Curriculum
for
Master of Technology
in
Computer Aided Analysis and Design (CAAD)

Department of Mechanical, Production, Industrial and Automobile Engineering
Delhi Technological University
Shahbad, Daulatpur, Delhi-110042

M. Tech (Computer Aided Analysis and Design)

M.Tech (Computer aided analysis and design) course is meant for those candidates, who are desirous of seeking higher education in the field of application of computational techniques in analysis of design. The basic purpose of this M.Tech. Course is to serve Delhi Technological University, government, and industry through research and development of advanced computational Mechanics, modeling, simulation, and design of physical systems to solve real world problems. Our aim is to build a centre of excellence for multidisciplinary engineering simulation and design which combines a range of analytical, computational and experimental techniques. Our strength lies in this sophisticated mix of engineering methods, coupled with industrial applications: a particular focus for our activities over the next few years will be the development of grid-based, problem-solving services to be used use by academia and industry. The primary research interests fall into three broad themed areas:

- Design optimisation and analysis
- Applied computational modelling
- Computational methods
- Latest tools like AI and data analytics

The overall purpose of the proposed M.Tech. Programme is to establish a cohesive and expanding base of research in applied computational science and analysis and Design engineering. It will produce sustained growth in research funding, excellence in integrated research and education, and increase in national and international stature and economic competitiveness for Indian Industries. Now a days, Computational Mechanics and Design methods are critically important for the analysis and design of sophisticated technological products and systems in a competitive global marketplace and fulfilling the needs of the society. The future security and economic well being of our country will depend in part on an adequate supply of scientists and engineers, who are highly skilled in the use of computers to solve important design problems using modeling, simulation and computer assisted design.

This evolution is expected to transform the use of advanced technology by introducing computational simulation and design software that supplements experiments and testing to produce competitive advantages in critical areas such as price, time-to-market, life-cycle costs, and overhead. Although these benefits to industry are driving the changes in engineering

practice and technical education in India, yet, it has not responded adequately to the challenge of providing graduates, post graduate and researchers, who are adequately prepared in Machine design field. In view of the extensive use of computational analysis methodologies in design by industry, there is a significant role for creating innovative curricula meant for educating the young minds. In this way, they may be able to solve programs of integrated research and graduate education (i.e., graduate research in an applications environment) that is distinct from traditional university research activity. The use of computers to solve complex, large-scale, practical problems is a trend that will accelerate in years to come.

In view of the large scale skill development in this emerging area of design, Delhi Technological University has recognized the needs of starting a post graduate program in the computer aided analysis and design area. This new program will offer opportunities to provide the leadership in computational applications driven research. This education is certainly needed for future competitiveness in the advanced technology sector of the global economy through starting of this master program in design area. The students graduating from this program will be able to carry out research in the area of computational mechanics and design, along with the capability of working on design and analysis of engineering systems for industry.

University Vision

"To be a world class university through education, innovation and research for the service of humanity "

University Mission

1. To establish centres of excellence in emerging areas of science, engineering, technology, management and allied areas.
2. To foster an ecosystem for incubation, product development, transfer of technology and entrepreneurship.
3. To create environment of collaboration, experimentation, imagination and creativity.
4. To develop human potential with analytical abilities, ethics and integrity.
5. To provide environment friendly, reasonable and sustainable solutions for local & global needs.

Program Educational Objectives PEOs

The objectives of the M.Tech. Programme in Computer Aided Analysis and Design are:

PEO 1: To develop the scientific and engineering manpower of high quality to cater to the needs of the industry and institutes.

PEO 2: To provide a broad grasp of the fundamental principles of the mechanics and design through its advanced curriculum.

PEO 3: To provide a deep understanding of the area of specialization to serve and understand better the industrial problems.

PEO 4: To provide an innovative ability to solve real case studies problems.

PEO 5: To provide a capacity to learn continually and interact with multidisciplinary groups.

PEO 6: To develop the students with a capability to cater the requirements and aspirations of society.

Program Outcomes (PO)

PO 1: An ability to independently carry out research/investigation and development work to solve practical problems.

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

PO 3: An ability to demonstrate expertise over the area as per the specialization of the program.

Programme Specific Outcomes (PSOs)

PSO 1: Build capability for research in the area of computational mechanics and design along with problem solving skills for industry.

PSO 2: Recognize the need for lifelong learning independently, with a high level of enthusiasm and commitment to improve knowledge and competence continuously.

PSO 3: The student will be equipped in the use of various CAD/CAE softwares, thereby having high employability potential for industry along with possibility of entrepreneurship and pursuit of higher studies.

With these objectives in mind, the M.Tech. Programme has been designed to include courses of study, practicals/seminars and project/thesis through which a student may develop his/her concepts and intellectual skills. The procedures and requirements stated in this proposal embody the philosophy and regulations of the M.Tech. education and ensure a high standard of performance at the University and industries.

This will certainly expand the demonstrated capability of the University in the area of Industrial Engineering & Management applications and to explore research activities that broaden and expand research expertise in this field. It will definitely find appropriate opportunities for educational outreach activities and training courses for other institutes and universities near Delhi to create awareness and to stimulate interest in Industrial Engineering & Management.

Eligibility Criteria: Students with Bachelor degree (4-years degree Programs; B.Tech./B.E/B.Sc.Engg., and equivalent degree) in the branch of Mechanical Engineering or Production Engineering or Design or Civil Engineering or Engineering Physics will be eligible to take admission in this program. For scholarship a valid GATE Score is mandatory.

Intake: 25

M. Tech (Computer Aided Analysis and Design) Scheme

	Semester -I

	Subject Code	Courses	Credits	Type	Total Credits	
Group A	CAD-501	System Modelling, Simulation and Analysis	4	Core	3-0-2	17
	CAD-503	Computational Mechanics of Materials	4	Core	4-0-0	
Group B	CAD5401/5403/5405	Elective Type 1	4	Elective	3-0-2	
	CAD5301/5303/5305	Elective Type 2	3	Elective	3-0-0	
	CAD5201/5203/5205 UEC5201/5203/...	Elective Type 3	2	Elective	2-0-0	
		Semester -II				
Group C	CAD 502	Finite Element Method	4	Core	3-0-2	17
	CAD 504	Computer Aided Design	4	Core	3-0-2	
Group D	CAD5402/5404/5406	Elective Type 4	4	Elective	3-0-2	
	CAD5302/5304/5306	Elective Type 5	3	Elective	3-0-0	
	CAD5202/5204/5206 UEC5202/5204/...	Elective Type 6	2	Elective	2-0-0	
		Semester -III				
Group E		Track 1*				12
	CAD 651	Research Project	12			
		Track 2				

	CAD6401/6403/6405	Elective Type 7	4	Elective	3-0-2	
	CAD6301/6303/6305	Elective Type 8	3	Elective	3-0-0	
	CAD6201/6203/6205	Elective Type 9	2	Elective	2-0-0	
	CAD601	Project-1	3	Core		
		Semester -IV				
Group F		Track 1*	12	Core		
	CAD 652	Research Project				12
		Track 2				
	CAD 602	Project-2	12	Core		

Marks Distribution

SI.No	Type of Course	Credit	L	T	P	CWS	PRS	MTE	ETE	PRE	Total
1.	Core	4	3	0	2	15	25	20	40	-	100
2.	Elective	4	3/4	0	2/0	15/20	25/0	20/30	40/50	-	100
3.	Elective	3	3	0	0	20	-	30	50	-	100
4.	Elective	2	2	0	0	20	-	30	50	-	100

List of electives:

	Semester -I	Credits

	Group B		
Elective Type 1	CAD5401	Advanced Vibration and Control	4(3-0-2)
	CAD5403	Fracture Mechanics	
	CAD5405	Theory of elasticity and plasticity	
Elective Type 2	CAD5301	Optimization Techniques in Design	3(3-0-0)
	CAD 5303	Numerical Methods in Engineering	
	CAD5305	Reliability Engineering	
Elective Type 3	CAD5207	Seminar	(0-0-4)
	CAD5201	Smart Materials	2(2-0-0)
	CAD5203	Human Factors in Engineering and Biomechanical Design	
	CAD5205	Design for Manufacture And CIM	
	Semester -II		
	Group D		
Elective Type 4	CAD5402	Engineering Tribology and Bearing Design	4(3-0-2)
	CAD5404	Rapid Prototyping and Tooling	
	CAD5406	Innovative Engineering Design	
Elective Type 5	CAD5308	Minor Project	3(3-0-0)
	CAD5302	Rotor Dynamics	
	CAD5304	Dynamic Behaviour of Materials	
	CAD5306	Product Design and Development	
Elective Type 6	CAD5202	Robotics and control	2(2-0-0)
	CAD5204	Product Life Cycle Management	
	CAD5206	Noise and Acoustics Design	
	Semester -III		
	Group E		
Elective Type 7	CAD6401	Computational Methods for Fluid Dynamics	4(3-0-2)
	CAD6403	Machine Tool Design	

	CAD6405	Pressure Vessels and Piping Design	
Elective Type 8	CAD6301	Machine Vision and Artificial Intelligence	3(3-0-0)
	CAD6303	Mechatronic System Design	
	CAD6305	Instrumentation and Control Systems	
Elective Type 9	CAD6201	Composite Material Technology	2(2-0-0)
	CAD6203	Surface Engineering	
	CAD6205	Automotive System Design	
	CAD6207	Data Analytics	

CAD501: System Modelling Simulation and Analysis (Core: 3-0-2)

Introduction: A review of basic probability and statistics, random variables and their properties, Estimation of means variances and correlation.

Physical Modelling: Concept of System and environment, Continuous and discrete systems, Linear and non-linear systems, Stochastic activities, Static and Dynamic models, Principles of modeling, Basic Simulation modeling, Role of simulation in model evaluation and studies, advantages of simulation

Modeling of Physical System Dynamics: A Unified Approach
Physical systems, Introduction to Bond graphs, Ports, Bonds and Power; Elements of Bond graphs:1-port elements – resistor R, Stiffness C, and Inertia I, Source of Effort Se and Flow SF; 2-port elements – Transformer TF and Gyrator GY, with modulation, Junction elements 1 and 0; Causality, Causality for basic 1-port and multi-ports. Derivation of System equations from Bond graphs in first order state space form.

Bond Graph Modeling of Multi-energy Systems
Mechanical Systems, Translation and rotation (about a fixed axis)

System Simulation: Techniques of simulation, Monte Carlo method, Experimental nature of simulation, Numerical computation techniques, Continuous system models, Analog and Hybrid simulation, Feedback systems, Computers in simulation studies, Simulation software packages.

System Dynamics: Growth and Decay models, Logistic curves, System dynamics diagrams. Probability Concepts in Simulation: Stochastic variables, discrete and continuous probability functions, Random Numbers, Generation of Random numbers, Variance reduction techniques, Determination of length of simulation runs.

Simulation of Mechanical Systems: Building of Simulation models, Simulation of translational and rotational mechanical systems, Simulation of hydraulic systems.

Lab contents

Recommended Books:
1. **System Simulation**- Geoffrey Gordon -Prentice Hall
2. **System Simulation: The Art and Science** -Robert E. Shannon -Prentice Hall
3. **System Modelling and Control** -J. Schwarzenbach and K.F. Gill Edward Arnold
4. **Modelling and Analysis of Dynamic Systems** -Charles M Close and Dean K. Frederick Houghton Mifflin
5. **Simulation of Manufacturing** -Allan Carrie John Wiley & Sons
6. **Bond Graph in Modeling, Simulation and Fault Identification**-Amalendu Mukherjee, RanjitKarmakar, ArunSamantary-I.K. Int. Pub. house

CAD503: Computational Mechanics of Materials (Core: 4-0-0)

Analysis of deformation and motion
Motion of a continuum, deformation gradient, polar decomposition, objectivity of tensor fields, measures of strain, rate of deformation and vorticity.

Transport theorem, balance laws
Mass conservation, momentum balance equations, Cauchy stress tensor, Conjugate stress tensors, stress rates.

General constitutive theory
Material symmetry, invariance requirements, Cauchy elastic material, Green elastic material.

Analysis of large deformation and strain in 3-D elastic continuum
Formulation of boundary value problems: examples.

Variational principles and conservation laws
Virtual work principle for large deformation problems.Principle of stationary potential energy, complementary and mixed variational principles, variational principles with constraints.

Recommended Books
1. **Continuum Mechanics**, Gurtin and Anand
2. **Continuum Mechanics**, J. N. Reddy
3. **Nonlinear elastic deformations**, R. W. Ogden

CAD5401: Advanced Vibration and Control (Elective 1: 3-0-2)

Introduction

Introduction to unwanted mechanical vibrations and their harmful effects including those on human beings

Two-degree of Freedom System
Principal modes of vibration, Spring coupled and mass coupled systems, Forced vibration of an undamped close coupled and far coupled systems, Undamped vibration absorbers, Forced damped vibrations, Vibration isolation.

Multi-degree Freedom systems
Eigen-value problem, Close coupled and far coupled systems, Orthogonality of mode shapes, Modal analysis for free, damped and forced vibration systems, Approximate methods for fundamental frequency-Rayleigh's, Dunkerely, Stodola and Holzer method, Method of matrix iteration, Finite element method for close coupled and far coupled systems.

Vibration Control:
Vibration control strategies and case studies, experimental and theoretical routes to vibration engineering, vibration testing. Lumped parameter and distributed parameter modeling of mechanical vibratory systems, Vibration control solutions, balancing of rotating and reciprocating machines, Design of vibration isolators, Auxilliary mass systems including tuned dampers for vibration control, Application of damping treatment for vibration control in machines and structures.

Dynamic Instability Control:
Dynamic instability control, Introduction to modal tesing, modal updating and structural dynamic modifications to improve dynamic design of machine structures, Active control of vibrations, Introduction to NVH and its control.Random vibrations, Measurement and processing of random data.

Continuous systems:
Forced vibration of systems governed by wave equation, Free and forced vibrations of beams/ bars

Non-linear Vibrations:
Non-linear systems, Undamped and forced vibration with non-linear spring forces, Self excitedvibrations.

Lab contents

Recommended Books
1. Theory and practice of Mechanical Vibrations -J.S. Rao and K. Gupta- New Age International
2. Mechanical Vibrations -G.K. Groover -Nem Chand & Brothers
3. Mechanical Vibration Practice -V. Ramamurti -Narosa Publications
4. Mechanical Vibrations- V.P. Singh- Dhanpat Rai & sons
5. Textbook of Mechanical Vibrations -R.V. Dukkipati& J. Srinivas -Prentice Hall of India
6. Dynamics of structures-Chopra, Pearson press
7. Vibration and Control, A.K. Mallik

CAD5403: Fracture Mechanics (Elective 1: 3-0-2)

Fracture mechanics principles: Introduction and historical review, Sources of micro and macro cracks. Stress concentration due to elliptical hole, Strength ideal materials, Griffith's energy balance approach. Fracture mechanics approach to design. NDT and Various NDT methods used in fracture mechanics, Numerical problems.

The Airy stress function: Complex stress function. Solution to crack problems.Effect of finite size. Special cases, Elliptical cracks, Numerical problems. Plasticity effects, Irwin plastic zone correction. Dugdale approach. The shape of the plastic zone for plane stress and plane strain cases, Plastic constraint factor. The Thickness effect, numerical problems.

Determination of Stress intensity factors and plane strain fracture toughness:
Introduction, analysis and numerical methods, experimental methods, estimation of stress intensity factors.Plane strain fracture toughness test, The Standard test.Size requirements.Non-linearity.Applicability.The energy release rate, Criteria for crack growth.The crack resistance(R curve).Compliance, J integral.Tearing modulus.Stability.

Elastic plastic fracture mechanics : Fracture beyond general yield. The Crack-tip opening displacement.The Use of CTOD criteria.Experimental determination of CTOD.Parameters affecting the critical CTOD.Use of J integral.Limitation of J integral.

Dynamics and crack arrest: Crack speed and kinetic energy. Dynamic stress intensity and elastic energy release rate. Crack branching. Principles of crack arrest. Crack arrest in practice. Dynamic fracture toughness, Testing for fracture,

Fatigue crack propagation and applications of fracture mechanics: Crack nucleation and growth and the stress intensity factor. Factors affecting crack propagation. , fatigue life prediction, Paris law, statistical analysis, variable amplitude service loading, Means to provide fail-safety, Required information for fracture mechanics approach, Mixed mode (combined) loading and design criteria. Fracture of composite materials. Use of FEM softwares like ABAQUS for analysis of bodies containing cracks.

Lab Contents

Recommended Books:

1. **Elementary Engineering Fracture Mechanics** - David Broek, Noordhoff.
2. **Fracture Mechanics-Fundamental and Application** - Anderson, T.L CRC press1998.
3. **Engineering fracture mechanics** - S.A. Meguid, Elsevier.
4. **Fracture of Engineering Brittle Materials,** Applied Science - Jayatilake, London.
5. **Fracture and Fatigue Control in Structures** - Rolfe and Barsom, , Prentice Hall.
6. **Introduction to fracture mechanics** - Karen Hellan, McGraw Hill.
7. **Fundamentals of V fracture mechanisms** - Knott, Butterworths.
8. **Fracture** –ed. Liebowitz, Volume II.
9. **Introduction to Fracture Mechanics**, Prashant Kumar

CAD5405: Theory of Elasticity and Plasticity (Elective 1: 3-0-2)

Introduction:
Analysis of stress and strain; Equilibrium; Specification of stress at a point. Principal stresses and Mohr's diagram in three dimensions. Boundary conditions .Stress components on an arbitrary plane, Stress invariants, Octahedral stresses, Decomposition of state of stress, compatibility and constitutive equations, Deformation**,** Strain Displacement relations, Strain components, The state of strain at a point, Principal strain, Strain transformation, Stress -Strain Relations and the General Equations of Elasticity**,** Saint -Venant's principle, Principle of super position and reciprocal theorem

Elastcity Problems
Airy's stress function, investigation for simple beam problems. Bending of a narrow cantilever beam under end load, simply supported beam with uniform load, Use of Fourier series to solve two dimensional problems. Two Dimensional Problems in Polar Co-Ordinates**:** General equations, stress distribution symmetrical about an axis, Pure bending of curved bar, Strain components in polar coordinates, Rotating disk and cylinder, Concentrated force on semi-infinite plane, Stress concentration around a circular hole in an infinite plate. Ax symmetric problems, elliptical hole. Introduction to three Dimensional Problems, Analysis of stress and strain in 3-d, stress , ellipsoid, variational methods, Castigliano's theorems. Anisotropic elasticity, finite deformation elasticity.

Introduction to Plasticity:
Definition and scope of the subject, Brief review of elasticity, Octahedral normal and shear stresses, Spherical and deviatric stress, Invariance in terms of the deviatoric stresses, Representative stress. Idealised stress-strain diagrams for different material models, Engineering and natural strains, Mathematical relationships between true stress and true strains, Cubical dilation, finite strains coefficients Octahedral strain, Strain rate and the strain rate tensor.

Yield Criteria for Materials
Yield criteria for ductile metal, Von Mises, Tresca, Yield surface for an Isotropic Plastic materials, Stress space, Experimental verification of Yield criteria, Yield criteria for an anisotropic material. Hills' criterion, Plastic stress-strain relations, PrandtlRoeuss Saint Venant, Levy - Von Mises, Experimental verification of the Prandtl-Rouss equation, Yield locus, Symmetry convexity, Normality rule.,

Upper and lower bound solutions
Upper and lower bound theorems and and corollaries. Application to problems: Uniaxial tension and compression, bending of beams, Torsion of rods and tubes, Simple forms of indentation problems using upper bounds. Slip line theory, Basic equations for incompressible two dimensional flow, continuity equations, Stresses in conditions of plain strain convention for slip-lines, Geometry of slip lines, Properties of slip lines.

Lab Contents

Recommended Books:
1. **Engineering Plasticity - Theory and Application to Metal Forming Process -** R.A.C..Slater, McMillan Press Ltd.
2. **Theory of Plasticity and Metal forming Process -** Sadhu Singh, Khanna Publishers, Delhi.
3. **Plasticity for Mechanical Engineers -** Johnson and Mellor.

CAD5301: Optimization Techniques in Design (Elective 2: 3-0-0)

Introduction to Optimization - Introduction, Engineering Applications, Problem Statement, Classification of optimization problems.

Classical Optimization techniques - Unconstrained Optimization: Optimizing Single-Variable Functions, conditions for Local Minimum and Maximum, Optimizing Multi- Variable Functions. Constrained Optimization: Optimizing Multivariable Functions with Equality Constraint: Lagrange Multipliers Method. Constrained Multivariable Optimization with inequality constrained: Kuhn-Tucker Necessary conditions, Kuhn –Tucker Sufficient Conditions.

Goal Programming: Formulation and solution of goal problems.

Non-Linear Programming- One-Dimensional Methods: Elimination Methods, Interpolation Methods, Direct Root Methods; Quasi-Newton Method, Secant Method. Docotomous search method, Fabonacci method, Golden section method, Unconstrained Optimization Techniques: Direct search methods, Descent Methods. Constrained Optimizations: Direct and Indirect methods.

Dynamic Programming: Concept of Dynamic Programming, Multi stage Decision Process, Calculus Method and Tabular Method.

Integer Programming – Branch and bound Method, Cutting Plane Method.

Introduction to Advanced Optimization Techniques - Genetic Algorithms (GA), Simulated Annealing, Particle Swarm Optimization (PSO), Ant Colony Optimization (ACO), Neural Network, Separable Programming, Stochastic Programming, Monte Carlo Simulation.

Recommended Books:

1. Taha, H . A., "**Operations Research**" PHI
2. **Optimization of Engineering Design**, "Deb, K." PHI
3. **Operations Research**, "D.S. Hira, P. K. Gupta" S. Chand
4. **Optimization techniques**, " Rao" New Age international
5. **Introduction to Optimal Design**, Jasbir Singh Arora, McGraw Hill International

CAD5303: Numerical Methods in Engineering (Elective 2: 3-0-0)

***Approximations*:** Accuracy and precision, definitions of round off and truncation errors, error propagation.

***Algebraic equations*:** Formulation and solution of linear algebraic equations, Gauss elimination, LU decomposition, iteration methods (Gauss- Seidal), convergence of iteration methods, eigen values and eigen vectors
Interpolation methods: Newton's divided difference, interpolation polynomials, Lagrange interpolation polynomials.

***Differentiation and Integration*:** High accuracy differentiation formulae, extrapolation, derivatives of unequally spaced data, Gauss quadrature and integration.

***Transform techniques**:* Continuous Fourier series, frequency and time domains, Laplace transform, Fourier integral and transform, Discrete Fourier Transform (DFT),Fast Fourier Transform(FFT).

***Differential equations**:* Initial and boundary value problems, eigenvalues problems, solutions to elliptical and parabolic equations, partial differential equations. ***Regression methods**:* Linear and non-linear regression, multiple linear regression, general linear least squares.

***Statistical methods**:* Statistical representation of data, modeling and analysis of data, test of hypotheses.

Solution to practical engineering problems using software tools

Recommended Books*:*
1. Schilling R.J and Harris S L, "**Applied Numerical Methods for Engineering using MatLab and C**", Brooks/Cole Publishing Co., 2000.
2. ChapraS C and CanaleR P, "**Numerical Methods for Engineers**", McGraw Hill, 1989.
3. Hines, W.W and Montrogmery, "**Probability and Statistics in Engineering and Management Studies"**, John Willey, 1990.
4. Santhosh K. Gupta, "**Numerical Methods for Engineers**", New Age international publishers, 2005.

CAD5305: Reliability Engineering (Elective 2: 3-0-0)

Introduction:
System concepts in reliability, availability and maintainability (RAM) Engineering, Practical applications of RAM Engineering to systems, products and processes; Concepts, terms and definitions; Failure rate function, Probability density function, Cumulative distribution function, reliability function, Mean time to failure (MTTF), MTBF, MTTR etc.

Fundamentals of reliability:
Failure distributions; Exponential, Weibull, Normal and Lognormal; Constant failure rate model and time dependent failure models

System reliability assessment:
Series, Parallel, Combined series-parallel configurations; Cut sets and path sets approach, fault tree analysis (FTA); State dependent systems; Markov analysis, load sharing system, standby system, degraded system, Monte Carlo simulation.

Design for Reliability and reliability improvement:
Reliability specifications and system measurements, reliability allocation ; exponential case, optimal allocations, arnica method, AGREE method, Various types of redundancies; active and passive redundancy, k-out-of-n- redundancy, standby redundancy, optimization , reliability-cost trade off.

Availability and maintainability:
Point, mission and steady state availability; Availability assessment, Maintainability and its assessment; Maintenance policies: individual policy, Planned, preventive and condition based maintenance; Opportunistic maintenance policy.

Design for maintainability:
Maintenance requirements, measurements and specifications, fault diagnosis, failure mode and effect analysis (FMEA), Parts standardization and interchangeability, modularization, accessibility, repair versus replacement, proactive maintenance, maintainability prediction and demonstration.

Recommended Books:
1. EbelingCharies E., "**An introduction to Reliability and Maintainability Engineering**", Tata McGraw-Hill Publishing Co. Ltd.,New Delhi,2000.
2. Srinath,L.S. " **Reliability Engineering**",Affiliated East –West Press Ltd., New Delhi,2006.
3. Dhillon,B.S., "**Engineering Maintainbility**",Prentice Hall of India, New Delhi,2000.
4. Blanchard, Benjamin,S., "**Logistics Engineering and Management**", Prentice Hall of India, New Delhi,2006.

CAD5201: Smart Materials (Elective 3: 2-0-0)

Overview of Smart Materials, Structures and Products Technologies.

Smart Materials (Physical Properties) piezoelectric materials, materials, magnetostrictiveelectrostrictive materials, magnetoelectric materials.magnetorheological fluids, electrorheological fluids, applications of electroreological fluids, shape memory materials, fiber-optic sensors.

Smart Sensor, Actuator and Transducer Technologies smart sensors: accelerometers; force sensors; load cells; torque sensors; pressure sensors; microphones; impact hammers; MEMS sensors; NEMS sensors, sensor arrays smart actuators: displacement actuators; force actuators; power actuators; vibration dampers; shakers; fluidic pumps; motors smart transducers: ultrasonic transducers; sonic transducers; air transducers.

Measurement, Signal Processing, Drive and Control Techniques quasi-static and dynamic measurement methods; signal-conditioning devices; constant voltage, constant current and pulse drive methods; calibration methods; structural dynamics and identification techniques; passive, semi-active and active control; feedback and feed forward control strategies.

Design, Analysis, Manufacturing and Applications of Engineering Smart Structures and Products : Case studies incorporating design, analysis, manufacturing and applicationissues involved in integrating smart materials and devices with signal processing and controlcapabilities to engineering smart structures and products. Emphasis on structures, automationand precision manufacturing equipment, automotives, consumer products, sporting products,computer and telecommunications products, medical and dental tools and equipment.

Recommended Books:

1. **Smart Materials and Structures** - M. V. Gandhi and B. So Thompson, Chapman and Hall, London; New York, 1992 (ISBN: 0412370107).
2. **Smart Structures and Materials** - B. Culshaw, Artech House, Boston, 1996 (ISBN :0890066817).
3. **Smart Structures: Analysis and Design** - A. V. Srinivasan, Cambridge University Press, Cambridge; New York, 2001 (ISBN: 0521650267).
4. **Electroceramics:** Materials, Properties and Applications - A. J. Moulson and J. M. Herbert. John Wiley & Sons, ISBN: 0471497429
5. **Piezoelectric Sensories:** Force, Strain, Pressure, Acceleration and Acoustic Emission Sensors. Materials and Amplifiers, Springer, Berlin; New York, 2002 (ISBN: 3540422595).
6. **Piezoelectric Actuators and Wtrasonic Motors** - K. Uchino, Kluwer Academic Publishers, Boston, 1997 (ISBN: 0792398114).
7. **Handbook of Giant Magnetostrictive Materials** - G. Engdahl, Academic Press, San Diego, Calif.; London, 2000 (ISBN: 012238640X).
8. **Shape Memory Materials** - K. Otsuka and C. M. Wayman, Cambridge University Press, Cambridge; New York, 199~ (ISBN: 052144487X).

CAD5203: Human factors Engineering and Biomechanical Design (Elective 3: 2-0-0)

Introduction

Human factors and systems. Human factors research methodologies

Information Input
Information Input and Processing, Text, Graphics, Symbols and Code, Visual Display of Dynamic Information, Auditory, Tactual and Olfactory Displays, Speech Communications

Human Output and Control
Physical Work and Manual Materials Handling Motor Skills, Human Control of systems, Controls and Data Entry devices, Hand tools and devices,

Workplace Design
Applied Anthropometry, Work-space design and Seating, Arrangement of Components within a Physical Space, Interpersonal Aspects of Workplace Design

Environmental Conditions
Illumination, Climate, Noise, Motion

Human Factors Applications
Human Error, Accidents and Safety, Human Factors and the Automobile. Human Factors in Systems design

Biomechanical Design
Biomechanical systems, Biomechanical analysis, Natural design vs Mechanical Design, Designing and developing equivalent mechanical systems, Case studies and analysis, Biomechanical modeling and simulation.

Recommended Books:
1. Mark Sanders, Ernest McCormick, **Human Factors In Engineering and Design**, 7th edition, McGraw-Hill International Editions.
2. Y.C. Fung, "**Biomechanics Vol. 1, 2, 3**."

CAD5205: Design for Manufacture and CIM (Elective 3: 2-0-0)

1. Effect of Materials And Manufacturing Process On Design: Major phases of design. Effect of material properties on design, Effect of manufacturing processes on design. Material selection process.

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

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

4. Datum Features: Functional datum, Datum for manufacturing, Changing the datum.

5. Design Considerations: Design of components with casting consideration. Pattern, Mould, and Parting line. Cored holes and Machined holes. Identifying the possible and probable parting line. Casting requiring special sand cores. Designing to obviate sand cores.

6. Component Design: Component design with machining considerations like design for turning, milling, Drilling and other related processes including finishing operations.

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

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

9. **Computer Integrated Manufacturing (CIM):** Basic concepts of CIM, Evolution of CIM, Unmanned manufacturing , Elements of CIM, CIM implementation , CIM hardware and CIM software. Product development through CIM, Sequential engineering, Concurrent engineering, Comparison of sequential and concurrent engineering, implementation of concurrent engineering, concurrent engineering and information technology, Characteristics of concurrent engineering. Soft computing in CIM: Artificial neural networks/Artificial intelligence, Fuzzy, Fuzzy AHP Benefits of CIM , Lean manufacturing , comparison of lean manufacturing with conventional manufacturing , applications of lean manufacturing , etc.

Recommended Books:

1. **Designing for Manufacturing -** Harry Peck, Pitman Publications, 1983.
2. **Machine Design -** Dieter McGraw hill Publications for topic 1.
3. **Metrology -** R.K. Jain Khanna Publication for topic 6.
4. **Product design for manufacture and assembly -** Geoffrey Boothroyd, peter dewhurst, Winston Knight, Merceldekker. Inc. New york.
5. **Material selection and Design, Vol. 20 -** ASM Hand book.

CAD502: Finite Element Method (Core : 3-0-2)

Introduction to Finite Element Method
Engineering Analysis, History, Advantages, Classification, Basic steps, Role of finite element analysis in computer-aided design., Mathematical Preliminaries, Differential equations formulations, Variational formulations, weighted residual method, Virtual work principle, Classification, boundary conditions and characteristics of second order partial differential equations, boundary value problems, eigenvalues problems, orthogonal matrices, similarity transformation.

One-Dimensional Elements-Analysis of Bars and Trusses
Basic Equations and Potential Energy Functional, 1-D Bar Element, Shape functions, Stiffness matrix, Assembly Procedure, Boundary Conditions, 2-D truss element.

Two-Dimensional Elements-Analysis of Plane Elasticity Problems: Linear Triangular and Quadrilateral Elements, Shape functions for Higher Order Elements, Lagrange elements, Serindipity elements, Isoparametric elements, Numerical integration, convergence criteria, discretization error, convergence rate, patch test, conforming, non-conforming elements.

Axi-symmetric Solid Elements-Analysis of Bodies of Revolution under axi-symmetric loading: Axisymmetric Triangular and Quadrilateral Ring Elements.

Three-Dimensional Elements-Applications to Solid Mechanics Problems
Tetrahedral Elements, Hexahedral Elements.

Beam Elements-Analysis of Beams and Frames: Beam elements, Reduced integration, Elements based on Bernoulli and Timoshenko theory of beams.

Heat Transfer *And* Fluid Flow: Steady state heat transfer, heat conduction governing equation, boundary conditions, Functional approach for heat conduction, Galerkin approach for heat conduction, heat flux boundary condition, Basic differential equation for fluid flow in pipes and around solid bodies.

Dynamic Considerations: Formulation for point mass and distributed masses, Consistent mass matrix, Lumped mass matrix, Evaluation of eigenvalues and eigenvectors.

Electromagnetic simulation using FEM. Use of softwares like Abaqus and Ansys.

Lab Contents

Recommended Books:
1. Chandrupatla T. R., "**Finite Elements in engineering"**- 2nd Edition, PHI, 2007.
2. Lakshminarayana H. V., "**Finite Elements Analysis"**– Procedures in Engineering, Universities Press,2004
3. Rao S. S. "**Finite Elements Method in Engineering"**- 4th Edition, Elsevier, 2006
4. P.Seshu, "**Textbook of Finite Element Analysis"**-PHI, 2004.
5. J.N.Reddy, "**Finite Element Method"**- McGraw -Hill International Edition.Bathe K. J. Finite Elements Procedures, PHI.
6. Cook R. D., et al. "**Concepts and Application of Finite Elements Analysis"**- 4th Edition, Wiley &Sons, 2003.
7. Finite Element Method, K.J. Bathe, Prentice Hall of India
8. FEM, Zienkiewicz and Taylor

CAD504: Computer Aided Design (Core : 3-0-2)

Introduction and Review of CAD
Introduction and Overview, Need and Scope of computer aided Machine design, Role of Geometric modelling, Principles of interactive Computer graphics, Overview of hardware available for use in CAD.

Three Dimensional Transformations
Geometric transformations & Axonometric, Diametric, Trimetric and oblique Projections, Windowing & View porting.

Geometric Modelling and Applications: Introduction, wire frame models and entities, curve representations, parametric representation of analytical curves, synthetic curves, Bezier curves, B-spline curves, Rational curves, curve manipulations, design and engineering applications.

Solid modelling
Half spaces, Boundary representation (B-rep), Constructive solid geometry (CSG), Sweep representation, Analytical solid making, and solid manipulation.

Advances in Computer Aided Engineering Design
Failure considerations in designing, Robust design, Reliability, Ergonomic considerations in Design, Feature based design, Design for manufacturing, Design for Automation, CAD of complex Engineering Systems.

Lab content

Recommended Books:

1. **Computer Graphics** -D Hearn & M P Baker- Prentice Hall
2. **CAD/CAM Theory and Practice**- Ibrahim Zeid& R Sivasubramanian -Tata McGraw- Hill
3. **CAD/CAM- Principles and Applications** -P N Rao Tata McGraw-Hill
4. **Computer Aided Engineering Design** -A Saxena and B Sahay- Anamya Publications
5. **Mathematical Elements for Comp. Graphics**- D F Rogers and J A Adams- McGraw-Hill International
6. **CAD/CAM** -H P Groover and E W Zimmers -Prentice Hall
7. Radhakrishnan and Kothandaraman, " **Computer Graphics and Design**" Dhanpat Rai 1997.
8. Rogers David F " **Procedures Elements for Computer Graphics**" second Ed. Tata McGraw Hill 2001

CAD5402: Engineering Tribology and Bearing Design (Elective 4:3-0-2)

Introduction
History of evolution and definition, Lubrication, wear, cost of friction and wear. Lubricants and their physical properties, viscosity index, Reynolds equation, Derivation and physical significance, standard reduction forms of Reynolds equation.

Friction and Wear
Law of sliding friction, concept of adhesion. Taylor's model of friction, Measurement of friction. Laws of wear, Abrasive, Erosive and Cavitation wear: Introduction, abrasive wear, mechanisms of abrasive wear, mechanisms of erosive wear, effect of impingement angle and impact speed on erosive wear rate. Effect of particle shape, hardness, size and flux rates on erosive wear rate. Erosive wear by liquid, Cavitation wear, mechanism of cavitation wear.

Adhesion and adhesive wear Mechanism of adhesion. Corrosive and oxidative wear: Introduction, corrosive wear, transition between corrosive and adhesive wear, synergism between corrosive and abrasive wear, oxidative wear, kinetics of oxide film growth on metals at high and low temperatures.

Fatigue wear: Introduction, fretting wear, melting wear, wear due to electrical discharges, diffusive wear, impact wear. Sitiback number, curve and law.

Lubrication
Solid lubrication and surface treatments: Introduction, Lubrication by solids, lubrication by lamellar solids. Hydrostatic Lubrication, formation of fluid film, pressure distribution and flow, normal load component, frictional torque and power loss. Introduction to gas lubrication.Thermo hydrodynamic lubrication: governing equation and boundary conditions.

Bearing Design
Design of bearing, Clearance in journal bearing, minimum film thickness, sommar-field number, oil grooves and flow of oil in axial and circumferential grooves cavitations and turbulence in oil bearings.Heat generation and cooling or bearing hydrostatic and dynamic and their applications in machine tools. Design of air bearing and other gas bearing.
Smart bearing and bearing with iot.

Recommended Books:
1. **Engineering Tribology**- Gwidon W. Stachowiak and Andrew W. Batchelor
2. **Fundamentals of fluid film lubrication**- Bernard J. Hamrock
3. **Industrial Tribology**, Dr.B.S.Prabhu, McGraw Hill

CAD5404: Rapid Prototyping and Tooling (Elective 4: 3-0-2)

Introduction: Historical developments, Fundamentals of RP Systems and its Classification, Rapid prototyping process chains, 3D modeling and mesh generation, Data conversion and transmission.

RP Systems: Liquid polymer based rapid prototyping systems, Teijin Seikis' solid form and other similar commercial RP systems, Solid input materials based rapid prototyping systems, laminated object manufacturing (LOM) and fused deposition modelling systems etc., Power based rapid prototyping systems, selective Laser sintering, Soligen Diren's shell production casting (DSPC), Fraunhofer's multiphase jet solidification (MJS) and MIT's 3D printing (3DP) etc.

RP Database: Rapid prototyping data formats, STL format, STL file problems, STL file repair, Network based operations, Digital inspection, Data warehousing and learning from process data.

RP Applications: Development of dies for moulding, RP applications in developing prototypes of products, application in medical fields, Development of bone replacements and tissues, etc., RP materials and their biological acceptability.

Recommended Books:

1. **Rapid Prototyping of Digital Systems: A Tutorial Approach**- Hamblen James O Kluwer Aca
2. **Rapid Prototyping: Principles And Applications**- Kai Chua Chee World Scie
3. **Rapid System Prototyping WithFpgas: Accelerating The Design Process**- R C CoferNewnes
4. **Rapid Prototyping of Digital Systems** -James O Hamblen Springer

CAD5406: Innovative Engineering Design (Elective 4: 3-0-2)

Creative Product & System Design

Creative design, Innovation versus invention, Globalisation, Team work, Project Scheduling and management.

Creative Mind
Whole Brain thinking, Creativity, What makes an individual creative?

Reclaiming Creativity
Mental Barriers, Types of mental Barriers, False assumptions and nonexistent limitations, Associating thinking, misunderstandings, inability to communicate properly, emotions, culture and environment related barriers, improper method of solution

Creative Problems solving Techniques
Brain storming, 6-3-5 method, Morphological attitude list, list of alternative actions, analogy (Case based reasoning) method, random attributes Scamper method

Imagination, visualisation, graphical representation and communication
Imagination, drawings, engineering drawings, realistic drawings, Perspectives and location of objects, determining depth in perspective: scale factors, drawing perspective, sketching, put in-the-box scheme

Design Consideration and Decisions
Cost, size, weight, material selection, method of fabrication, Physical and structural standards, Function standards and expectations, performance, efficiency, reliability, Company image and mission, quality, service ability, Styling shape, aesthetics and packaging, Safety, human factors, Environmental effects, Disposability, sustainability, Assembly-Disassembly, life expectancy, ethical issue, Patent and other intellectual property rights, Legal matters.

Economics of Design
Value of a Product or System, Global Economics Models, Costs, Revenues and Profits, Cost Breakdown of Products and Systems, Product Life Span, Engineering Economy

Design and Product Liability
Product Liability History and Background, Major Administrative Law Related to Product Liability, Basic Theories of Product Liability Law, reducing Product Liability Risk, Failure Mode and Effect Analysis (FMEA), Code of Ethics for Engineers, Standards and Codes.

Lab content

Recommended Books:
1 Saeed Benjamin Niku, **Creative Design of Products and Systems**

CAD5302: Rotor Dynamics (Elective 5 : 3-0-0)

Fluid Film Lubrication: Basic theory of fluid film lubrication, Derivation of generalized Reynolds equations, Boundary conditions, Fluid film stiffness and Damping coefficients, Stability and dynamic response for hydrodynamic journal bearing, Two lobe journal bearings.

Stability of Flexible Shafts: Introduction, equation of motion of a flexible shaft with rigid support, Radial elastic friction forces, Rotary friction, friction Independent of velocity, friction dependent on frequency, Different shaft stiffness Constant, gyroscopic effects, Nonlinear problems of large deformation applied forces, instability of rotors in magnetic field.

Critical Speed: Dunkerley's method, Rayleigh's method, Stodola's method.

Rotor Bearing System: Instability of rotors due to the effect of hydrodynamic oil layer in the bearings, support flexibility, Simple model with one concentrated mass at the center.

Turbo-rotor System Stability by Transfer Matrix Formulation: General turbo-rotor system, development of element transfer matrices, the matrix differential equation, effect of shear and rotary inertia, the elastic rotors supported in bearings, numerical solutions.

Turbo-rotor System Stability by Finite Element Formulation: General turbo-rotor system, generalized forces and co-ordinates system assembly element matrices, Consistent mass matrix formulation, Lumped mass model, Linearised model for journal bearings, System dynamic equations Fix stability analysis non dimensional stability analysis, unbalance response and Transient analysis.

Blade Vibration: Centrifugal effect, Transfer matrix and Finite element, approaches.

Recommended Books:

1. **Principles of Lubrication** - Cameron Longmans.
2. **Non-conservative problems of the Theory of elastic stability** - Bolotin, Pergamon.
3. **Matrix methods of Elastomechanics**- Peztel, Lockie, McGraw Hill.
4. **Vibration Problems in Engineering** - Timosenko, Young, Von Nostrand 5. Zienkiewicz, "The Finite Element Method", McGraw Hill.
5. **Rotor Dynamics**- J.S. Rao
6. **Rotor Dynamics**-Tondel

CAD5304: Dynamic Behaviour of Materials (Elective 5 : 3-0-0)

Elastic Wave propagation

Introduction: dynamic deformation and failure, Introduction to waves: elastic waves; types of elastic waves; reflection, refraction and interaction of waves.

Inelastic wave propagation

Plastic waves and shock waves: Plastic waves of uniaxial stress, uniaxial strain and combined stress; Taylor's experiments; shock waves, Shock wave induced phase transformation; Explosive-material interaction and detonation.

Experimental Techniques

Experimental techniques for dynamic deformation: intermediate strain rate tests; split Hopkinson pressure bar; expanding ring test; gun systems, Review of mechanical behavior of materials (especially metals): Elastic and plastic deformation of metals; dislocation mechanics.

Plastic deformation of metals at high strain rates

Empirical constitutive equations; relationship between dislocation velocity and applied stress; physically based constitutive equations, Plastic deformation in shock waves: Strengthening due to shock wave propagation; dislocation generation; point defect generation and deformation twinning, Strain localization/shear bands: Constitutive models; metallurgical aspects.

Dynamic fracture mechanics

Fundamentals of fracture mechanics; limiting crack speed, crack branching and dynamic fracture toughness; spalling and fragmentation.

Dynamic deformation of non-metals

Dynamic deformation of materials other than metals: Polymers; ceramics; composites, Applications: Armor applications; explosive welding and forming.

Recommended Books :

1. Marc A. Meyers, Dynamic Behavior of Materials, John Wiley & Sons, New York, 1994

2. L.B. Freund, Dynamic Fracture Mechanics, Cambridge, 1990
3. Y. Bai B. Dodd, Adiabatic Shear Localization, Pergamon, Oxford, UK, 1992
4. G.E. Dieter, Mechanical Metallurgy, McGraw Hill, 1986
5. J.W. Swegle, D.E. Grady, in Shock Waves in Condensed Matter- 1985,

CAD5306: Product Design and Development (Elective 5: 3-0-0)

Stages in design process
Introduction to various stages of the design process: Formulation of problem, Generation of alternatives, Evaluation, Guided Redesign. Case study.

Product life cycle
New product introduction: early introduction, increased product life. Life cycle management tools: System integration, QFD, House of quality, Pugh's method, Pahl and Beitz method. Case studies.

Value engineering
Introduction, nature and measurement of value.Value analysis job plan.Creativity and techniques of creativity.Value analysis test.Case studies.

Concurrent/ reverse engineering
Introduction, basic principles, components, benefits of concurrent engineering. Concept of reverse engineering

Material selection
Materials in design.The evolution of engineering materials. Design tools and material data. Function, material, shape and process. Material selection strategy, attribute limits, selection process, computer aided material selection. Case studies.

Process selection
Introduction. Process classification: shaping, joining and finishing. Systematic process selection.Ranking, process cost. Computer – aided process selection

Design for manufacture and assembly
Design for Manufacture and Assembly (DFMA). Reasons for not implementing DFMA.Advantages of DFMA with case studies. Design features and requirements with regard to assembly, production. Design for Manufacture in relation to any two manufacturing processes: machining and injection molding. Need, objectives.

Design for "X"
Introduction. Design for: Safety, packaging and storage, quality, reliability, energy conservation, environment, aesthetics, ergonomics, maintenance, recyclability and disposal. Case studies.

Patents, liability and ethics
Introduction. Protecting your design: patents, copyright, basic tools of design protection. Liability issues in product design. Ethical considerations.Examples/ case studies.

Recommended Books:
1. **Product Design and Development**, "Karl T. Ulrich, Steven D. Eppinger" Mc GrawHill
2. **Integrated Product and Process Development**, "John M. Usher, Utpal Roy and H. R. Parasaei
3. **Product Design for Manufacture and Assembly**, "G. Boothroyd, P. Dewhurst and W. Knight" Marcel Daker
4. **Engineering Design and Design for Manufacturing**: A structured approach, "John R. Dixon and CorrodoPoli" Field Stone Publishers, USA.
5. **Material Selection in Mechanical Design**, "M. F. Ashby" Elsevier.

CAD5202: Robotics and Control (Elective 6: 2-0-0)

Introduction
Evolution of robot and robotics, laws of robotics, robot anatomy: Links, joints, Degrees of freedom (DOF), Arm configuration, wrist configuration, end-effectors

Coordinate Frame, Mapping and Transforms

Coordinate frames, description of objects in space, transformation of vectors, inverting a homogeneous transform, fundamental rotation matrices

Kinematics
Denavit- Hartenberg Notation, kinematic relationship between adjacent links, Manipulator transformation matrix, Inverse kinematics Linear and angular velocity of a rigid body, velocity propagation along links, manipulator jacobian

Dynamics
Lagrange-Euler Formulation, Newton-Euler Formulation

Control of manipulators
Position control, Force control: Applications of standard control strategies

Actuators
Types, Characteristics of actuating system: weight, Power-to-weight ratio, Operating pressure, Stiffness vs. compliance, Use of reduction gears, Comparision of hydraulic, Electric, pneumatic, actuators, Hydraulic actuators, Proportional feedback control, Electric Motors: DC motors, Reversible AC motors, Brushless DC motors, Stepper motors- structure and principle of operation, Stepper motor speed-torque characteristics.

Sensors: Sensor characteristics, Position sensors- potentiometers, Encoders, LVDT, Resolvers, Displacement sensor, Velocity sensor- encoders, tachometers, Acceleration sensors, Force and Pressure sensors - piezoelectric, force sensing resistor, Torque sensors, Touch and tactile sensor, Proximity sensors-magnetic, Optical, Ultrasonic, Inductive, Capacitive, Eddy-current proximity sensors.

Advances in Robots

Recommended Books:
1. **Fundamental Concepts and Analysis** - Ghosal A., Robotics, Oxford, 2006.
2. **Introduction to Robotics Analysis -** Niku, S. B., Systems, Applications, Pearson Education, 2008.
3. **Introduction to Robotics: Mechanica and Control** - **2nd Edition** - Craig, J. J., Addison-Welsey, 2nd edition 1989.
4. **Fundamentals of Robotics, Analysis and Control -** Schilling R. J., PHI, 2006.
5. **Robotics Control, Sensing, Vision and Intelligence -** Fu, K, S., Gonzalez R. C., Lee C.S. G., McGraw Hill, 1987.

CAD5204: Product Life Cycle Management (Elective 6: 2-0-0)

Introduction: Extensive definition of Concurrent Engineering (CE), CE design methodologies, Review of CE techniques like DFM (Design for manufacture), DFA (Design for assembly), QFD (Quality function deployment), RP (Rapid prototyping), TD (Total design), for integrating these technologies, Organizing for CE, CE tool box, Collaborative product development.

Use of Information Technology: IT support, Solid modeling, Product data management, Collaborative product Commerce, Artificial Intelligence, expert systems, Software hardware component design.

Design Stage: Lifecycle design of products, Opportunities for manufacturing enterprises, Modality of concurrent engineering design, automated analysis Idealization control, CE in optimal structural design, Real time constraints.

Need for PLM: Importance of PLM, Implementing PLM, Responsibility for PLM, Benefits to different managers, Components of PLM, Emergence of PLM, Lifecycle problems to resolve, Opportunities to seize. Role of sustainability, Sustainable product life management.

Components of PLM: Components of PLM, Product lifecycle activities, Product organizational structure, Human resources in product lifecycle, Methods, techniques, Practices, Methodologies, Processes, System components in lifecycle, slicing and dicing the systems, Interfaces, Information, Standards.

Block chain concept in product life

Recommended Books:

1. **Integrated Product Development** M.M. Anderson and L Hein IFS Publications
2. **Design for Concurrent Engineering** J. Cleetus CE Research Centre, Morgantown
3. **Concurrent Engineering Fundamentals: Integrated Product Development** -Prasad Prentice hall India
4. **Concurrent Engineering in Product Design and Development** -I Moustapha New Age International
5. **Product Lifecycle Management** -John Stark Springer-Verlag, UK
6. **Product Lifecycle Management** -Michael Grieves McGraw Hill
7. **Concurrent Engineering**: **Automation tools and Technology-** Andrew Kusiak Wiley Eastern

CAD5206: Noise and Acoustic Design (Elective 6: 2-0-0)

Mathematical Basis of Acoustics

Acoustics waves – Linear wave equation – sound in fluids – Harmonic plane waves – Energy density – Acoustics intensity – Specific acoustic impedance – spherical waves – Describer scales. Reflection and Transmission: Transmission from one fluid to another normal and oblique incidence – method of images.

Radiation and Reception of Acoustics Waves
Radiation from a pulsating sphere – Acoustic reciprocity – continuous line source – radiation impedance - Fundamental properties of transducers. Absorption and attenuation of sound Absorption from viscosity – complex sound speed and absorption – classical absorption coefficient

Pipes Resonators and Filters
Resonance in pipes - standing wave pattern absorption of sound in pipes – long wavelength limit – Helmoltz resonator - acoustic impedance - reflection and transmission of waves in pipe – acoustic filters – low pass, high pass and band pass.

Noise, Signal detection, Hearing and speech
Noise, spectrum level and band level – combing band levels and tones – detecting signals in noise – detection threshold – the ear – fundamental properties of hearing – loudness level and loudness – pitch and frequency – voice.

Architectural Acoustics
Sound in enclosure – A simple model for the growth of sound in a room – reverberation time - Sabine, sound absorption materials – measurement of the acoustic output of sound sources in live rooms – acoustics factor in architectural design.

Environmental Acoustics:
Weighted sound levels speech interference – highway noise – noise induced hearing loss – noise and architectural design specification and measurement of some isolation design of portions.

Measurement of Sound and Vibration
Measurement microphones: construction, sensitivity, linearity, frequency response, polar response, dynamic range. Relevant standards for sound level meters, Calibration and calibrators.Measurement of sound pressure level, sound power level, sound intensity level, vibration transducers.

Noise Pollution
Sources of noise and its intensity, effects of noise pollution, Prevention and control measures of noise pollution.

Recommended Books:
1. LawerenceE.Kinsler, Austin, R.Frey, Alan B.Coppens, James V.Sanders, **Fundamentals of Acoustics**, 4ht edition, Wiley, 2000.
2. L. Berarek ,**"Acoustics**" - McGraw-Hill

CAD6401: Computational Fluid Dynamics (Elective 7: 3-0-2)

Introduction: Conservation equation, Mass Momentum and Energy equations, Convective form of the equation and general description.

Classification into various types of equations: Parabolic, Elliptic, Boundary and initial conditions, Overview of numerical methods.

Finite difference methods: Different means for formulating finite difference equations, Taylor series expansion, Integration over element, Local function method; Finite volume methods; Central, upwind and hybrid formulations and comparison for convection-diffusion problem, Treatment of boundary conditions; Boundary layer treatment; Variable property, Interface and free surface treatment, Accuracy of F.D. method.

Solution of finite difference equations; Iterative methods; Matrix inversion methods, ADI method, Operator splitting, Fast Fourier Transform applications.

Phase change problems, Rayleigh-Ritz, Galerkin and Least square methods; Interpolation functions, One and two dimensional elements, Applications. Phase change problems; Different approaches for moving boundary; Variable time step method, Enthalpy method.

Recommended Books:

1. **Computational Methods for Fluid Dynamics** Ferziger Joel H Springer-Verlog
2. **Principles of Heat Transfer** Kaviany M Wiley-International
3. **Radiative Heat Transfer** Modest Michael, Academic Press

CAD6403: Machine Tool Design (Elective 7: 3-0-2)

Design approach

Design requirements of machine tools. A design approach for machine tools. Identification and quantification of objectives and constraints in machine tool design. Kinematics of machine tool drives, stepped and stepless speed regulation,

Power requirements

Estimation of power requirements and selection of motor for metal cutting machine tool spindles.
1. Gearbox design
2. Design of gearbox, spindle and guide-ways.

Structural design
Principles of design of structural components, namely, head stock, tail stock, carriage, table, knee, column and over arms to achieve desired static & fatigue strength, stiffness, dynamic characteristics and other requirements. Exercises on the design of machine tools using existing CAD software packages. Hydraulic drives testing of machine tools. Dynamics acceptance tests, Damping in machine tools Modern trends in machine tool design, transfer machines.

CNC machine design
Introduction to computer integrated manufacturing systems and CNC machine tools.

Design of CNC systems
Design/selection of linear motion systems, ball, screws, CNC feedback devices, controllers, feed drives and servomotors for CNC machine tools.Recent developments in CNC and other machine tools.

Recommended Books:
1. **Design of Devices and Systems**, "William H. Middendorf and Richard H. Engelmann" CRC Press.
2. **Computer numerical control of machine tools**, "G. E. Thyer" Heinemann Professional Publishing.
3. **Machine Design Fundamentals: A Mechanical Designers' Workbook** , Joseph Edward Shigley and Charles R. Mischke, Mcgraw Hill.
4. **Numerical Control and Computer aided manufacture**, "Kundra, Rao, Tiwari" Tata McGraw Hill.

CAD6405: Pressure Vessels and Piping Design (Elective 7: 3-0-2)

Stresses in pressure vessels
Membrane stresses, dilation of pressure vessels, thick cylinder and thick sphere, bending of plate, discontinuity stresses in pressure vessels, thermal stresses.

Factors influencing the design of pressure vessels
Design criterion of elliptical, hemispherical, conical, toriconical and torispherical heads, Autofrettage.

Design of pressure vessel components such as shells, heads, nozzles, flanges as per ASME and IS codes

Localised stresses, stress concentration about a circular and an elliptical opening, theory of reinforced openings, nozzle reinforcement, welded joints.

Fracture Control
Fatigue of various components of pressure vessels, Fatigue life prediction, thermal stress fatigue, criteria for design with defects.

Piping elements, Dynamic analysis of piping

Use of FEM softwares for stress calculations

Recommended Books:
1. **Pressure vessel design-** Harvey

CAD6301: MACHINE VISION and ARTIFICIAL INTELLIGENCE (Elective 8: 3-0-0)

Course Learning Objectives

1) To gain and understanding of the fundamental issues and techniques for extracting information from digital images.
2) To have knowledge of well-established methods for processing, segmentation, feature extraction and recognition of objects.
3) To provide the student with programing experience from implementing computer

vision and object recognition applications

Course Content

1. **Introduction**
   Machine Vision, difference between computer vision and machine vision.ralationship of machine vision to other fields, Applications of machine vision, typical machine visiontasks, components of digital image processing system, Digital images. Types of images, Elements of machine vision system, Basic relationship between pixels (neighbors of a pixel,connectivity,path,foreground,background,connectedcomponent,boundary,interior)lab eling of connected components, Distance measure

2. **Image Processing**
   Digitization, Noise, Level of operations, Look up table. Image enhancement techniques by point processing(Negative of image, Contraststretching, HistogramEqualization, Histogram specification),Image enhancement based on the neighborhood of pixels (spatial domain and frequency domain) spatial domain techniques (Low pass filters and high pass filters, High boost filters),Image enhancement in frequency domain (Low pass and High pass filters)

3. **Image Analysis**
   Segmentation of images (region based, Edge detection),Region based-thresholding, Types of thresholds, Iterative threshold selection, Adaptive thresholding,Refion growing by pixel aggregation, Split and merge algorithm, Edge detection-point detection, line detection, edge detection(Roberts,prewitt,Sobel,Laplacian operations)

4. **Description**
   Shape representation, Topological shape descriptors, Contour-based Shape Representation Techniques-Simple Shape Descriptors,Signatures,Fourier descriptors, Boundary moments, Polygon approximation, Chain code, Region based shape representation techniques-simple shape descriptors, Moment based features, Convex Hull, Skeleton of a region. Medical axis transform

5. **Pattern Recognition**
   Pattern recognition methods-Structural methods, syntactic methods, Template matching, artificial neural network-biological neural network, usefulness and capabilities perceptron-single layer, multi-layer, back propagation Neural Network

6. **Artificial Intelligence**
   Advanced search, Constraint satisfaction problems, Knowledge representation and reasoning, Non-standard logics, Uncertain and probabilistic reasoning (Bayesian networks, fuzzy sets). Foundations of semantic web: semantic networks and description logics. Rules systems: use and efficient implementation. Planning systems.

Course Outcomes:

1) Students will be able to understand the application of computer vision in industrial tasks
2) Students will have the knowledge of various methods of enhancing Images
3) Students will be able to segment the images using spatial domain and frequency domain methods
4) Students will be able to find features invariant to translation, rotation, scale
5) Students will be able to recognized/classify the objects using Artificial Neural Network

Reference Books:

1) Digital image processing by Rfael C. Gonzalez and Richard E. Woods.
2) Fundamentals of Digital image processing by Anil K. Jain
3) Digital image processing-Concepts, Algorithms and Scientific Applications by Bernd Jahne.
4) Machine vision by Ramesh Jain, Rangachar Kasturi, Brain G.Schunck.
5) Introduction to Neural Networks using MATLAB, S.N. Sivanandam.Sumuthi & S.N. Deepa.
6) Artificial Intelligence: A Modern Approach, Stuart Russel, Peter Norvig
7) Artificial Intelligence, 2nd Edition, Rich and Knight

CAD6303: Mechatronics System Design (Elective 8: 3-0-0)

Introduction: Definition and Introduction to Mechatronic Systems. Modeling & Simulation of Physical systems. Overview of Mechatronic Products and their functioning measurement systems. Control Systems, simple Controllers.

Study of Sensors and Transducers: Pneumatic and Hydraulic Systems, Mechanical Actuation System, Electrical Actual Systems, Real time interfacing and Hardware components for Mechatronics. Interfacing, ADC, DAC, software and hardware principles and tools to build mechatronic systems.

Electrical Actuation Systems: Electrical systems, Mechanical switches, Solid state switches, solenoids, DC & AC motors, Stepper motors. Design and selection of mechatronic elements

namely sensors like encoders and resolvers. Stepper and servomotors. Ball screws, solenoid like actuators, and controllers

System Models: Mathematical models:- mechanical system building blocks, electrical system building blocks, thermal system building blocks, electromechanical systems, hydro-mechanical systems, pneumatic systems.

Signal Conditioning: Signal conditioning, the operational amplifier, Protection, Filtering, Wheatstone Bridge, Digital signals , Multiplexers, Data Acquisition, Introduction to digital system processing, pulse-modulation.

MEMS and Microsystems: Introduction, Working Principle, Materials for MEMS and Microsystems, Micro System fabrication process, Overview of Micro Manufacturing, Micro system Design, and Micro system Packaging.

Data Presentation Systems: Basic System Models, System Models, Dynamic Responses of System.

Advanced Applications in Mechatronics: Fault Finding, Design, Arrangements and Practical Case Studies, Design for manufacturing, User-friendly design. . Analysis and synthesis of mechatronic systems with applications to CNC systems, robotics, consumer electronic products etc.

Recommended Books:

1. **"Mechatronics"** - W. Bolton, 2 Ed. Addison Wesley Longman, Pub, 1999
2. HSU "**MEMS and Microsystems design and manufacture**"- TMH
1. Kamm, "**Understanding Electro-Mechanical Engineering an**
2. **Introduction to Mechatronics"**- PHI.
3. **"Fine Mechanics and Precision Instruments"**- Pergamon Press, . 1971.
4. Shetty and Kolk "**Mechatronics System Design**"-Thomson.
5. Mahalik "**Mechatronics**"- TMH.
6. **"Mechatronics"–** HMT, TMH.

CAD6305: Instrumentation and Control Systems (Elective 8: 3-0-0)

Introduction

Classification and representation of control systems Examples of control systems, closed loop and open loop control systems, The Laplace transform

Mathematical Modelling of Dynamic systems

Transfer function and impulse response function, block diagrams, signal flow graph, state-space representation, Transient response analysis of first order and second order systems

Time domain analysis and design

Root locus method, Routh stability criteria, effect of poles and zeros on system performance.

Frequency domain analysis and design
Bode plot , Nyquist stability criteria, Lag , lead compensation

Modern Control Theory
Modern control theory. Sequence control and programmable logic controllers. Control components. Comparators, hydraulic, pneumatic and electrical type of controllers, servomotors.

Electromechanical and electro-optical transducers and control elements. Signal conditioning, indicating and recording elements.

Computer based systems
Computer based data acquisition systems, ADC, DAC. Microprocessor applications in measurement and control. Static and dynamic analysis. FFT analysers.

Analysis and design
Controllability and observability, pole placement method, examples of control system design using MATLAB, Current developments in measurement and control of motion, force, torque, pressure, temperature, flow, noise etc. Virtual instrumentation.

Recommended Books:
1. **Modern Control Engineering**, "K. Ogata" PHI.
2. **Automatic Control Systems**, B.C. Kuo, PHI.
3. **Control System Engineering**, Nise, Wiley.
4. **Modern Control Systems**, Dorf and Bishop, Pearson Education.
5. **Modern Control System Theory,** M. Gopal, New Age International

CAD6201: Composite Material Technology (Elective 9: 2-0-0)

Introduction to Composite Materials: Definition, Classification, Types of matrices material and reinforcements, Characteristics & selection, Fiber composites, laminated composites, Particulate composites, Prepegs, and sandwich construction.

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

Micro Mechanical Analysis of a Lamina: Introduction, Evaluation of the four elastic moduli, Rule of mixture, Numerical problems.

Biaxial Strength Theories: Maximum stress theory, Maximum strain theory, Tsa-Hill theory, Tsai, Wu tensor theory, Numerical problems.

Macro Mechanical Analysis of Laminate: Introduction, code, Kirchoff hypothesis, CL T, A, B, and D matrices (Detailed derivation) Engineering constants, Special cases of laminates, Numerical problems.

Manufacturing: Lay up and curing - open and closed mould processing, Hand lay, Up techniques, Bag moulding and filament winding. Pultrusion, Pulforming, Thermoforming, Injection moulding, Cutting, Machining and joining, tooling, Quality assurance, Introduction, material qualification, Types of defects, NDT methods.

Application Developments: Aircrafts, missiles, Space hardware, automobile, Electrical and Electronics, Marine, Recreational and sports equipment-future potential of composites.

Metal Matrix Composites: Manufacturing of MMC, Reinforcement materials, Types, Characteristics and selection, Base metals, Selection, Applications.

Recommended Books:

1. **Composite Materials handbook,** Mein Schwartz Mc Graw Hill Book Company, 1984.
2. **Mechanics of composite materials,** Autar K. Kaw CRC Press New York.
1. **Mechanics of Composite Materials,** Rober M. Joness Mc-Graw Hill Kogakusha Ltd.
2. **Stress analysis of fiber Reinforced Composite Materials,** Michael W, Hyer Mc-Graw Hill International.
3. **Composite Material Science and Engineering,** Krishan K. Chawla Springer.
4. **Fibre Reinforced Composites,** P.C. Mallik Marcel Decker.

CAD6203: Surface Engineering (Elective 9: 2-0-0)

Introduction- thermal spray coating. Definition, History, Coating Build-up, Market segmentation, Material used for spraying, Method of powders production, Methods of powder characterization, Spray drying, Cladding, Mechanical alloying, Self propagating high temperature synthesis.

Pre-spray treatment: Introduction, Surface cleaning, Substrate shaping, Surface activation, Masking, Thermal spraying techniques.

Thermal spray process: Introduction, Flame spraying, Atmospheric plasma spraying, Arc spraying, Detonation gun spraying, High velocity oxy fuel spraying, Vacuum plasma spraying.

Post spray treatment: Heat treatment, Impregnation, Finishing, Method of coating characterization, Method of microstructure characterization, Mechanical properties of coating, Physical properties of coating, Chemical properties of coating.

Properties of coatings: Mechanical properties, Thermo-physical properties, Electric properties, Magnetic properties, Optical properties, Corrosion resistance, Application of coatings: Corrosion protection, Iron and steel industries, Energy generation and transport, Non-ferrous metal industries, Paper industries.

Recommended Books:

1. Introduction to surface engineering and functionally engineered materials, Peter Martin, John Wiley and Sons, 2011.
2. Tribology and Surface Engineering, "J. Paulo Davum, Nova Science Publishing.
3. Advances in Surface Engineering, SA, 2002.
4. Material and Surface Engineering in Tribology, Jamal Takadoum, Wiley

CAD6205: Automotive System Design (Elective 9: 2-0-0)

Introduction

Design Requirement of Automobile (power-speed curves), Engine as a system and its subsystems, Fuel injection systems, Cooling system.

Design of Various subsystems

Design requirements of the automobile transmission, Automatic transmissions, Dynamic considerations in designing of suspension system, modern systems of suspensions, Kinematic requirements of a steering mechanism, Need for power steering, Braking requirements of an automobile, brake materials.

Modeling and simulation

Modeling and simulation of different subsystems, e.g., suspension system, Wheels, Braking system etc.

Instrumentation and control
gauges(speedometer, oil, temperature indicators etc.), microprocessor controlled units, safety and comfort aspects in the automotive component designs.

Computer application in automotive Design
Use of softwares like Adams, Abaqus etc to analyse subsystems like transmission system, suspension mechanism and steering mechanism etc.

Electric vehicle design

Crash modeling of vehicles.

Recommended Books:
1. **Light and Heavy Vehicle Technology**, " MJNunney" Elsevier Butterworth Heinemann, IV Edition, 2007.
2. **An Introduction to Modern Vehicle Design**, " JullianHappian Smith", SAE, 2002.
3. **Crashworthiness of Vehicles**, "Johnson W. and Mamalis AG" MEP London, 1995.

CAD6207: Data Analytics (Elective 9: 2-0-0)

Probability Theory: Sample Spaces- Events - Axioms – Counting - Conditional Probability and Bayes' Theorem – The Binomial Theorem – Random variable and distributions: Mean and Variance of a Random Variable-Binomial-Poisson-Exponential and Normal distributions.

Curve Fitting and Principles of Least Squares- Regression and correlation. Sampling Distributions & Descriptive Statistics: The Central Limit Theorem, distributions of the sample mean and the sample variance for a normal population, Sampling distributions (Chi-Square, t, F, z).

Test of Hypothesis- Testing for Attributes – Mean of Normal Population – One-tailed and two-tailed tests, F-test and Chi-Square test, Analysis of variance ANOVA – One way and two-

way classifications. Tabular data- Power and the computation of sample size- Advanced data handling

Multiple regression- Linear models- Logistic regression- Rates and Poisson regression

Nonlinear curve fitting. Density Estimation- Recursive Partitioning- Smoothers and Generalised Additive Models - Survivals Analysis- Analysing Longitudinal Data- Simultaneous Inference and Multiple Comparisons- Meta-Analysis- Principal Component Analysis- Multidimensional Scaling Cluster Analysis.

Introduction to R- Packages- Scientific Calculator- Inspecting Variables- Vectors Matrices and Arrays- Lists and Data Frames- Functions- Strings and Factors- Flow Control and Loops- Advanced Looping- Date and Times.

Introduction to Python Packages- Fundamentals of Python- Inserting and Exporting Data- Data Cleansing Checking and Filling Missing Data- Merging Data- Operations- Joins.

Books:

1. Richard Cotton, “Learning R”, O’Reilly, 2013.

2. Dalgaard, Peter, “Introductory Statistics with R”, Springer Science & Business Media, 2008.

3. Brain S. Everitt, “A Handbook of Statistical Analysis Using R”, Second Edition, LLC, 2014.

4. Samir Madhavan, “Mastering Python for Data Science”, Packt, 2015.

5. Sheldon M. Ross, Introduction to Probability and Statistics for Engineers and Scientists, 4th edition, Academic Press; 2009.

6. Paul Teetor, “R Cookbook, O’Reilly, 2011. 7. Mark Lutz,” Learning Python”, O’Reilly,5th Edition,2013