELECTIVES

140CC9111 INDUSTRIAL ROBOTICS AND EXPERT SYSTEMS 3 0 0 3

AIM:
To study the components of Industrial robotics and expert systems.

OBJECTIVES:

- To know the basics about robotics and robot manipulation in space
- To study about the controlling of Robots and devices system
- To acquire knowledge on Sensor technology
- To do Robot programming and expert system

UNIT I INTRODUCTION AND ROBOT KINEMATICS 10

Definition need and scope of Industrial robots – Robot anatomy – Work volume – Precision movement – Classifications of Robots.Robot Kinematics – Direct and inverse kinematics – Robot trajectories – Control of robot manipulators – Robot dynamics – Methods for orientation and location of objects.

UNIT II ROBOT DRIVES AND CONTROL 9

Controlling the Robot motion – Position and velocity sensing devices – Design of drive systems – Hydraulic and Pneumatic drives – Linear and rotary actuators and control valves – Electro hydraulic servo valves, electric drives – Motors – Designing of end effectors – Vacuum, magnetic and air operated grippers.

UNIT III ROBOT SENSORS 9

Transducers and Sensors – Sensors in Robot – Tactile sensor – Proximity and range sensors – Sensing joint forces – Robotic vision system – Image Gribbing – Image processing and analysis – Image segmentation – Pattern recognition – Training of vision system.

UNIT IV ROBOT CELL DESIGN AND APPLICATION 9

Robot work cell design and control – Safety in Robotics – Robot cell layouts – Multiple Robots and machine interference – Robot cycle time analysis. Industrial application of robots.

UNIT V ROBOT PROGRAMMING, ARTIFICIAL INTELLIGENCE AND EXPORT SYSTEMS 8

Methods of Robot Programming – Characteristics of task level languages lead through programming methods – Motion interpolation. Artificial intelligence – Basics – Goals of artificial intelligence – AI techniques – problem representation in AI – Problem reduction and solution techniques - Application of Artificial Intelligence in Robots.

L: 45, T: 0, Total: 45

REFERENCES:

1. Mikell, P. Groover, Mitchell Weis, Roger, N. Nagel, Nicholas G. Odrey," Industrial Robotics Technology, Programming and Applications", Mc Graw-Hill, Int. 2000.
2. Fu. K.S., Gonzalez. R.C. and Lee. C.S.G., "Robotics Control, Sensing, Vision and Intelligence", Mc Graw Hill, 1987.
3. Yoram Koren," Robotics for Engineers' Mc Graw-Hill, 1985.
4. Kozyrey, Yu. "Industrial Robots", MIR Publishers Moscow, 1985
5. Richard. D, Klafter, Thomas, A, Chmielewski, Michael Negin, "Robotics Engineering – An Integrated Approach", Prentice-Hall of India Pvt. Ltd., 1989
6. Deb, S.R." Robotics Technology and Flexible Automation", Tata Mc Graw-Hill, 2001.
7. Timothy Jordanides et al ,"Expert Systems and Robotics ", Springer –Verlag, New York, May 1991

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BoS Chairman

140CC9112 MECHATRONICS SYSTEM DESIGN 3 0 0 3

AIM:
To enable the students to familiarize about various sensors, Transducers, microprocessor and PLC.

OBJECTIVES:
- To study the sensors and transducers used in Mechanical Engineering
- To learn how microprocessors can be used to do simple application
- To study about PLC and its applications

UNIT I INTRODUCTION **3**
Introduction to Mechatronics - Systems - Mechatronics in Products - Measurement Systems - Control Systems - Traditional design and Mechatronics Design.

UNIT II SENSORS AND TRANSDUCERS **12**
Introduction - Performance Terminology - Displacement, Position and Proximity - Velocity and Motion - Fluid pressure - Temperature sensors - Light sensors - Selection of sensors - Signal processing - Servo systems.

UNIT III MICROPROCESSORS IN MECHATRONICS **15**
Introduction - Architecture - Pin configuration - Instruction set - Programming of Microprocessors using 8085 instructions - Interfacing input and output devices - Interfacing D/A converters and A/D converters –Applications - Temperature control - Stepper motor control - Traffic light controller.

UNIT IV PROGRAMMABLE LOGIC CONTROLLERS **8**
Introduction - Basic structure - Input / Output processing - Programming -Mnemonics Timers, Internal relays and counters - Data handling - Analog input / output - Selection of PLC.

UNIT V DESIGN AND MECHATRONICS **7**
Designing - Possible design solutions - Case studies of Mechatronics systems.

L: 45, T: 0, Total: 45

REFERENCES:

1. Michael B.Histand and David G. Alciatore, "Introduction to Mechatronics and Measurement Systems", McGraw-Hill International Editions, 2007.
2. Bradley, D.A., Dawson, D, Buru, N.C. and Loader, A J., " Machatronis ", Chapman and Hall, 1993
3. Ramesh.S, Gaonkar, " Microprocessor Architecture, Programming and Applications, "Wiley Eastern, 2002.
4. Lawrence J.Kamm," Understanding Electro-Mechanical Engineering, An Introduction to Mechatronics ", Prentice-Hall, 1996.
5. Ghosh, P.K. and Sridhar, P.R., 0000 to 8085, "Introduction to Microprocessors for Engineers and Scientists ", Second Edition, Prentice Hall, 2004

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BoS Chairman

140CC9113 ADVANCED TOOL DESIGN 3 0 0 3

AIM:
To develop the ability to design cutting tools and press tools for given condition

OBJECTIVES:

- To study tool materials and their properties
- To learn to design single point cutting tools and twist drills
- To design various types of dies
- To develop blank development for different components
- To design jigs and fixtures for simple components

UNIT I TOOL-DESIGN METHODS 5

Introduction – The Design Procedure – Statement of the problem – The Needs Analysis – Research and Ideation – Tentative Design Solutions – The Finished Design – Drafting and Design Techniques in Tooling drawings – Screws and Dowels – Hole location – Jig-boring practice – Installation of Drill Bushings – Punch and Die Manufacture – Electro-discharge machining – Electro-discharge machining for cavity.

UNIT II TOOLING MATERIALS AND HEAT TREATMENT 9

Introduction – Properties of Materials – Ferrous Tooling Materials – Tool steels – Cast Iron – Mild, or low-carbon Steel – Nonmetallic Tooling Materials – Nonferrous Tooling Materials – Metal cutting Tools – Single-point cutting tools – Milling cutters – Drills and Drilling – Reamer classification – Taps – Tap classification- the selection of carbide cutting tools – Determining the insert thickness for carbide tools

UNIT III DESIGN OF DRILL JIGS 9

Introduction – Fixed Gages – Gage Tolerances – The selection of material for Gages – Indicating Gages – Automatic gages – Principles of location – Locating methods and devices – Principles of clamping – Drill jigs – Chip formation in drilling – General considerations in the design of drill jigs – Drill bushings – Methods of construction – Drill jigs and modern manufacturing

UNIT IV DESIGN OF FIXTURES AND DIES 14

Introduction – Fixtures and economics – Types of Fixtures – Vise Fixtures – Milling Fixtures – Boring Fixtures – Broaching Fixtures – Lathe Fixtures – Grinding Fixtures – Types of Die construction – Die-design fundamentals – Blanking and Piercing die construction – Pilots – Strippers and pressure pads-Presswork materials – Strip layout – Short-run tooling for Piercing – Bending dies – Forming dies – Drawing operations.

UNIT V TOOL DESIGN FOR NUMERICALLY CONTROLLED MACHINE TOOLS 8

Introduction – The need for numerical control – A basic explanation of numeric control – Numerical control systems in use today – Fixture design for numerically controlled machine tools – Cutting tools for numerical control – Tool holding methods for numerical control – Automatic tool changers and tool positioners – Tool presetting – Introduction – General explanation of the Brown and sharp machine – tooling for Automatic screw machines

L: 45, T: 0, Total: 45

REFERENCES:

1 Mehta,N.K., "Machine Tool design and Numerical Control", Tata McGraw Hill,2002.
2 Cyrll Donaldson, George H.LeCain, V.C. Goold, "Tool Design", Tata McGraw Hill Publishing Company Ltd., 2001.
3 Prakash Hiralal Joshi, "Machine tools handbook: design and operation ", Tata McGraw Hill Publishing Company Ltd., 2007

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BoS Chairman

140CC9114 PRODUCTIVITY MANAGEMENT AND RE-ENGINEERING 3 0 0 3

AIM:

To study the basic concepts of productivity management and re-engineering.

OBJECTIVE:

- To give clear insight about various aspects of Productivity concepts, organizational transformation and re-engineering process and improvement models

UNIT I INTRODUCTION **5**

Productivity concepts - Macro and Micro factors of productivity, Productivity benefit model, productivity cycle.

UNIT II PRODUCTIVITY MODELS **12**

Productivity measurement at International, National and Organizational level, Total productivity models. Productivity management in manufacturing and service sector. Productivity evaluation models, Productivity improvement models and techniques.

UNIT III ORGANIZATIONAL TRANSFORMATION **8**

Principles of organizational transformation and re-engineering, fundamentals of process reengineering, preparing the workforce for transformation and reengineering, methodology, guidelines, DSMCQ and PMP model.

UNIT IV RE-ENGINEERING PROCESS IMPROVEMENT MODELS **10**

PMI models, Edosomwan model, Moen and Nolan strategy for process improvement, LMICIP model, NPRDC model.

UNIT V RE-ENGINEERING TOOLS AND IMPLEMENTATION **10**

Analytical and process tools and techniques - Information and communication technology - Enabling role of IT, RE-opportunities, process redesign - cases. Software methods in BPR - specification of BP, case study - Order, processing, user interfaces, maintainability and reusability

L: 45, T: 0, Total: 45

REFERENCES:

1 Sumanth, D.J., " Productivity engineering and management ", TMH, New Delhi, 1990.

2 Edosomwan, J.A., " Organizational transformation and process re-engineering", British Library cataloging in pub. data, 1996.

3 Rastogi, P.N. " Re-Engineering and Re-inventing the enterprise ", Wheeler pub. New Delhi, 1999

4 Premvrat, Sardana, G.D. and Sahay, B.S, " Productivity Management - A systems approach ", Narosa Pub. New Delhi, 1998.

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BoS Chairman

140CC9115 APPLIED MATERIALS ENGINEERING 3 0 0 3

AIM:

On completion of the course the student will have knowledge about the different materials and their selection and applications.

OBJECTIVES:

This course will enable the students to know more about

- Different materials with their properties
- Various production techniques and applications
- Fracture analysis for different metals
- Strengthening mechanisms and
- Applications of metallic and non metallic materials

UNIT I ELASTIC AND PLASTIC BEHAVIOUR 10

Elasticity in metals and polymers - Mechanism of plastic deformation, role of dislocations, yield stress, shear strength of perfect and real crystals - Strengthening mechanisms, work hardening, solid sectioning, grain boundary strengthening, poly phase mixture, precipitation, particle, fiber and dispersion strengthening. Effect of temperature, strain and strain rate on plastic behaviors - Super plasticity - Deformation of non-crystalline material

UNIT II FRACTURE BEHAVIOUR 10

Griffith theory, stress intensity factor and fracture toughness - Toughening mechanisms - Ductile, brittle transition in steel - High temperature fracture, creep - Larson-Miller parameter - Deformation and fracture mechanism maps - Fatigue, low and high cycle fatigue test, crack initiation and propagation mechanisms and Paris law - Effect of surface and metallurgical parameters on fatigue - Fracture of non metallic materials - Failure analysis, sources of failure, procedure of failure analysis.

UNIT III SELECTION OF MATERIALS 10

Motivation for selection, cost basis and service requirements - Selection for mechanical properties, strength, toughness, fatigue and creep - Selection for surface durability corrosion and wear resistance - Relationship between materials selection and processing - Case studies in materials selection with relevance to aero, auto, marine, machinery and nuclear applications.

UNIT IV MODERN METALLIC MATERIALS 7

Dual phase steels, Micro alloyed, High strength low alloy (HSLA) steel, Transformation induced plasticity (TRIP) steel, Maraging steel - Intermetallics, Ni and Ti aluminides - Smart materials, shape memory alloys - Metallic glass - Quasi crystal and nano crystalline materials.

UNIT V NON METALLIC MATERIALS 8

Polymeric materials - Formation of polymer structure - Production techniques of fibers, foams, adhesives and coatings - Structure, properties and applications of engineering polymers - Advanced structural ceramics, WC, TiC, TaC, Al2O3, SiC, Si3N4, CBN and diamond - properties, processing and applications.

L: 45, T: 0, Total: 45

REFERENCES:

1. Thomas H.Courtney, " Mechanical Behaviour of Materials ", (2nd Edition), McGraw-Hill, 2000.
2. Charles J.A., Crane, F.A.A and Furness, J.A.G., " Selection and use of Engineering Materials ", (3rd Edition), Butterworth-Heiremann, 1997.
3. Flinn, R.A. and Trojan, P.K., " Engineering Materials and their Applications ", (4th Edition), Jaico, 1999.
4. George E.Dieter, " Mechanical Metallurgy ", McGraw Hill, 1988.
5. Metals Hand Book, Vol.10, " Failure Analysis and Prevention ", (10th Edition), 1994

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BoS Chairman

140CC9116 COMPUTER AIDED PROCESS PLANNING 3 0 0 3

AIM:

To provide the importance of CAPP and different steps involved in its implementation

OBJECTIVES:

This subject impregnates

- Concepts and to plan the various processes involved in manufacturing
- Modern approaches in generative approach, AI and expert systems in planning the processes

UNIT I INTRODUCTION 9

Introduction to Process Planning and Production Planning – Process Planning in the Manufacturing cycle - Process Planning and Concurrent Engineering, CAPP, Group Technology.

UNIT II PART DESIGN REPRESENTATION 9

Design Drafting - Dimensioning - Conventional tolerance - Geometric tolerance - CAD - input / output devices - topology - Geometric transformation - Perspective transformation - Data structure - Geometric modelling for process planning - GT layout, GT- coding - The optiz system - The MICLASS system- CODE system.

UNIT III PROCESS ENGINEERING AND PROCESS PLANNING 9

Experienced, based planning - Decision table and decision trees - Process capability analysis – Process boundaries – Process parameters – Process optimization. Process Planning - Variant process planning - Generative approach - Forward and Backward planning, Input format, AI.

UNIT IV COMPUTER AIDED PROCESS PLANNING SYSTEMS 9

Logical Design of a Process Planning - Implementation considerations -manufacturing system components, production Volume, No. of production families - CAM-I, CAPP, MIPLAN, APPAS, AUTOPLAN and PRO, CPPP.

UNIT V AN INTEGRATED PROCESS PLANNING SYSTEMS 9

Totally integrated process planning systems - An Overview – TIPPS Design philosophy- CAD Interface, Modulus structure – Interactive surface identification, Process knowledge- Description language - Data Structure, operation - Input and Display of CAD model- surface identification - select process- select process parameters- Report Generation- Testing results, Expert process planning.

L: 45, T: 0, Total: 45

REFERENCES:

1. Gideon Halevi and Roland D. Weill, " Principles of Process Planning ", A logical approach, Chapman & Hall, 1995
2. Tien-Chien Chang, Richard A.Wysk, "An Introduction to automated process planning systems ", Prentice Hall, 1985
3. Chang, T.C., " An Expert Process Planning System ", Prentice Hall, 1985
4. Nanua Singh, " Systems Approach to Computer Integrated Design and Manufacturing ", John Wiley & Sons, 1996.
5. Rao,P.N " Computer Aided Manufacturing ", Tata McGraw Hill Publishing Co., 2001

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BoS Chairman

140CC9117 METROLOGY AND NON DESTRUCTIVE TESTING 3 0 0 3

AIM:

To highlight the basics of metrology,SQC and NDT.

OBJECTIVES:

- To learn Purpose and use of sampling and its benefits
- To know the fundamentals and principles of NDT techniques like Liquid Penetrant, Magnetic Particle Tests, Radio Graphy,Ultrasonic and Acoustic Emission Techniques

UNIT I MEASURING MACHINES 9

Tool Maker's microscope - Co-ordinate measuring machines - Universal measuring machine - Laser viewers for production profile checks - Image shearing microscope - Use of computers - Machine vision technology - Microprocessors in metrology.

UNIT II STATISTICAL QUALITY CONTROL 9

Data presentation - Statistical measures and tools - Process capability - Confidence and tolerance limits - Control charts for variables and for fraction defectives - Theory of probability - Sampling - ABC standard - Reliability and life testing.

UNIT III LIQUID PENETRANT AND MAGNETIC PARTICLE TESTS 9

Characteristics of liquid penetrants - different washable systems - Developers - applications - Methods of production of magnetic fields - Principles of operation of magnetic particle test - Applications - Advantages and limitations.

UNIT IV RADIO GRAPHY 9

Sources of ray-x-ray production - properties of d and x rays - film characteristics - exposure charts - contrasts - operational characteristics of x ray equipment - applications.

UNIT V ULTRASONIC AND ACOUSTIC EMISSION TECHNIQUES 9

Production of ultrasonic waves - different types of waves - general characteristics of waves - pulse echo method - A, B, C scans - Principles of acoustic emission techniques - Advantages and limitations - Instrumentation - applications.

L: 45, T: 0, Total: 45

REFERENCES:

1. Jain, R.K. " Engineering Metrology ", Khanna Publishers, 2005.
2. Barry Hull and Vernon John, " Non Destructive Testing ", MacMillan, 1988.
3. American Society for Metals, " Metals Hand Book ", Vol.II, 1988.
4. Progress in Acoustic Emission, " Proceedings of 10th International Acoustic Emission Symposium ", Japanese Society for NDI, 1990.

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BoS Chairman

140CC9118 **DATA COMMUNICATION IN CAD / CAM** **3 0 0 3**

AIM:
To Highlight the Basics of Data Communication in Cad / Cam

OBJECTIVES:
- To understand the Basics of digital computers & micro processors
- To learn about Operating system & environments
- To develop knowledge on Computer networks

UNIT I DIGITAL COMPUTERS & MICRO PROCESSORS **9**

Block diagram - register transfer language - arithmetic, logic and shift micro operations - instruction code - training and control instruction cycle - I/O and interrupt design of basic computer., Machine language - assembly language - assembler.

Registers ALU and Bus Systems - timing and control signals - machine cycle and timing diagram - functional block diagrams of 80 x 86 and modes of operation. Features of Pentium Processors

UNIT II OPERATING SYSTEM & ENVIRONMENTS **9**

Types - functions - UNIX & WINDOWS NT - Architecture - Graphical User Interfaces.
Compilers - Analysis of the Source program - the phases of a compiler - cousins of the compiler, the grouping of phases - compiler construction tools.

UNIT III COMMUNICATION MODEL **9**

Data communication and networking - protocols and architecture - data transmission concepts and terminology - guided transmission media - wireless transmission - data encoding - asynchronous and synchronous communication - base band interface standards RS232C, RS449 interface.

UNIT IV COMPUTER NETWORKS **9**

Network structure - network architecture - the OSI reference model services - network standardization – example - Managing remote systems in network - network file systems - net working in manufacturing.

UNIT V INTERNET **9**

Internet services - Protocols - intranet information services - mail based service - system and network requirements - Internet tools - usenet - e-mail - IRC - www - FTP - Telnet.

L: 45, T: 0, Total: 45

REFERENCES:

1. Morris Mano. M., "Computer System Architecture", Prentice Hall of India, 2002.
2. Gaonkar R.S., "Microprocessor Architecture, Programming and Applications of 8085", Penram International, 1997
3. Peterson J.L., Galvin P. and Silberschaz, A., "Operating Systems Concepts", Addison Wesley, 2005.
4. Alfred V. Aho, Ravi Setjhi, Jeffrey D Ullman, "Compilers Principles Techniques and Tools", Addison Wesley, 2006.
5. William Stallings, "Data of Computer Communications" Pearson Educational Pvt. Ltd, 2002
6. Andrew S. Tanenbanum "Computer Networks", Prentice Hall of India 3rd Edition, 1999.
7. Christian Crumlish, "The ABC's of the Internet", BPB Publication, 1996.

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BoS Chairman

140CC9119 **COMPUTATIONAL FLUID DYNAMICS** **3 0 0 3**

AIM:

To impart knowledge on various computational methods for fluid flow and make student solve simple fluid dynamics problems.

OBJECTIVES:

- To expose to governing equations required for CFD and their mathematical behaviour
- To know grid generation principles and types of grids required for different problems
- To make aware of solution techniques and computer codes

UNIT I GOVERNING DIFFERENTIAL EQUATION AND FINITE DIFFERENCE METHOD 10

Classification, Initial and Boundary conditions, Initial and Boundary value problems. Finite difference method, Central, Forward, Backward difference, Uniform and non-uniform Grids, Numerical Errors, Grid Independence Test.

UNIT II CONDUCTION HEAT TRANSFER 10

Steady one-dimensional conduction, Two and Three-dimensional steady state problems, Transient one-dimensional problem, Two-dimensional Transient Problems.

UNIT III INCOMPRESSIBLE FLUID FLOW 10

Governing Equations, Stream Function – Verticity method, Determination of pressure for viscous flow, SIMPLE Procedure of Patankar and spalding, Computation of Boundary layer flow, Finite difference approach.

UNIT IV CONVECTION HEAT TRANSFER AND FEM 10

Steady One-Dimensional and Two-Dimensional Convection – Diffusion, Unsteady one-dimensional convection – Diffusion, Unsteady two-dimensional convection – Diffusion – Introduction to finite element method – Solution of steady heat conduction by FEM – Incompressible flow – Simulation by FEM.

UNIT V TURBULENCE MODELS 5

Algebraic Models – One equation model, K - $\in$ Models, Standard and High and Low Reynolds number models, Prediction of fluid flow and heat transfer using standard codes.

L: 45, T: 0, Total: 45

REFERENCES:

1. John D. Anderson, Computational Fluid Dynamics, McGraw-Hill International Editions, 2010
2. Muralidhar, K., and Sundararajan, T., "Computational Fluid Flow and Heat Transfer", Narosa Publishing House, New Delhi, 2011
3. Ghoshdasdidar, P.S., "Computer Simulation of flow and heat transfer" Tata McGraw-Hill Publishing Company Ltd., 1998.
4. Subas, V.Patankar "Numerical heat transfer fluid flow", Hemisphere Publishing Corporation, 2011.
5. Taylor, C and Hughes, J.B. "Finite Element Programming of the Navier Stock Equation., Pineridge Press Limited, U.K., 1981
6. Anderson, D.A., Tannehill, J.I., and Pletcher, R.H., "Computational fluid Mechanics and Heat Transfer ", Hemisphere Publishing Corporation, New York, USA, 1998
7. Fletcher, C.A.J. "Computational Techniques for Fluid Dynamics 1", Fundamental and General Techniques, Springer – Verlag, 1991.
8. Fletcher, C.A.J. "Computational Techniques for Fluid Dynamics 2", Specific Techniques for Different Flow Categories, Springer – Verlag, 1991
9. Bose, T.X., "Numerical Fluid Dynamics", Narosa Publishing House, 1997

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BoS Chairman

140CC9120 MODELING OF DYNAMIC SYSTEM 3 0 0 3

AIM:

To highlight the basics of modeling of dynamic system.

OBJECTIVES:

- To be aware of Mathematical models of physical systems
- To gain knowledge on Time response analysis and stability in time domain
- To introduce design and state variable analysis

UNIT I MATHEMATICAL MODELS OF PHYSICAL SYSTEMS 9

Introduction to control systems, differential equations of physical systems, dynamics of robotic mechanism, transfer functions, block diagram algebra, signal flow graphs.

UNIT II FEEDBACK CHARACTERISTICS OF CONTROL SYSTEMS AND COMPONENTS 9

Feed back and non feedback systems, reduction of parameter variations, control over system dynamics, control of the effects of disturbance signals, linearizing effect, regenerative feedback.. Linear approximation on non-linear systems, stepper motors, hydraulic systems, pneumatic systems.

UNIT III TIME RESPONSE ANALYSIS AND STABILITY IN TIME DOMAIN 9

Standard test signals, time response of first-order systems, time response of second-order systems, steady-state errors and error constraints, effect of adding a zero to a system, design specifications of second-order systems, design considerations for higher-order system, performance indices, robotic control systems, state variable analysis, approximation of higher-order systems by lower order systems, concept of stability, necessary conditions, Routh stability criterion, relative stability analysis

UNIT IV FREQUENCY RESPONSE ANALYSIS AND STABILITY IN FREQUENCY DOMAIN 9

Correlation between time and frequency response, polar plots, bode plots, all-pass and minimum-phase systems, experimental determination of transfer functions, log-magnitude versus phase plots, Nyquist stability criterion, assessment of relative stability, closed loop frequency response, sensitivity analysis.

UNIT V INTRODUCTION TO DESIGN AND STATE VARIABLE ANALYSIS 9

Preliminary considerations, realization of basic compensators, cascade compensation in time domain and frequency domain, feedback compensation, robust control system design. Concepts of state, state variables and state model, state models for linear-continuous-time systems, state variables and linear discrete-time systems, solutions of state equations, concepts of controllability and observability, pole placement by state feedback.

L: 45, T: 0, Total: 45

REFERENCES:

1 Nagrath I J, and Gopal M, "Control Systems Engineering"' New Age International Publishers, Fourth edition, 2005

2 Okata K, "Modern Control Engineering"' Pearson/Prentice hall of India Pvt. Ltd., New Delhi, 1997.

3 Gopal M, "Control Systems-Principles and design"' Tata McGraw Hill Co. ltd., 2nd Edition, 2002

4 Norman S Nise, " Control System Engineering"' John Wiley & Sons Inc., 2001

5 Sergey Edward Lyshevski, "Control Systems-Theory with Engineering Applications"' Springer-Verlag, New York Inc., 2002

6 Stainslaw H Zak, "Systems and Control"' Oxford University Press Inc., 2003

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BoS Chairman

140CC9121 DESIGN OF AUTOMOTIVE SYSTEMS 3 0 0 3

AIM:
To impart knowledge on automotive system design.

OBJECTIVE:
- The student will know about the design of clutch, gear, suspension and brakes in automobiles and their principle of operation and performance.

UNIT I INTRODUCTION 9
Fundamentals of designing automobiles-performance of automobiles, general layout of the automobile Design conditions-loading conditions, maximum moments in automobile transmission, forced vibrations of sprung mass with random disturbance, fatigue resistance analysis procedure.

UNIT II CLUTCH 9
Introduction-design diagrams of clutch, calculation of critical parameters of clutches, design calculation of standard elements of friction clutches, torsional vibration dampers, clutch control drives.

UNIT III TRANSMISSION 9
Determining main parameters of transmission, gear shift mechanisms, main gear, differential, differential housings, axle shafts, fear box, auxiliary gear box, transfer case, planetary gears, kinematics of universal joints, design of universal joint and propeller shaft, location determination of universal joint and propeller shaft.

UNIT IV SUSPENSION AND STEERING SYSTEM 9
Oscillation and smoothness of ride, elastic characteristics of ride, elastic elements of suspension, shock absorbers. Fundamentals of designing and calculating steering control linkage, steering gears, hydraulic booster.

UNIT V BRAKES 9
Pressure distribution along shoe length, determining braking torque, design of drum and disk brakes, fundamentals of designing brake force regulators, antilocking system.

L: 45, T: 0, Total: 45

REFERENCES:

1 Lukin P Gasparyants G and Rodionov V, "Automobile Chassis Design and Calculations", Mir Publishers, 1989.
2 Heinz Heisier, "Vehicle and Engine technology"' SAE, New York, 1999.
3 Reza.N.jazar, " Vehicle Dynamics: Theory and applications"' Springer., 2008
4 Schwaller A E, "Motor Automotive Technology"' Third Edition, Delman Publishers, New York, 2008.

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BoS Chairman

140CC9122 DESIGN AND ANALYSIS OF THERMAL SYSTEMS 3 0 0 3

AIM:

The purpose of this course is to impart knowledge about thermal system design and analysis.

OBJECTIVE:

- The student will know about the basic principles, mathematical modeling and modeling thermal equipments

UNIT I INTRODUCTION **8**

Design Principles, workable systems, optimal systems, matching of system components, economic analysis , depreciation, gradient present worth factor.

UNIT II MATHEMATICAL MODELING **9**

Equation fitting, nomography, empirical equation, regression analysis, different modes of mathematical models, selection, computer programmes for models.

UNIT III MODELLING THERMAL EQUIPMENTS **9**

Modelling heat exchangers, evaporators, condensers, absorption and rectification columns, compressor, pumps, simulation studies, information flow diagram, solution procedures.

UNIT IV SYSTEMS OPTIMIZATION **10**

OBJECTIVES function formulation, constraint equations, mathematical formulation, Calculas method, dynamic programming, geometric programming, linear programming methods, solution procedures.

UNIT V DYNAMIC BEHAVIOUR OF THERMAL SYSTEM **9**

Steady state simulation, Laplace transformation, feedback control loops, stability analysis, non-linearties.

L: 45, T: 0, Total: 45

REFERENCES:

1 Stoecker W F, "Design of Thermal Systems"' McGraw Hill, 1980.
2 Kapur J N, "Mathematical Modelling"' New Age International Pvt Ltd Publishers , 2008.
3 Stoecker W F, "Refrigeration and Air-Conditioning"' TMH, 1985
4 Fanger P O, "Thermal Comport"' McGraw Hill, USA 1972
5 McQuiston F C and Parker T D, " Heating, Ventilating and Air conditioning, Analysis and design"' John Wiley and Sons, USA,6th edition 2005.

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BoS Chairman

140CC9123 **DESIGN OF PLASTIC PARTS** **3 0 0 3**

AIM:
To impart knowledge about plastic parts design.

OBJECTIVES:
- To study Basic principles
- To design injection molded parts
- To design Compression and transfer mould design

UNIT I SELECTION OF PLASTICS **9**
Mechanical Properties- Material Selection for Strength – Degradation - Wear Resistance and Frictional Properties- Special Properties - Processing - Costs. Mechanical Behavior of Plastics- Short term tests -Long term testing -Design Methods for Plastics using deformation data -Pseudo-Elastic design method for plastics-Thermal stresses and Strains- - Time Temperature Superposition - Fracture behavior - Creep behavior - Impact behavior.

UNIT II DESIGN OF INJECTION MOLDED PARTS **9**
Manufacturing Considerations -Mold Filling Considerations -Weld line-Shrinkage and Warpage - Cooling and Solidification-Structural design Considerations-Structural Members-Design for Stiffness - Processing Limitations in Product Design.

UNIT III INTRODUCTION TO MOULD DESIGN **9**
Types of moulds and dies for various processing methods - Mould and Die Design Concept and Materials. Injection Mould Design - Basics of mould construction - Methodical Mould Design - Design of Feed System, Ejection System - Venting - Design of Cooling system -Mould alignment concepts and Demoulding Techniques.

UNIT IV COMPRESSION AND TRANSFER MOULD DESIGN **9**
Basics of mould construction - Mould design -Positive moulds- Positive moulds with Lands- Multi cavity moulds with individual, common Loading Chamber - Moulds with a slide core - Split cavity moulds, Heat losses and energy requirement.

UNIT V BLOW MOULD DESIGN **9**
Materials Selection, Mould Cooling, Clamping Force, Venting, Pinch-off, Head die design, Parison Diameter Calculation, Wall Thickness, Vertical-load strength, Blow ratio, Base pushup, Neck and Shoulder Design, Thread and beads, Bottom Design. Extrusion Die Design - Die geometry, Die Design, Materials and Classification.

L: 45, T: 0, Total: 45

REFERENCES:

1 Cracknell. P.S. and Dyson. R.W, Handbook of Thermoplastics - Injection Mould Design, Chapman & Hall, 1993
2 Laszlo Sors and Imre Balazs, Design of Plastics Moulds and Dies, Elsevier, Amsterdam, 1989.
3 Pye. R.G.W., Injection Mould Design, SPE Publication, 2000.
4 Crawford. R J, Plastics Engineering, Butterworth-Heinemann, Oxford, 1999
5 Edward Miller(Ed), Plastics Product Design Handbook Part A –Materials and Components, Marcel Dekker, 1981
6 Malloy. R.A., Plastic Part Design for Injection Molding An Introduction, Hanser, 1997
7 Rao. N., O'Brien. K, Design Data for Plastics Engineers, Hanser, New York, 1998

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BoS Chairman

140CC9124 **ENTERPRISE RESOURCE PLANNING** **3 0 0 3**

AIM:

This course provides the basic knowledge on aspects of entrepreneurship and supports extended to entrepreneurs.

OBJECTIVES:

- To gain knowledge on planning an enterprise
- To apply technology related developments
- To apply ERP implementation strategies and relate organizational issues
- To apply ERP on the net

UNIT I ENTERPRISE RESOURCE PLANNING **10**

Principle – ERP framework – Business Blue Print – Business Engineering vs Business process Re-Engineering – Tools – Languages – Value chain – Supply and Demand chain – Extended supply chain management – Dynamic Models –Process Models

UNIT II TECHNOLOGY AND ARCHITECTURE **10**

Client/Server architecture – Technology choices – Internet direction – Evaluation framework – CRM – CRM pricing – chain safety – Evaluation framework.

UNIT III ERP SYSTEM PACKAGES **10**

SAP - People soft, Baan and Oracle – Comparison – Integration of different ERP applications – ERP as sales force automation – Integration of ERP and Internet – ERP Implementation strategies – Organizational and social issues.

UNIT IV ORACLE **7**

Overview – Architecture – AIM: – applications – Oracle SCM. SAP: Overview – Architecture – applications -Before and after Y2k – critical issues – Training on various modules of IBCS ERP Package-Oracle ERP and MAXIMO, including ERP on the NET

UNIT V ERP PROCUREMENT ISSUES **8**

Market Trends – Outsourcing ERP – Economics – Hidden Cost Issues – ROI – Analysis of cases from five Indian Companies.

L: 45, T: 0, Total:45

REFERENCES:

1. Sadagopan. S , ERP-A Managerial Perspective, Tata McGraw Hill, 1999.
2. Jose Antonio Fernandez, The SAP R/3 Handbook, Tata McGraw Hill, 1998.
3. Vinod Kumar Crag and N.K.Venkitakrishnan, Enterprise Resource Planning – Concepts and Practice, Prentice Hall of India, 1998.
4. ERPWARE, ERP Implementation Framework, Garg & Venkitakrishnan, Prentice Hall, 1999.
5. Thomas E Vollmann and Bery Whybark, Manufacturing and Control Systems, Galgothia Publications, 1998.

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BoS Chairman

140CC9125 ADVANCED MECHANISMS DESIGN AND SIMULATION 3 0 0 3

AIM:

To expose the students on the advances of various laws governing rigid bodies and its motions.

OBJECTIVES:

- Basic mechanisms, velocity and acceleration of simple mechanisms
- Drawing the profile of cams and its analysis
- Mechanisms in robotics

UNIT I INTRODUCTION **5**

Review of fundamentals of kinematics – mobility analysis – formation of one D.O.F. multi loop kinematic chains, Network formula – Gross motion concepts.

UNIT II KINEMATIC ANALYSIS **5**

Displacement , Velocity and acceleration analysis of simple mechanisms, instant centres kinematic analysis of complex mechanisms , Goodman analysis , auxiliary point method.

UNIT III PATH CURVATURE THEORY **6**

Inflection point and inflection circles. Euler – Savary equation, Bobilliers constructions , Hartmann's construction, the cubic of stationary curvature or Burmester's circle point and center point curves for four infinitesimally close positions of the moving plane.

UNIT IV SYNTHESIS OF MECHANISMS **15**

Type synthesis – Number synthesis – Associated Linkage Concept. Dimensional synthesis – function generation, path generation, motion generation. Graphical methods. Cognate linkages -Coupler curve synthesis, design of six-bar mechanisms. Algebraic methods. Application of instant center in linkage design. Cam Mechanisms – determination of optimum size of Cams.

UNIT V DYNAMICS OF MECHANISMS AND SPATIAL MECHANISMS AND ROBOTICS **14**

Static force analysis with friction – Inertia force analysis – combined static and inertia force analysis, shaking force, Kinetostatic analysis. Introduction to force and moment balancing of linkages.

Kinematic Analysis of Spatial RSSR mechanism – Denavit – Hartenberg Parameters. Forward and inverse Kinematics of Robotic Manipulators. Study and use of Mechanism using Simulation Soft-ware packages.

L: 45, T: 0, Total: 45

REFERENCES:

1. Uicker, J.J, Pennock G.R. and Shigley, J.E., "Theory of Machines and Mechanisms", Oxford University Press, NY, 2003
2. Amitabha Ghosh and Asok Kumar Mallik, "Theory of Mechanism and Machines", EWLP, Delhi, 1999.
3. Sandor G.N., and Erdman A.G., "Advanced Mechanism Design Analysis and Synthesis", Prentice Hall, 4th edition 2001.
4. Nortron R.L., "Design of Machinery", McGraw Hill, 1999.
5. Kenneth J, Waldron, Gary L. Kinzel, "Kinematics, Dynamics and Design of Machinery", John Wiley-sons, 1999.

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BoS Chairman

140CC9126 FLEXIBLE COMPETITIVE MANUFACTURING SYSTEM 3 0 0 3

AIM:
To introduce the basics and components of FMS to the learners.

OBJECTIVES:
To familiarise
- Basic concepts and components of FMS
- Automated material handling systems used in FMS
- FMS control using computers
- Software used in FMS & scheduling of FMS

UNIT I MANUFACTURING IN A COMPETITIVE ENVIRONMENT 9
Automation of manufacturing process - Numerical control - Adaptive control - material handling and movement - Industrial robots - Sensor technology - flexible, fixturing - Design for assembly, disassembly and service.

UNIT II GROUP TECHNOLOGY 9
Part families - classification and coding - Production flow analysis - Machine cell design - Benefits.

UNIT III FLEXIBLE MANUFACTURING SYSTEMS 9
Introduction - Components of FMS - Application workstations - Computer control and functions - Planning, scheduling and control of FMS - Scheduling - Knowledge based scheduling - Hierarchy of computer control - Supervisory computer.

UNIT IV COMPUTER SOFTWARE, SIMULATION AND DATABASE OF FMS 9
System issues - Types of software - specification and selection - Trends - Application of simulation - software - Manufacturing data systems - data flow - CAD/CAM considerations - Planning FMS database.

UNIT V JUST IN TIME 9
Characteristics of JIT - Pull method - quality -small lot sizes - work station loads - close supplier ties - flexible work force - line flow strategy - preventive maintenance - Karban system - strategic implications - implementation issues - MRD JIT - Lean manufacture.

L: 45, T: 0, Total: 45

REFERENCES:

1. Groover M.P., "Automation, Production Systems and Computer Integrated Manufacturing ", Prentice-Hall of India Pvt. Ltd., New Delhi, 2007.
2. Jha, N.K. " Handbook of Flexible Manufacturing Systems ", Academic Press Inc., 1991
3. Kalpakjian, " Manufacturing Engineering and Technology ",Prentice Hall; 6 edition , 2009.
4. Taiichi Ohno, Toyota, " Production System Beyond Large-Scale production", Productivity Press (India) Pvt. Ltd., 1992

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BoS Chairman

140CC9127 OPTIMIZATION TECHNIQUES IN DESIGN 3 0 0 3

AIM:

To study the principles of optimization and various techniques which can be used for Mechanical Engineering optimization along with applications

OBJECTIVES:

- To know the Principles of optimization and its needs
- To learn various conventional optimization techniques
- To solve multivariable problems
- To solve problems using Unconventional optimization techniques
- To apply optimization to design of machine elements

UNIT I INTRODUCTION 5

General Characteristics of mechanical elements, adequate and optimum design, principles of optimization, formulation of OBJECTIVES function, design constraints – Classification of optimization problem.

UNIT II UNCONSTRAINED OPTIMIZATION 8

Single variable and multivariable optimization, Techniques of unconstrained minimization – Golden section, pattern and gradient search methods – Interpolation methods.

UNIT III CONSTRAINED OPTIMIZATION 12

Optimization with equality and inequality constraints - Indirect methods using penalty functions, Lagrange multipliers; Geometric programming- Constrained, mixed inequality and unconstrained minimization; Genetic algorithms.

UNIT IV STATIC APPLICATIONS 10

Structural applications – Design of simple truss members. Design applications – Design of simple axial, transverse loaded members for minimum cost, maximum weight – Design of shafts and torsionally loaded members – Design of springs.

UNIT V DYNAMIC APPLICATIONS 10

Dynamic Applications – Optimum design of single, two degree of freedom systems, vibration absorbers. Application in Mechanisms – Optimum design of simple linkage mechanisms.

L: 45, T: 0, Total: 45

REFERENCES:

1. Singiresu S.Rao., "Engineering Optimization Theory and Practice", Wiley; 4 edition 20, 2009 .
2. Johnson Ray, C., "Optimum design of mechanical elements", Wiley, John & Sons, 1990.
3. Kalyanamoy Deb, "Optimization for Engineering design algorithms and Examples", Prentice Hall of India Pvt. 1995
4. Goldberg, D.E., "Genetic algorithms in search, optimization and machine", Barnen, Addison-Wesley, New York, 1989.
5. Saravanan.R, "Manufacturing optimization through intelligent techniques", Taylor and Francis Publications, CRC Press, 2006.

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BoS Chairman

140CC9128 **TRIBOLOGY IN DESIGN** **3 0 0 3**

AIM:
To study the surface properties, wear and lubrication in Mechanical Engineering.

OBJECTIVES:
- To identify the tribological problems in real environment
- To know the how to rectify these problems

UNIT I SURFACES, FRICTION AND WEAR **9**

Topography of surfaces – Surfaces features – Experimental Determinations of surface structure – Chemical analysis of surface – surface effects in Tribology – Analysis of surface roughness – measurement of surface roughness. Friction – Mechanism of friction, measuring friction, equations and models of friction – Friction properties of metallic and non metallic materials, friction in extreme conditions. Wear – Types, mechanism, mapping, measurements, wear resistance materials – surface treatment, surface modifications and surface coatings. Computer Simulations of friction, lubrication and wear.

UNIT II LUBRICATION THEORY **9**

Lubricants – selection criteria – lubrication regimes – Hydrodynamic, elasto and plasto hydrodynamic lubrication, basic equations, Reynold's equation, energy equation, boundary lubrication, boundary lubricating films and its properties. Hydrostatic lubrication – Gas lubrication

UNIT III DESIGN OF FLUID FILM BEARINGS **9**

Dynamic analysis of hydrodynamic bearing performance, trust and journal bearings– full, partial, fixed and pivoted – mass flow rate, friction, power loss, heat and temperature difference, dynamic loads, oil film thickness, stiffness of squeeze film and dynamic co-efficient – hydrostatic bearing design.

UNIT IV INDUSTRIAL COMPONENTS AND SYSTEMS **9**

Slider bearings – self acting finite bearings, failure modes, materials rolling element bearings – Types, contact mechanics, bearing internal load distribution, lubrication – Bearing geometry and kinematics, load ratings and life prediction, torque calculation, temperature analysis, endurance testing and failure analysis.

UNIT V SPACE AND AUTOMOTIVE TRIBOLOGY **9**

Introduction – Mechanism, components, liquid and solid lubricants, accelerated testing and life testing of space mechanism. Principles of Aerospace eccentric bearing test mechanism. Engine Tribology – importance, lubrication regimes, engine bearings, wheel bearings, tire. Mechanics of load transfer – contact area and normal pressure distribution, brakes, effects of service on engine oil properties. Tribology in manufacturing – macro and micro tribology of MEMS materials. Technologies for machinery diagnosis and prognosis.

L: 45, T: 0, Total: 45

REFERENCES:

1. Cameron, A. "Basic Lubrication Theory", Ellis Herward Ltd., UK, 1983
2. Hulling, J. (Editor) – " Principles of Tribology", MacMillan, 1984
3. Williams, J.A. "Engineering Tribology", Oxford University Press, 1994
4. Neale, M.J. "Tribology Handbook", Butterworth Heinemann, 1995
5. Bharat Bhushan, "Modern Tribology Handbook" Vol. – I & II.,2001

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BoS Chairman

140CC9129 **ADVANCED STRENGTH OF MATERIALS** **3 0 0 3**

AIM:

To familiarize the students in the area of stress, strain and deformation for a 3D problems.

OBJECTIVE:

- To solve practical problems involving Unsymmetrical bending, stress in flat plates, Torsion of noncircular sections and contact stresses.

UNIT I ELASTICITY **8**

Stress – Strain relation and General equation of elasticity in cartesian, polar and spherical coordinates-differential equation of equilibrium – compact ability – boundary conditions, representations of three dimensional stress of a tension – generalized Hooke's law – St.Vennant's principle – Plane strain, plane stress – Airy's stress function. hear Centre:Location of shear centre for various sections – shear flow.

UNIT II UNSYMMETRICAL BENDING **10**

Stresses and deflection in beams subjected to unsymmetrical loading – Kern of a section. Curved flexural members - circumferential and radial stresses – deflection and radial curved beam with re-strained ends – closed ring subjected to concentrated load and uniform load – chain link and crane hooks.

UNIT III THICK CYLINDERS AND ROTATING DISKS **10**

Thick walled cylinder subjected to internal and external pressures – Shrink fit joints – Stresses due to rotation – Radial and tangential stresses in solid disc and ring of uniform thickness and varying thickness – allowable speed. – Rotating shafts and cylinders.

UNIT IV TORSION OF NON CIRCULAR SECTIONS **8**

Torsion of rectangular cross section – St.Vennant Theory – elastic membrane analogy – Prandtl's stress function – Torsional stresses in hollow thin walled tubes.

UNIT V STRESSES IN FLAT PLATES **9**

Stresses in circular and rectangular plates due to various types of loading and end conditions – Buckling of plates. Theory of contact stresses – methods of computing contact stresses – deflection of bodies in point and line contact – applications.

L: 45, T: 0, Total: 45

REFERENCES:

1. Arthur P.Boresi and Richard J.Schmidt, "Advanced Mechanics of Materials", John, Willey & Sons, Inc., 2003.
2. Arthur P.Boresi and Omar M.Siseborttom, "Advanced Mechanics of Materials", John, Willey International Education, 1985.
3. Robert,D.Cook, Wareen.C.Yound, "Advanced Mechanics of Materials", Macmillon Publishers Company, 1985.
4. Srinath.L.S., Advanced Mechanics of Solids, Tata McGraw Hill Publishing Company Limited, 2003
5. KrishnaRaju.N.,Gururaja.D.R, Advanced Mechanics of Solids and Structures,Narosa Publishing House, 1997.
6. Jindal. U.C., "Advanced Topics of Strength of materials", Galgotia Publications, First edition, 1997.

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BoS Chairman

140CC9130 DESIGN OF MATERIAL HANDLING EQUIPMENT 3 0 0 3

(Use of approved data book is permitted)

AIM:

To study the design of material handling equipments like Elevators, cranes and its drives.

OBJECTIVES:

- To study the material handling equipments such as Elevators, Cranes, its characteristics and applications
- To select / design various machine elements and components for material handling equipments

UNIT I FLEXIBLE HOISTING APPLIANCES 9

Type, selection and applications of material handling equipments, choice of material handling equipment – hoisting equipment – components and theory of hoisting equipment – chain and ropes – selection of ropes, pulleys, pulley systems, sprockets and drums.

UNIT II LOAD HANDLING EQUIPMENTS AND BRAKES 9

Forged standard hooks – forged Ramshorn hooks – solid triangular eye hooks – crane grabs, electric lifting magnetic – grabbing attachments for loose materials. arresting gear – brakes: shoe, band and cone types – elements of shoe brakes – thermal calculation in shoe brakes.

UNIT III SURFACE AND OVERHEAD TRANSPORTATION EQUIPMENTS 9

Hand operated trucks – powered trucks – tractors – electronically controlled tractors - hand truck on rails – industrial railroad equipments: locomotives - winches – capstans – turntables – monorail conveyors – pipe rail systems – flat bar monorails. Rail traveling mechanism, cantilever and monorail cranes, cogwheel drive, monocable tramways- reversible tramways.

UNIT IV ELEVATING EQUIPMENTS 9

Continuous-motion vertical conveyors – reciprocating-motion vertical conveyors – stackers – work levelers and tail gates – industrial lifts – passenger lifts – freight elevators – mast type elevators – vertical skip hoist elevators, bucket elevators: design, loading and bucket arrangements.

UNIT V CONVEYING EQUIPMENTS 9

Belt conveyors - chain conveyors – apron conveyors – escalators – flight conveyors – roller conveyors - oscillating conveyors. design of belt conveyors, screw conveyors and pneumatic conveyors.

L: 45, T: 0, Total: 45

REFERENCES:

1. Rudenko. N., Materials Handling Equipment – MIR Publishers, 1969
2. Spivakovsky. A.O and Dyachkov. V.K., Conveying Machines, Volume I and II, MIR Publishers, 1985
3. Alexandrov, M., Materials Handling Equipments, MIR Publishers, 1981
4. Boltzharol, A., Materials Handling Handbook, The Ronald Press Company, 1958.
5. P.S.G Tech.., Design Data Book, Kalaikathir Achchagam, 2003
6. Lingaiah. K. and Narayana Iyengar, Machine Design Data Hand Book, Vol. 1 & 2, Suma Publishers, 1986
7. Chowdary.R.B and Tagore.G.R.N.– Materials Handling Equipment –Khanna Publishers, 1996

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BoS Chairman

140CC9131 MECHANICS OF COMPOSITE MATERIALS 3 0 0 3

AIM:

To study the composition, properties and analysis of composite materials.

OBJECTIVES:

- To analyze the characteristics of fiber-reinforced plastics
- To understand the various moulding process of composite materials, stress analysis of composite beams, plates and shells

UNIT I INTRODUCTION 8

Definition – Need – General Characteristics, Applications. Fibers – Glass, Carbon, Ceramic and Aramid fibers. Matrices – Polymer, Graphite, Ceramic and Metal Matrices – Characteristics of fibers and matrices. Fiber surface treatments, Fillers and additives, Fiber content, density and void content.

UNIT II MECHANICS 12

Rule of mixture -volume and mass fractions – density - void content, Evaluation of four elastic moduli based on strength of materials approach and Semi-Empirical model-Longitudinal Young's modulus-transverse Young's modulus–major Poisson's ratio-In-plane shear modulus, Ultimate strengths of a unidirectional lamina. Characteristics of Fiber-reinforced lamina–laminates–lamination theory, Interlaminar stresses

UNIT III PERFORMANCE 5

Static Mechanical Properties – Fatigue and Impact Properties – Environmental effects – Long term properties, Fracture Behavior and Damage Tolerance.

UNIT IV MANUFACTURING 8

Bag Moulding – Compression Moulding – Pultrusion – Filament Winding – Other Manufacturing Processes – Quality Inspection methods. Processing of MMC –diffusion bonding – stir casting – squeeze casting.

UNIT V DESIGN 12

Failure Predictions, Laminate Design Consideration-design criteria-design allowables -design guidelines, Joint design-Bolted and Bonded Joints, Design Examples-Design of a tension member – design of a compression member – design of a beam-design of a torsional member, Application of FEM for design and analysis of laminated composites.

L: 45, T: 0, Total: 45

REFERENCES:

1. Mallick, P.K., "Fiber Reinforced Composites: Materials, Manufacturing and Design", Marcel Dekker Inc, 1993
2. Autar K. Kaw, "Mechanics of Composite Materials" CRC Press, 2006
3. Agarwal, B.D., and Broutman L.J., "Analysis and Performance of Fiber Composites", John Wiley and Sons, New York, 1999.
4. Ronald Gibson, "Principles of Composite Material Mechanics", Tata McGraw Hill, 2007
5. Chawla K.K., "Composite materials", Springer – Verlag, 2006

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BoS Chairman

140CC9132 DESIGN OF HYDRAULIC AND PNEUMATIC SYSTEMS 3 0 0 3

AIM:

To study the principles and applications of Hydraulic and Pneumatic systems.

OBJECTIVES:

- To create part and assembly models of machines
- To learn about different types of pumps, motors, their construction and operations etc
- To be aware of different types of valves and its practical applications
- To design hydraulic circuit for lift, press and other practical applications
- To understand the basic concepts of pneumatic principles, ckts and its application

UNIT I OIL HYDRAULIC SYSTEMS AND HYDRAULIC ACTUATORS 5

Hydraulic Power Generators – Selection and specification of pumps, pump characteristics-Determination of volumetric, mechanical and overall efficiencies of positive displacement pumps. Linear and Rotary Actuators – selection, specification and characteristics.

UNIT II CONTROL AND REGULATION ELEMENTS 12

Pressure - direction and flow control valves - relief valves, non-return and safety valves - actuation systems. Electrical control solenoid valves, relays, Electro hydraulic servo valves.

UNIT III HYDRAULIC CIRCUITS 5

Reciprocation, quick return, sequencing, synchronizing circuits - accumulator circuits - industrial circuits - press circuits - hydraulic milling machine - grinding, planning, copying, - forklift, earth mover circuits-design and selection of components - safety and emergency mandrels.

UNIT IV PNEUMATIC SYSTEMS AND CIRCUITS 16

Pneumatic fundamentals - control elements, position and pressure sensing - logic circuits - switching circuits - fringe conditions modules and these integration - sequential circuits - cascade methods - mapping methods - step counter method - compound circuit design - combination circuit design.

UNIT V INSTALLATION, MAINTENANCE AND SPECIAL CIRCUITS 7

Pneumatic equipments- selection of components - design calculations – application -fault finding - hydro pneumatic circuits - use of microprocessors for sequencing - PLC, Low cost automation - Robotic circuits.

L: 45, T: 0, Total: 45

REFERENCES:

1. Bolton. W., "Pneumatic and Hydraulic Systems ", Butterworth –Heinemann, 1997.
2. Antony Espossito, "Fluid Power with Applications", Prentice Hall, 2008.
3. Dudleyt, A. Pease and John J.Pippenger, Industrial Hydraulics, Tata MGraw Hill Prentice Hall, 1985.
4. Andrew Parr, "Hydraulic and Pneumatic" (HB), Jaico Publishing House, 2004.
5. Majumdar, S.R., Oil Hydraulic Systems, Principles and Maintenance, Tata MGraw Hill Prentice Hall, 2001.

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BoS Chairman

140CC9133 PRODUCT DATA MANAGEMENT 3 0 0 3

AIM:

To gain knowledge about the principles and applications of product data management.

OBJECTIVES:

- To learn about the components of a typical PDM
- To develop the simple projects in life cycle of a product
- To study about the Data Management Systems for FEA data

UNIT I INTRODUCTION 3

Introduction to PDM-present market constraints-need for collaboration - internet and developments in server-client computing.

UNIT II COMPONENTS OF PDM 9

Components of a typical PDM setup-hardware and software-document management-creation and viewing of documents-creating parts-versions and version control of parts and documents-case studies.

UNIT III CONFIGURATION MANAGEMENT 5

Base lines-product structure-configuration management-case studies.

UNIT IV PROJECTS AND ROLES 12

Creation of projects and roles-life cycle of a product- life cycle management-automating information flow-work flows- creation of work flow templates-life cycle-work flow integration-case studies.

UNIT V CHANGE MANAGEMENT 6

Change issue- change request- change investigation- change proposal - change activity - case studies.

UNIT VI GENERIC PRODUCTS AND VARIANTS 10

Data Management Systems for FEA data - Product configurator - comparison between sales configuration and product configurator-generic product modeling in configuration modeler-use of order generator for variant creation-registering of variants in product register-case studies.

L: 45, T: 0, Total: 45

REFERENCES:

1. Kevin Otto, Kristin Wood, "Product Design", Pearson, 2001.
2. Daniel Amor, "The E-Business Revolution", Prentice-Hall, 2000.
3. David Bed worth. Mark Henderson & Phillip Wolfe. "Computer Integrated Design and Manufacturing ". McGraw Hill Inc...1991.
4. Terry Quatrain. "Visual Modeling with Rational Rose and UML ". Addison Wesley...1998.
5. Wind-Chill RUNIT V0Reference Manuals...2000.

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BoS Chairman

140CC9134 **RAPID PROTOTYPING AND TOOLING** **3 0 0 3**

AIM:

To provide knowledge on different types of Rapid Prototyping systems and its applications in various fields.

OBJECTIVE:

- Generating a good understanding of RP history, its development and applications.Expose the students to different types of Rapid prototyping processes, materials used in RP systems and reverse engineering.

UNIT I INTRODUCTION **8**

Need - Development of RP systems – RP process chain - Impact of Rapid Prototyping on Product Development –Digital prototyping - Virtual prototyping- Rapid Tooling - Benefits- Applications.

UNIT II REVERSE ENGINEERING AND CAD MODELING **10**

Basic concept- Digitization techniques – Model Reconstruction – Data Processing for Rapid Prototyping: CAD model preparation, Data Requirements – geometric modeling techniques: Wire frame, surface and solid modeling – data formats - Data interfacing, Part orientation and support generation, Support structure design, Model Slicing and contour data organization, direct and adaptive slicing, Tool path generation.

UNITIII LIQUID BASED AND SOLID BASED RAPID PROTOTYPING SYSTEMS **10**

Stereolithography (SLA): Apparatus: Principle, per-build process, part-building, post-build processes, photo polymerization of SL resins, part quality and process planning, recoating issues, materials, advantages, limitations and applications. Solid Ground Curing (SGC): working principle, process, strengths, weaknesses and applications. Fused deposition Modeling (FDM): Principle, details of processes, process variables, types, products, materials and applications. Laminated object manufacturing(LOM): Working Principles, details of processes, products, materials, advantages, limitations and applications - Case studies.

UNIT IV POWDER BASED RAPID PROTOTYPING SYSTEMS **10**

Selective Laser Sintering(SLS): Principle, process, Indirect and direct SLS- powder structures, modeling of SLS, materials, post processing, post curing, surface deviation and accuracy, Applications. Laser Engineered Net Shaping (LENS): Processes, materials, products, advantages, limitations and applications– Case Studies.

UNIT V OTHER RAPID PROTOTYPING TECHNOLOGIES **7**

Three dimensional Printing (3DP): Principle, basic process, Physics of 3DP, types of printing, process capabilities, material system. Solid based, Liquid based and powder based 3DP systems, strength and weakness, Applications and case studies. Shape Deposition Manufacturing (SDM): Introduction, basic process, shape decomposition, mold SDM and applications. Selective Laser Melting, Electron Beam Melting – Rapid manufacturing.

L: 45, T: 0, Total: 45

REFERENCES:

1. Chua C.K., Leong K.F., and Lim C.S, "Rapid prototyping: Principles and applications"", second edition, , World Scientific Publishers, 2003.
2. Andreas Gebhardt , "Rapid prototyping", Hanser Gardener Publications, 2003.
3. Liou W.Liou, Frank W.Liou,"Rapid Prototyping and Engineering applications : A tool box for prototype development", CRC Press, 2007.
4. Ali K. Kamrani, Emad Abouel Nasr,"Rapid Prototyping: Theory and practice", Springer,2006.
5. Peter D.Hilton, Hilton/Jacobs, Paul F.Jacobs, "Rapid Tooling: Technologies and Industrial Applications", CRC press, 2000.

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BoS Chairman

140CC9135 **RESEARCH METHODOLOGY** **3 0 0 3**

AIM:

To develop a rigorous understanding of the key principles and practice of research

OBJECTIVES:

- To develop a thorough understanding of the fundamental theoretical ideas and logic of research. These fundamental ideas underpin our approach to research, the vast range of research methods available and the researcher's choice of methods.
- To develop a thorough understanding of the issues involved in planning, designing, executing, evaluating and reporting research.
- To introduce you to many of the technical aspects of how to do empirical research using some of the main data collection and analysis techniques used by researchers.

UNIT I INTRODUCTION AND DATA COLLECTION **9**

Research methodology – definition, mathematical tools for analysis, Types of research, exploratory research, conclusive research, modeling research, algorithmic research, Research process- steps. Data collection methods- Primary data – observation method, personal interview, telephonic interview, mail survey, questionnaire design. Secondary data- internal sources of data, external sources of data.

UNIT II SCALES AND SAMPLING **9**

Scales – measurement, Types of scale – Thurstone's Case V scale model, Osgood's Semantic Differential scale, Likert scale, Q- sort scale.Sampling methods- Probability sampling methods – simple random sampling with replacement, simple random sampling without replacement, stratified sampling, cluster sampling. Non-probability sampling method – convenience sampling, judgment sampling, quota sampling.

UNIT III HYPOTHESIS TESTING-I (PARAMETRIC TESTS) **9**

Hypotheses testing – Testing of hypotheses concerning means (one mean and difference between two means -one tailed and two tailed tests), concerning variance – one tailed Chi-square test.

UNIT IV HYPOTHESIS TESTING-II (NON PARAMETRIC TESTS) **9**

Nonparametric tests- One sample tests – one sample sign test, Kolmogorov- Smirnov test, run test for randomness, Two sample tests – Two sample sign test, Mann- Whitney U test, K-sample test – Kruskal Wallis test (H-Test)

UNIT V DATA ANALYSIS AND REPORT PREPARATION **9**

Introduction to Discriminant analysis, Factor analysis, cluster analysis, multidimensional scaling, conjoint analysis. Report writing- Types of report, guidelines to review report, typing instructions, oral Presentation

L: 45, T: 0, Total: 45

REFERENCES:

1.Kothari, C.R., Research Methodology –Methods and techniques, New Age Publications, New Delhi, 2009
2.Panneerselvam, R., Research Methodology, Prentice-Hall of India, New Delhi, 2004

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BoS Chairman

140CC9136 ENGINEERING FRACTURE MECHANICS 3 0 0 3

AIM:
To familiarize the students in the area of fracture mechanics.

OBJECTIVES:
- To learn the behaviors of materials during fracture
- To study the Stress analysis of cracked bodies
- To study the role of fracture mechanics in engineering applications

UNIT I ELEMENTS OF SOLID MECHANICS 9
The geometry of stress and strain, elastic deformation, plastic and elasto-plastic deformation - limit analysis – Airy's function – field equation for stress intensity factor.

UNIT II STATIONARY CRACK UNDER STATIC LOADING 9
Two dimensional elastic fields – Analytical solutions yielding near a crack front – Irwin's approximation - plastic zone size – Dugdaale model – determination of J integral and its relation to crack opening displacement.

UNIT III ENERGY BALANCE AND CRACK GROWTH 9
Griffith analysis – stable and unstable crack growth –Dynamic energy balance – crack arrest mechanism –K1c test methods - R curves - determination of collapse load.

UNIT IV FATIGUE CRACK GROWTH CURVE 9
Empirical relation describing crack growth law – life calculations for a given load amplitude – effects of changing the load spectrum -- rain flow method– external factors affecting the K1c values.- leak before break analysis.

UNIT V APPLICATIONS OF FRACTURE MECHANICS 9
Crack Initiation under large scale yielding – thickness as a design parameter – mixed mode fractures - crack instability in thermal and residual stress fields - numerical methods.

L: 45, T: 0, Total: 45

REFERENCES:

1. David Broek, "Elementary Engineering Fracture Mechanics ", Fifthoff and Noerdhoff International Publisher, 1978.
2. Kare Hellan, "Introduction of Fracture Mechanics", McGraw-Hill Book Company, 1985
3. Preshant Kumar, "Elements of Fracture Mechanics", Wheeler Publishing, 1999.
4. John M.Barson and Stanely T.Rolfe Fatigue and fracture control in structures Prentice hall Inc. Englewood cliffs. 1987

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BoS Chairman

140CC9137 **WELDING METALLURGY** **3 0 0 3**

AIM:

To study the metallurgical concepts in welding process.

OBJECTIVES:

- To learn the thermal cycles in welding
- To understand the weldability of non-ferrous alloys and ferrous alloys
- To study the defects in welding
- To enable the students to solve problems in welding

UNIT I THERMAL CYCLES IN WELDING **9**

Heat flow-Basic heat transfer equations, temperature distributions and cooling curves- Influence of heat input, Joint Geometry, plate thickness, preheating and other factors. Comparison of welding processes based on these considerations. Solidification – Epitaxial growth – weld metal solidification – cellular and columnar structures – effect of welding parameters – absorption of gases – gas/metal and slag/metal reactions.

UNIT II WELDING METALLURGY OF STEELS **9**

Effects of steel composition on weldability - formation of different microstructural zones in welded plain carbon steels, C-Mn Steels Phase transformation in weld and heat affected zones – formation of acicular ferrite – carbon equivalent – concept of preheating and post heating – considerations governing their choice and applications.Cold cracking – Factors affecting cold cracking- remedies. Hot cracking of steels- Factors affecting hot cracking-remedies. Weldability – Concept, testing methods.

UNIT III WELDABILITY OF STEELS **9**

Weldability of low alloy steels, Steels for low and high temperature use, all types of stainless steels, Cast Irons and selection. Also selection of welding process and procedure appropriate for each steel.

UNIT IV WELDABILITY OF NON-FERROUS ALLOYS **9**

Weldability of aluminum and its alloys, copper and its alloys, Titanium and its alloys Ni and its alloys and Mg and its alloys – Selection of welding process and procedure appropriate for each material.

UNIT V DISSIMILAR WELDING AND WELDING DEFECTS **9**

Dissimilar welding: Metallurgical problems in dissimilar welding- calculation of dilution- methods of controlling dilution - techniques of dissimilar welding- welding of various dissimilar metals combinations like steels, cast irons, Al, Cu, Mg, Ni to other alloys.

Welding Defects: Lamellar tearing and reheat cracking. Defects in welded joints: Origin, effects, and remedies. Arc welding defects, resistance welding defects, defects in friction welding, defects in welds of other welding processes.

L: 45, T: 0, Total: 45

REFERENCES:

1. Linnert. G.E. "Welding Metallurgy", Vol. 1 and Vol.2 4th Edition. A W S. 1994.
2. .Granjon. H. "Fundamentals of Welding Metallurgy". Jaico Publishing House.1994
3. Easterlin.K.E.,"Introduction of Physical Metallurgy of Welding", 2nd ed. Butterworth Heinmann. 1992
4. Saferian D. "The Metallurgy of Welding". Chapman and Hall. 1985.
5. Kou. S. "Welding Metallurgy", John Wiley & Sons. 1987.
6. Norman Bailey. "Weldability of Ferritic Steels". Jaico Publishing House. 1997.
7. Parmer R.S. "Welding Engineering and Technology", Khanna Publishers. 1997.
8. Lancaster J.F. "Metallurgy of Welding", George Allen & Unwin. Boston. 1980.
9. AWS Welding Hand book. 8th edition. Vol-UNIT I Welding Technology. 1998.

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BoS Chairman

140CC9138 COMBUSTION AND EMISSION IN ENGINES 3 0 0 3

AIM:

To expose the students in the basics concepts of combustion and emission and its impact on environment .

OBJECTIVES:

- To gain knowledge in Chemistry of combustion
- To learn combustion in engines and turbines
- To understand the concepts of emission and its effect on environment

UNIT I COMBUSTION PRINCIPLES **8**

Combustion – Combustion equations, heat of combustion - Theoretical flame temperature - chemical equilibrium and dissociation - Theories of Combustion - Pre-flame reactions - Reaction rates - Laminar and Turbulent Flame Propagation in Engines.

UNIT II COMBUSTION IN S.I. ENGINE **12**

Initiation of combustion, stages of combustion, normal and abnormal combustion, knocking combustion, pre-ignition, knock and engine variables, features and design consideration of combustion chambers. Flame structure and speed, Cycle by cycle variations, Lean burn combustion, stratified charge combustion systems. Heat release correlations. After treatment devices for SI engines.

UNIT III COMBUSTION IN C.I. ENGINE **10**

Stages of combustion, vaporization of fuel droplets and spray formation, air motion, swirl measurement, knock and engine variables, features and design considerations of combustion chambers, delay period correlations, heat release correlations, Influence of the injection system on combustion. Direct and indirect injection systems. Afer treatment devices for diesel enignes.

UNIT IV COMBUSTION IN GAS TURBINES **5**

Flame stability, re-circulation zone and requirements - Combustion chamber configuration, materials.

UNIT V EMISSIONS **10**

Main pollutants in engines, Kinetics of NO formation, NOx formation in SI and CI engines. Unburned hydrocarbons, sources, formation in SI and CI engines, Soot formation and oxidation, Particulates in diesel engines, Emission control measures for SI and CI engines, Effect of emissions on Environment and human beings.

L: 45, T: 0, Total: 45

REFERENCES:

1. Ramalingam, K.K., Internal Combustion Engines, Scitech Publications (India) Pvt. Ltd., 2009
2. Ganesan, V, Internal Combustion Engines, Tata McGraw Hill Book Co., 2002
3. John B.Heywood, Internal Combustion Engine Fundamentals,McGraw Hill Book, 1998
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5. Obert,E.F., Internal Combustion Engine and Air Pollution, International Text Book Publishers, 1968
6. Cohen,H, Rogers,G,E.C, and Saravanamuttoo, H.I.H., Gas Turbine Theory, Longman Group Ltd., 1980.

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BoS Chairman