# DR. A.P.J. ABDUL KALAM TECHNICAL UNIVERSITY, UTTAR PRADESH, LUCKNOW

# Syllabus

# For

# M.Tech. (COMPUTER AIDED DESIGN & MANUFACTURING)

**(Effective from the Session: 2016-17)**

# Dr. A.P.J. Abdul Kalam Technical University, Lucknow, Uttar Pradesh

## COURSE STRUCTURE AND EVALUATION SCHEME FOR
## M.TECH - COMPUTER AIDED DESIGN & MANUFACTURING

(EFFECTIVE FROM THE SESSION: 2016-17)

### Semester -I

| S. No. | Subject Code | Name of the Subject | Periods | | | Credit | Evaluation Scheme | | | | | Subject Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | L | T | P | | Theory | | | Practical | | |
| | | | | | | | CT | TA | ESE | TA | ESE | |
| 1 | MTME 101 | Simulation Modelling and Analysis | 3 | 0 | 0 | 3 | 20 | 10 | 70 | -- | -- | 100 |
| 2 | MTCM 101 | Computer Aided Design | 3 | 0 | 0 | 3 | 20 | 10 | 70 | -- | -- | 100 |
| 3 | | Departmental Elective-I | 3 | 0 | 0 | 3 | 20 | 10 | 70 | -- | -- | 100 |
| 4 | | Departmental Elective-II | 3 | 0 | 0 | 3 | 20 | 10 | 70 | -- | -- | 100 |
| 5 | | Research Process & Methodology | 3 | 0 | 0 | 3 | 20 | 10 | 70 | -- | -- | 100 |
| 6 | MTME 151 | Simulation Modelling and Analysis lab | -- | -- | 3 | 2 | -- | -- | -- | 20 | 30 | 50 |
| 7 | MTCM 151 | Computer Aided Design Lab | -- | -- | 2 | 1 | -- | -- | -- | 20 | 30 | 50 |
| | | **Total** | | | | 18 | | | | | | **600** |

| | | |
|---|---|---|
| **Departmental Elective – I** | MTCM 011 | Computer Aided Inspection and Testing |
| | MTCM 012 | Instrumentation and Experimental Methods |
| | MTCM 013 | Advanced Automatic Control |
| | MTCM 014 | Computer Aided Manufacturing |

| | | |
|---|---|---|
| **Departmental Elective – II** | MTCM 021 | Bearing Design |
| | MTCM 022 | Advanced Mechanical Vibrations |
| | MTCM 023 | Artificial Intelligence |
| | MTCM 024 | Friction and Wear |

### Semester –II

| S. No. | Subject Code | Name of the Subject | Periods | | | Credit | Evaluation Scheme | | | | | Subject Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | L | T | P | | Theory | | | Practical | | |
| | | | | | | | CT | TA | ESE | TA | ESE | |
| 1 | MTCM 201 | Computer Graphics & Geometric Modeling | 3 | 0 | 0 | 3 | 20 | 10 | 70 | -- | -- | 100 |
| 2 | MTME 202 | Advanced Mechanics of Solid | 3 | 0 | 0 | 3 | 20 | 10 | 70 | -- | -- | 100 |
| 3 | | Departmental Elective-III | 3 | 0 | 0 | 3 | 20 | 10 | 70 | -- | -- | 100 |
| 4 | | Departmental Elective-IV | 3 | 0 | 0 | 3 | 20 | 10 | 70 | -- | -- | 100 |
| 5 | | Elective-V | 3 | 0 | 0 | 3 | 20 | 10 | 70 | -- | -- | 100 |
| 6 | MTCM 251 | Computer Graphics & Geometric Modeling Lab | -- | -- | 3 | 2 | -- | -- | -- | 20 | 30 | 50 |
| 7 | MTCM 252 | Seminar-I | -- | -- | -- | 1 | -- | -- | -- | 50 | -- | 50 |
| | | **Total** | | | | 18 | | | | | | **600** |

| | | |
|---|---|---|
| **Departmental Elective – III** | MTME 031 | Advanced Finite Element Analysis |
| | MTCM 031 | Computer Aided Analysis Of Mechanical System |
| | MTCM 032 | Fracture Analysis |
| | MTCM 033 | Mechatronics |

| | | |
|---|---|---|
| **Departmental Elective – IV** | MTME 041 | Optimisation Techniques And Design Of Experiment |
| | MTCM 041 | Dynamics Of Mechanical Systems |
| | MTCM 042 | Advanced Machine Design |
| | MTCM 043 | Mechanics Of Composite Material |

| | | |
|---|---|---|
| **Elective – V** | MTME 051 | Flexible Manufacturing Systems |
| | MTCM 051 | Robotics And Control |
| | MTME 053 | Additive Manufacturing & Tooling |
| | MTCM 052 | Manufacturing System Analysis |

**Semester – III**

| S. No. | Subject Code | Name of the Subject | Periods | | | Credit | Evaluation Scheme | | | | | Subject Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | L | T | P | | Theory | | | Practical | | |
| | | | | | | | CT | TA | ESE | TA | ESE | |
| 1 | MTCM 352 | Seminar-II | 0 | 0 | 6 | 3 | -- | -- | -- | 100 | -- | 100 |
| 2 | MTCM 351 | Dissertation | 0 | 0 | 30 | 15 | -- | -- | -- | 200 | 300 | 500 |
| | | **Total** | | | | 18 | | | | | | **600** |

**Semester – IV**

| S. No. | Subject Code | Name of the Subject | Periods | | | Credit | Evaluation Scheme | | | | | Subject Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | L | T | P | | Theory | | | Practical | | |
| | | | | | | | CT | TA | ESE | TA | ESE | |
| 1 | MTCM 451 | Dissertation (Final) | 0 | 0 | 36 | 18 | -- | -- | -- | 200 | 400 | 600 |
| | | **Total** | | | | 18 | | | | | | **600** |

## SIMULATION, MODELLING & ANALYSIS

**MTME 101** **L T P**
**3 0 0**

**Introduction:** Simulation: a tool, advantages and disadvantages of simulation, areas of application, systems and system environment, components of a system, discrete and continuous systems, discrete event system simulation.
**General Principles:** Concepts in discrete event simulation, time advance algorithm, manual simulation using event scheduling, basis properties and operations.

**Models In Simulation:** Terminology and concepts, statistical models: queuing systems; inventory systems; reliability and maintainability, limited data, discrete distributions: Bernoulli distribution; Bionomial distribution; Geometric distribution, continuous distribution: Uniform distribution; Exponential distribution; Gamma distribution; Normal distribution; Weibull distribution; Triangular Distribution; Lognormal distribution, poisson process,

**Queueing Models:** Characteristics of queuing systems, the calling population, system capacity, arrival process, service mechanism, queuing notations, long run measures of performance of queuing systems, server utilization in G/G/1/∞/∞ queues, server utilization in G/G/C/∞/∞ queues, server utilization and system performance, costs in queuing problems, Larkovian models.

**Random Number Generation:** Properties of random numbers, Pseudo random numbers, techniques of generating random numbers, tests of random numbers.
**Random Variate Generation:** Inverse transform technique, Direct transformation for the Normal and Lognormal distribution, Convolution Method, Acceptance rejection technique.

**Input Modelling And Validation:** Steps in the development of model, data collection, Distribution identification, Parameter estimation, Goodness of Fit Tests,selecting input models without data, verification and validation of simulation models.

**Books:**

1. Simulation Modelling and Analysis by Law and Kelton, Mc Graw Hill.
2. Simulation Model Design& execution by Fishwich, Prentice Hall.
3. Discrete event system simulation by Banks, Carson, Nelson and Nicol.

# COMPUTER AIDED DESIGN

**MTCM 101** **L T P**
**3 0 0**

**Introduction:** Definitions, Historical Development. Geometric Modeling, Nameable and Unnamable shapes, Explicit and Implicit Equations, Intrinsic Equations, Parametric Equations, Coordinate Systems.

**Design Of Curves:** Algebraic and Geometric Forms, Parametric space of a curve, Blending functions, Reparametrization, Truncating, Extending and subdividing, Space curve, Four point form, Straight lines, Spline Curves, Bezier Curves, B-spline Curves, Rational Polynomials, introduction to NURBS

**Design Of Surfaces:** Algebraic and Geometric form, Tangent and Twist Vectors, Normal, Parametric space of a surface, Blending Functions, Reparametrization of a surface patch, subdividing, Sixteen Point form, Four Curve Form, Plane surface, Cylindrical Surface, Ruled surface, Surface of Revolution. Bezier Surface, B-Spline Surface.

**Solid Modeling Fundamentals:** Topology of Closed Paths, Piecewise flat surfaces, topology of closed curved surfaces, Generalized Concept of boundary, Set theory, Boolean operators, Set-membership Classification, Euler operators, Formal Modeling Criteria.

**Solid Model Construction:** Graph Based methods, Boolean models, Instances and Parameterized Shapes, Cell Decomposition and spatial-Occupancy Enumeration, Sweep Representation, Constructive Solid Geometry, Boundary Representation

**Transformations:** Translation, Rotation, Scaling Symmetry and Reflection, Homogeneous Transformations. Orthographic Projections, Axonometric Projections, Oblique Projections, Perspective Transformation.

**Introduction to Assembly**-modeling, Analytical Properties, Relational Properties and intersections, Data transfer formats.

**Applications:** Implementation of the algorithms on MATLAB, Construction of Solid and Surface Models on any of the high end solid modelers (IDEAS / ProE and Imageware Surfacer ), Course Project.

**Books:**


1. Geometric Modeling: Michael E. Mortension, John Wiley.
2. Mathematical Elements of Computer Graphics: Roger and Adams, McGraw Hill.
3. CAD CAM Theory and Practice: I. Zeid, McGraw Hill.
4. Computer Aided Engineering Design, Saxena and Sahay, Anamaya N. Delhi.

## SIMULATION, MODELLING & ANALYSIS LAB

**MTME 151** **L T P**
**0 0 3**

1. Study of simulation software Like ARENA , MATLAB.
2. Simulation of translational and rotational mechanical systems
3. Simulation of Queuing systems
4. Simulation of Manufacturing System
5. Generation of Random number
6. Modeling and Analysis of Dynamic Systems
7. Simulation mass spring damper system
8. Simulation of hydraulic and pneumatic systems.
9. Simulation of Job shop with material handling and Flexible manufacturing systems
10. Simulation of Service Operations

## COMPUTER AIDED DESIGN LAB

**MTCM 151** **L T P**
**0 0 2**

**List of Experiments:**

1. Introduction and Installation of CAD/CAE Softwares
2. Introduction to Solid Modelling & Pro/E Package
3. Introduction to MATLAB Programming
4. Working with advanced modeling tools (Sweep, Blend & Swept Blend)
5. Assembly modelling in Pro/E
6. Generating, editing and modifying drawings in Pro/E
7. Creating an assembly, moving components, wire frame and surface geometry.
8. Generating of ferguson's cubic surface patches, Bezier surface patches and coons patches.
9. Exercises on Analytic Curves (Lines, Circles, Ellipses, Parabolas, Hyperbolas, Conics) using MATLAB Programming
10. Exercises on Synthetic Curves (Cubic Spines, Bezier Cures, B-Spine Curves) using MATLAB Programming
11. Working with CAD Data Exchange formats: IGES, ACIS, DXF and STL

## DEPARTMENTAL ELECTIVE-I

## COMPUTER AIDED INSPECTION AND TESTING

**MTCM 011** **L T P**
**3 0 0**

**Introduction:** Computer aided testing (CAT) and computer aided inspection (CAI), computer aided quality control ( CAQC), on-line inspection and quality control, technology of automation Gauging, automatic inspection machines, in-process gauging,

**Co-Ordinate Measuring Machines:** Basic Types of Measuring Machines, probe types, operating modes, programming software's, accessories, measurement and inspection capabilities, flexible inspection systems, inspection problems.

**Machine Vision:** Functions of machine vision system, evaluating the performance of machine vision system, machine vision applications.

**Scanning Laser Beam Devices:** Laser interferometer, laser, alignment devices, X-ray optics, CCD (Charge-coupled Devices) Array, ultrasonic system.

**Machine Tool Sensing**: Part measurement, Tool wear, Axial, motion, Sequence of functions, tool Identification. Computer aided surface roughness measuring systems, High accuracy profile measuring systems.

**Proximity Sensing:** Photoelectric Transducers, Image processing for vision sensor, 3 dimensional object recognition.

**Books:**


1. Machine Vision-Nello Zueh and Richard K.Miller prentice hall.
2. Roborts Sensor -Pugh, IFS Publication.
3. Transducers and Interfacing -Bannister and Whitehead~ Von Nostrand.
4. Computer Control of Manufacturing Systems -Koren, McGraw Hill.

## INSTRUMENTATION AND EXPERIMENTAL METHODS

**MTCM 012** **L T P**
**3 0 0**

**Significance of Measurement and Instrumentation:** Introduction; generalized configuration and functional stages of measuring systems. The transducer and its environment; an overview; sensing process and physical laws.

Types of measurement problems. Transducer classification and their modeling; information, energy and incremental models; characteristics of instruments, design and selection of components of a measuring system.

**Dynamic Response of Instruments:** Mathematical model of a measuring system, response of general form of instruments to various test inputs; timedomain and frequency domain analysis. Elementary transfer functions and Bode plots of general transfer functions.

**Errors in Measurement and Its Analysis:** Causes and types of experimental errors; systematic and random errors. Uncertainty analysis; computation of overall uncertainty; estimation for design and selection for alternative test methods.

**Transducers:** Developments in sensors, detectors and transducer technology; displacement transducers; force, torque and motion sensors; piezoelectric transducers; capacity type transducers; Strain gage transducers; accelerometers, pressure transducers based on elastic effect of volume and connecting tubing.

**Data Acquisition and Signal Processing**: Systems for data acquisition and processing; modules and computerized data system; digitization rate; time and frequency domain representation of signals, and Nyquist criterion. A brief description of elements of mechatronics; modular approach to mechatronics and engineering design.

**Flow Measurement:** Flow visualization, shadowgraph; schlieren and interferometric techniques; Pitot static tubes; hot wire anemometers; Laser Doppler velometer; flow measurements using coriolis effect.

**Temperature and Heat Flux Measurement:** Thermoelectric sensors; electric resistance sensors; thermistors; radiations pyrometers; Temperature measuring problems in flowing fluids, dynamic compensation.

**Books:**


1. Measurements System Application and Design, Doeblin E. O., McGraw Hill.
2. Transducers in Mechanical and Electronic Design Trietly Harry L., Dekker Marcel, CRC Press.
3. Mechanical Measurements Beckwith T. G., Marangoni R. D., and Lienhard J. H, 6th Ed., Prentice Hall.
4. Measurements in Heat Transfer, Eckert E. R. G. and Goldstein R. J.,2nd Ed., Springer.
5. Fluid Mechanics Measurement, Goldstein R. J., Hemisphere Publishing Company.

## ADVANCED AUTOMATIC CONTROLS

**MTCM 013** **L T P**
**3 0 0**

**Mathematical Models of Linear Systems:** Linear systems and state equations, linearization of non linear equations, linearizing functions, linearizing differential equations

**Linear Algebra:** Vector spaces, linear dependence and independence, bases, change of basis, rank and degeneracy, norms, Gram-Schmidt orthonormalization, subspaces and projection theorem.

**State Variable Analysis**: State variable representation, conversion of state variable model to transfer function, characteristic equation, eigenvalues, eigenvectors, conversion of transfer function to canonical state variable models, solution to state equations.

**Stability of Control Systems:** Bounded input, bounded output stability, zero input and asymptotic stability of continuous data system, Lyapunov stability, Lyapunov's direct method, external stability, relationship between stability types.

**Controllability and Observability:** Controllability tests for LTI systems, modal controllability and observability, controllability and observability of time varying systems, discrete time systems.

**System Realizations:** Minimal realization, specific realization, Markov parameters, balanced realizations.

**State Feedback and Observers:** State feedback for SISO systems, multivariable canonical forms and feedback, observers, state estimator- multivariable case.

**Optimal Control and Estimation:** The principle of optimality, optimal estimator.

**Pole Placement and Model Matching:** Unity feedback configuration, implementable transfer function, multi variable unity feedback system, multivariable model matching.

**Books:**


1. Modern Control Engineering, Ogata, K., Prentice Hall of India.
2. Automatic control Theory, Raven, F.H., McGraw Hill.
3. Automatic Control System, Kuo, B.C., Prentice Hall of India.
4. Linear System Theory & Design, Chen, C.T., Oxford University Press.
5. Automatic Controls, Harrison, H.L. and Bollinger, J. G., International Text Book Company.
6. Fundamentals of Linear State Space Systems, Bay, J.S., McGraw Hill.
7. Control Systems Engineering, Norman, S.N., John Wiley and Sons.

## COMPUTER AIDED MANUFACTURING

**MTCM 014** **L T P**
**3 0 0**

**Introduction:** Introduction to manufacturing systems and their performance analysis; Introduction to automation; Introduction to computer integrated manufacturing (CIM).

**Numerical Control (NC):** Introduction, numerical control – its growth and development, components of NC system, input devices, control systems – point to point, straight cut, and continuous path NC, open loop and closed loop NC systems, NC interpolations – linear, circular, helical, parabolic and cubic interpolation, applications of NC systems, merits and demerits.

**Extensions of NC:** Concepts of computer numerical control (CNC), machining center, and direct numerical control (DNC), and their advantages.

**Robotics:** Robot anatomy and related attributes, robot control systems –limited sequence, playback with point to point, playback with continuous and intelligent control; End effectors – gripper, tools; Sensors in robotics – tactile sensors, proximity, optical sensors and machine vision; Applications of industrial robots, robot programming.

**Material Handling and Storage:** Overview of material handling equipments, automated material handling equipments – AGVs, conveyor systems, performance analysis of material handling systems, automated material storage systems – ASRS and carousel storage, analysis of automated storage systems.

**Manufacturing Support Functions:** Introduction to group technology (GT), computer aided process planning (CAPP), material requirement planning MRP (MRP), capacity planning, scheduling etc.

**Books:**


1. Automation, Production systems and Computer Integrated Manufacturing , Groover, M. P., Prentice-Hall.
2. Systems Approach to Computer Integrated Design and Manufacturing, Singh, N., John Wiley & Sons..
3. Computer Aided Manufacturing Chang, T.-C., Wysk, R. A. and Wang, H.-P., Prentice Hall.
4. Computer Integrated Manufacturing, Rembold, U., Nnaji, B. O. and Storr A., Addison Wesley.
5. Computer Aided Design and Manufacture, Besant, C. B. and Lui, C. W. K., Ellis Horwood Ltd..
6. Computer Aided Manufacturing, Rao, P. N., Tiwari, N. K. and Kundra, T.K., Tata McGraw Hill.

## DEPARTMENTAL ELECTIVE II

## BEARING DESIGN

**MTCM 021** **L T P**
**3 0 0**

**Lubrication:** Fundamentals, Types of Lubrication, Viscosity and its Types of Lubrication, Types of Bearings, Equations of Continuity and Motion, Hydrodynamics of Simple Configuration.

**Hydrodynamic Lubrication**: Pertoff's Equation, Generalized Reynolds Equation, Simplification of Full Reynolds Equation, Infinitely Long Bearings Infinitely Short Bearings, Converging-Diverging Channel, Full Sommerfi.eld Condition, Half Sommerfield and Reynolds, Center of Pressure, Friction.

**Journal Bearings:** Geometry, Pressure, Equation -Short Bearing, Load, Attitude Angle, Friction, Full Journal Bearing, Friction, Pressure Distribution, Load Carrying Capacity, Partial Journal Bearings, Influence of End Leakage on Behaviour of Bearings.

**Thrust Bearings:** Geometry, Pressure, Equation Infinite Bearing, Finite Thrust Bearing, Friction, Pressure Distribution, Center of Pressure, Load Carrying Capacity.

**Hydrostatic Bearings:** Applications, Features, Analysis of Footstep Bearing, Compensators, and Practical Considerations.

**Porous Bearings:** Introduction, Geometry, Reynold's Equation Hydrodynamic Gas Bearings, On Newtonian Fluids and Elasto-Hydrodynamic Lubrication: Difference Between Gas And Oil Lubrication, General Conditions, Solution to Gas Lubricated Hydrodynamic Bearipgs, Hybrid Bearings, Magnetic Bearings

**Bearings Materials:** General Requirements and Different Types of Bearing Materials.

**Books:**


1. Fundamentals of Fluid Film Lubrication, Hamrock, Schmid, Jacobson.
2. Applied Tribology Bearing Design and Lubrication, Khonsari and Booser.
3. Principles of Lubrication, Cameron.
4. Principles and Applications of Tribology, Bhushan, B.
5. Magnetic Bearings and Bearingless Drives, Fukao, Oshima, Takemoto, Dorell.

# ADVANCED MECHANICAL VIBRATIONS

**MTCM 022** **L T P**
**3 0 0**

**Introduction:** Review of free and forced vibrations with and without damping.
**Isolation:** Vibration isolation and transmissibility; Un-damped vibration absorbers.
**Multi degree of freedom system:** Generalized coordinates and coordinate coupling; Orthogonality of modes, Free and forced vibration of multi-degree of freedom systems with and without viscous damping; Lagrange's equation; Holzer's method. Solution of Eigen value problem, transfer matrix and modal analysis.
**Stability criterion**: Self excited vibrations; Criterion of stability; Effect of friction on stability.
**Non linear vibration:** Free vibrations with non-linear spring force or nonlinear damping; Phase plane; Energy curves; Lienard's graphical construction; Method of isoclines.
**Vibration of continuous system**: Vibrations of strings; Free and forced longitudinal vibrations of prismatic bars; Ritz and Galerkin methods.
**Random vibration:** Mathematical descriptions of stochastic processes; Stationary and ergodicity; Gaussian random process, correlation functions and power spectral density.
**Diagnostic techniques:** Introduction to diagnostic maintenance and signature analysis.

**Books:**


1. Rao, S.S., "Mechanical Vibrations", 4th Ed., Pearson Education.
2. Meirovitch, L., "Fundamental of Vibrations", Mc-Graw Hill.
3. Inman, D.J., "Vibration and Control", John Willey & Sons.
4. Tamadonni, S. and Kelly, G.S., "Mechanical Vibrations", Mc-Graw Hill.

## ARTIFICIAL INTELLIGENCE

**MTCM 023** **L T P**
**3 0 0**

**Overview of History and Goals of AI:** Artificial Intelligence -- Definition, components, scope, and application areas; Turing's test; Review of AI success and failure.

**State Spaces, Production Systems, and Search**: State space representation of problems; Problem solving using search; Definition and examples of production systems; Heuristic search techniques i.e. generate-and-test, hill climbing, best-first search, constraint satisfaction and mean-ends analysis.

**Knowledge Representation:** Definition of knowledge; Issues in knowledge representation; Procedural vs declarative knowledge and their representation; Predicate logic, production rules, semantic nets, and frames; Meta-knowledge.

**Reasoning and Inference Strategies**: Forward vs backward reasoning; Depth first, breadth first, min-max etc.; Non-monotonic reasoning; Symbolic reasoning under uncertainty; Probability and Baye's theorem; Certainty factors, Dempster-Shafer theory; Fuzzy logic etc.

**Expert Systems and their Applications:** Justification, structure, knowledge sources; Expert knowledge acquisition; Expert system languages; ES building tools/shells; Applications of AI in CAD, CAPP, process selection, GT, MRP II, adaptive control, robotics, process control, fault diagnosis, failure analysis, etc.

**Books:**


1. Artificial Intelligence, Rich, E., Knight, K. and Nair, S. B., 3rd Ed., Tata McGraw Hill.
2. Artificial Intelligence: A Modern Approach, Russell, S. and Norvig, P., 3rd Ed., Prentice-Hall.
3. Artificial Intelligence:Theory and Practice Dean, T. L., Allen, J., and Aloimonos, Y., Benjamin/Cummings Publishing Company.
4. Logical Foundations of Artificial Intelligence, Genesereth, M. R. and Nilsson, N., Morgan Kaufmann.

# FRICTION AND WEAR

**MTCM 024** **L T P**
**3 0 0**

**Fundamental Review**: Surface Topography and contacts, Measurement of surface topography, Surface roughness and its quantification, Topography of surfaces, Contact between surfaces

**Friction**: Definition, Sliding Friction: Quantitative Laws of sliding friction, magnitude of the friction force, criticism of the adhesive theory, other contributions to the friction force, rolling Force, sliding friction, Models of asperity deformation, friction of metals ceramics and Polymers.

**Rolling Friction**: Laws of roIling friction, the measurement of friction.

**Types Of Wear**: Uses of Wear, types of wear the measurement of wear.

**Adhesive Wear**: Introduction, mechanism of adhesive wear, the sizes and shapes of transferred fragments, the size distribution of wear fragments, quantitative laws of adhesive wear, alternative forms of wear equation, equilibrium distribution of transferred particles and the minimum load for transfer materials to be used in adhesive wear situations.

**Abrasive Wear**: Introduction quantitative expression for abrasive wear, experimental evidence for the abrasive wear equation, effect of hardness on abrasive wear rate, influence of abrasive particle, size on abrasive wear rate, effect of moisture contents and lubrication.

**Corrosive Wear**: Introduction, Brittle Fracture wear, Transition between corrosive & adhesive & abrasive wear, Triboochemical polishing, Oxidative wear,

**Fatigue Wear**: Fatigue wear during sliding Surface crack initiated fatigue wear Subsurface crack initiated fatigue wear Effect of lubrication on fatigue wear during sliding, Fatigue wear during rolling.

**Books:**


1. Friction and Wear of Materials by Rabinowicz.
2. Fundamentals of Tribology by Basu, Sengupta, Ahuja.
3. Fundamentals of Fluid Film Lubrication by Hamrock, Schmid, Jacobson.
4. Applied Tribology Bearing Design and Lubrication by Khonsari and Booser.

# COMPUTER GRAPHICS & GEOMETRIC MODELING

**MTCM 201** **L T P**
**3 0 0**

Introduction: Role of Computer Graphics in CAD/CAM, configuration of graphic workstations, menu design and Graphical User Interfaces (GUI), customization and parametric programming.

Geometric Transformations and Projections: Vector representation of geometric entities, homogeneous coordinate systems, fundamentals of 2D and 3D transformations: Reflection, translation, rotation, scaling, and shearing, various types of projections.

Curves: Modeling planar and space curves, analytical and synthetic approaches, non-parametric and parametric equations.

Surfaces: Modeling of bi-parametric freedom surfaces, Coons, Bezier, B-spline, and NURBS surfaces, surface manipulation techniques.

Geometric Modeling: Geometric modeling techniques, wireframe modeling, solid modeling: B-Rep, CSG, hybrid modelers, feature based, parametric and variational modeling.

Data Structure in Computer Graphics: Introduction to product data standards and data structures, data-base integration for CIM.

**Books:**


1. Rogers, D. F., and Adams, J. A., “Mathematical Elements for Computer Graphics”, McGraw Hill.
2. Faux, I. D. and Pratt, M. J., “Computational Geometry for Design and Manufacture”, Ellis Horwood Ltd.
3. Mortenson, M. E., “Geometric Modeling”, 3rd Ed., Industrial Press.
4. Zeid, I., “CAD/CAM: Theory and Practice”, Tata McGraw Hill.
5. Choi, B. K., “Surface Modeling for CAD/CAM", John Wiley & Sons.

# ADVANCED MECHANICS OF SOLIDS

**MTME 202** **L T P**
**3 0 0**

**Mathematical Preliminaries**: Scalars, vectors and matrix variables, index notation and the related rules, Cartesian tensors and their algebra, coordinate transformation, transformation rules for the *n*th order tensors, elements of tensor calculus and the related theorems (divergence, Stokes' and Green's), principal value theorem, eigenvalues and eigenvectors, invariants of a 2nd order tensor.

**Kinetics of Deformation:** Types of forces (point, surface and body), traction vector, state of stress at a point, Cauchy's relation and its proof, conservation of linear and angular momentum, stress equilibrium equations, symmetry of stress tensor, stress transformation, principal stresses and the associated planes, 3D Mohr's circle representation, planes of maximum shear, octahedral planes, hydrostatic and deviatoric stress, first and second Piola-Kirchoff stress tensors and their properties.

**Kinematics of Deformation**: Material and spatial co-ordinates, Eulerian and Lagrangian description of motion; deformation and displacement gradients, Green-Lagrange and Almansi strain tensor; Cauchy's small strain tensor and the rotation tensor, geometrical interpretation of strain components and sign convention, principal strains and directions, strain invariants, octahedral strain, maximum shear strain, volumetric strain, strain compatibility equations.

**Constitutive Modeling:** Thermodynamic principles, first and second law of thermodynamics, Generalized Hooke's law for isotropic materials, elastic constants and their relations, anisotropic, hyperelastic and viscroelastic material models, strain hardening, constitutive relations for elasto-plastic materials, flow and hardening rules.

**Boundary Value Problems in Linear Elasticity:** Field equations and boundary conditions, Navier equations, Beltrami-Michell stress compatibility conditions, 2D approximations (plane stress and plane strain) and solution strategies.

**Variational Principles in Solid Mechanics:** Elements of variational calculus, extremum of a functional, Euler-Lagrange equation and its application, types of boundary conditions, principle of virtual work, Principle of total potential energy and complementary potential energy, Ritz

method, time-dependent problems and Hamilton's principle for continuum.

**Books:**


1. Sadd, M.H., "Elasticity Theory Applications and Numerics", Elsevier Academic Press.
2. Boresi, A.P., Sidebottom, O. M., "Advanced Mechanics of Materials", 5th Ed., John Wiley and Sons.
3. Singh, A.K., "Mechanics of Solids", PHI Learning Private Limited.
4. Timoshenko, S.P., and Goodier, J.M., "Theory of Elasticity", 3rd Ed., McGraw Hill
5. Srinath, L.S., "Advanced Mechanics of Solids",Tata McGraw Hill Education Private Limited.
6. Fung, Y.C., " Foundations of Solid Mechanics", Prentice Hall Inc.

## COMPUTER GRAPHICS & GEOMETRIC MODELING

**MTCM 251** **L T P**
**0 0 3**

**List of Experiments:**

1. Write a program to scale a geometric model
2. Write a program to rotate a geometric model
3. To drwa a 3D model of mechanical components
4. Virtual Prototype modeling of assemblies by geometric modeling and rendering using commercial
5. CAD/CAM systems
6. Surface modeling and sheet metal features design for industrial components
7. CAD data preparation for Rapid prototyping, Virtual reality and Finite element Solvers
8. Surface reconstruction from point cloud data for reverse engineering and inspection

## DEPARTMENTAL ELECTIVE III

## ADVANCED FINITE ELEMENT ANALYSIS

**MTME 031** **L T P**
**3 0 0**

Introduction to FEM, basic concepts, historical back ground, applications of FEM, general description, comparison of FEM with other methods, variational approach, Glerkin's Methods. Co-ordinates, basic element shapes, interpolation function, Virtual energy principle, Rayleigh – Ritz method, properties of stiffness matrix, treatment of boundary conditions, solution of system of equations, shape functions and characteristics, Basic equations of elasticity, strain- displacement relations.

**1 -D STRUCTURAL PROBLEMS**: Axial bar element – stiffness matrix, load vector, temperature effects, Quadratic shape functions and problems.
**ANALYSIS OF TRUSSES** : Plane Trusses and Space Truss elements and problems
**ANALYSIS OF BEAMS** : Hermite shape functions – stiffness matrix – Load vector – Problems.

**2-D PROBLEMS:** CST, LST, force terms, Stiffness matrix and load vectors, boundary conditions, Isoparametric elements – quadrilateral element, shape functions – Numerical Integration. Finite element modeling of Axi-symmetric solids subjected to Axi-symmetric loading with triangular elements.
**3-D PROBLEMS**: Tetrahedran element – Jacobian matrix – Stiffness matrix.

**SCALAR FIELD PROBLEMS**: 1 -D Heat conduction-Slabs – fins - 2-D heat conduction problems – Introduction to Torsional problems.

Dynamic considerations, Dynamic equations – consistent mass matrix – Eigen Values, Eigen vector, natural frequencies – mode shapes – modal analysis.

**REFERENCES:**


1. The Finite Element Methods in Engineering / SS Rao / Pergamon.
2. Finite Element Methods: Basic Concepts and applications, Alavala, PHI
3. Introduction to Finite Elements in Engineering, Chandrupatla, Ashok and Belegundu, Prentice –Hall
4. Finite Element Method – Zincowitz / Mc Graw Hill
5. Introduction to Fininte element analysis- S.Md.Jalaludeen,Anuradha Publications, print-2012
6. A First Course in the Finite Element Method/Daryl L Logan/Cengage Learning/5th Edition
7. Finite Element Method – Krishna Murthy / TMH
8. Finite Element Analysis – Bathe / PHI

## COMPUTER AIDED ANALYSIS OF MECHANICAL SYSTEMS

**MTCM 031** **L T P**
**3 0 0**

**Introduction:** Introduction to mechanical systems analysis.

**Kinematic Modeling:** Modeling the kinematics of mechanical systems; Vector loop methods, vector chain methods.

**Solution of Kinematic Models:** Solution of kinematic models for displacements, velocities, accelerations; Direct analytical solutions of position, velocity, acceleration problems; Numerical solution of position problem; Matrix method solutions of velocity and acceleration problems.

**Dynamic Modeling:** Modeling the dynamics of mechanical systems; Newton-Euler methods to define dynamic constraints between forces, moments, and accelerations, energy methods to define dynamic constraints between input and output links.

**Solution of Dynamics Models**: Solution of inverse dynamics models for joint-link forces and torques, solution of forward dynamics models using numeric integration, model formulation into standard format for solution, Euler's method of integration, Runge-Kutta methods of integration, modeling and analysis of the Trebuchet mechanism.

**Advanced Dynamic Analysis & Simulation:** Bond graph modeling of dynamic systems, generation of system equations, causality, and simulation.

**Books:**


1. Norton R., "Design of Machinery", McGraw-Hill.
2. Palm W. J., "Introduction to MATLAB 6 for Engineers", McGraw-Hill.
3. Nikravesh, P. E., "Computer-Aided Analysis of Mechanical Systems", Prentice Hall.
4. Haug, E. J., "Computer Aided Analysis and Optimization of Mechanical System Dynamics", Springer-Verlag.
5. Mukherjee, A., Karmaker, R. and Samantaray, A.K., "Bond Graph in. Modeling, Simulation and Fault Identification", I & K International.

## FRACTURE MECHANICS

**MTCM 032** **L T P**
**3 0 0**

**Introduction to Fracture Mechanics:** Introduction to the realm of fracture and back ground history of development of fracture mechanics; Discrepancy between theoretical and real strength of materials, conventional failure criteria based on stress concentration and characteristic brittle failures, Griffith's work.

**Linear Elastic Fracture Mechanics (LEFM) Based Design Concepts:** Crack deformation modes and basic concepts, crack tip stresses and deformation, stress intensity factor (SIF) and its criticality in different modes, superposition of SIFs, LEFM design concept applications; Concept of energy release rate, equivalence of energy release rate and SIF.

**Fracture toughness:** Fracture toughness and its laboratory determination procedure, test specimen size requirement etc.; Effect of temperature and loading rate on fracture toughness; Fatigue and fatigue crack propagation laws, fatigue life calculations under constant and variable amplitude loading, mixedmode fatigue crack propagation.

**Strain Energy Density Failure Criterion:** Introduction, volume strain energy density, basic hypothesis and application of energy density based failure criteria for two and three dimensional linear elastic crack problems.

**Elastic Plastic Fracture Mechanics Based Design Criteria:** Design criteria for non-brittle materials; plastic zone corrections, crack opening displacement (COD), J-contour integral and crack growth resistance (R-curve) concepts.

**Books:**


1. Gdoutos, E.E., "Fracture Mechanics: An Introduction", 2nd Ed., Springer.
2. Broek, D., "Elementary Engineering Fracture Mechanics", 3rd Ed., Springer.
3. Kumar, P., "Elements of Fracture Mechanics", Wheeler Publishing.
4. Anderson, T. L., "Fracture Mechanics: Fundamentals and Applications", 3rd Ed., CRC Press.
5. Shukla, A., "Practical Fracture Mechanics in Design", 2nd Ed., CRC Press.
6. Bazant, Z. P. and Cedoliin, L., "Stability of Structures: Elastic, Inelastic, Fracture and Damage Theories", World Scientific Publishers.

# MECHATRONICS

**MTCM 033** **L T P**
**3 0 0**

**Introduction:** Definition of mechatronics, measurement system, control systems, microprocessor based controllers, mechatronics approach.

**Sensors and Transducers:** Sensors and transducers, performance terminology, photoelectric transducers, flow transducers, optical sensors and transducers, semiconductor lasers, selection of sensors, mechanical / electrical switches, inputting data by switches.

**Actuators:** Actuation systems, pneumatic and hydraulic systems, process control valves, rotary actuators, mechanical actuation systems, electrical actuation systems.

**Signal Conditioning:** Signal conditioning, filtering digital signal, multiplexers, data acquisition, digital signal processing, pulse modulation, data presentation systems.

**Microprocessors and Microcontrollers:** Microcomputer structure, microcontrollers, applications, programmable logic controllers.

**Modeling and System Response:** Mathematical models, bond graph models, mechanical, electrical, hydraulic and thermal systems, dynamic response of systems, transfer function and frequency response, closed loop controllers.

**Design and Mechatronics:** Input/output systems, computer based modular design, system validation, remote monitoring and control, designing, possible design solutions, detailed case studies of mechatronic systems used in photocopier, automobile, robots.

**Books:**


1. Bolton, W., "Mechatronics", Longman.
2. Alciatore, D. G. and Histrand, M. B., "Introduction to Mechatronics", Tata McGraw Hill.
3. Shetty, D. and Richard, A.K., "Mechatronics System Design", PWS Pub. Boston.
4. Mahalik, N., "Principles, Concept and Applications: Mechatronics", Tata McGraw.
5. Bishop, R.H. "Mechatronics Handbook", CRC Press. 2002
6. Bolton, W., "Mechatronics: A Multidisciplinary Approach", 4th Ed., Prentice Hall.
7. Merzouki R., Samantaray A. K., Pathak P.M., Bouamama B. Ould, Intelligent
8. Mechatronic Systems: Modeling, Control and Diagnosis, Springer.

## DEPARTMENTAL ELECTIVE IV

## OPTIMIZATION TECHNIQUES & DESIGN OF EXPERIMENTS

**MTME 041** **L T P**
**3 0 0**

**SINGLE VARIABLE NON-LINEAR UNCONSTRAINED OPTIMITION**: One dimensional Optimization methods, Uni-modal function, elimination method, Fibonacci method, golden section method, interpolation methods- quadratic & cubic interpolation methods.

**MULTI VARIABLE NON-LINEAR UNCONSTRAINED OPTIMIZATION**: Direct search method – Univariant Method – pattern search methods – Powell's – Hook – Jeeves, Rosenbrock search methods – gradient methods, gradient of function, steepest decent method, Fletcher reeves method. **Variable** metric method.

**GEOMETRIC PROGRAMMING:** Polynomials – arithmetic – geometric inequality – unconstrained G.P – constrained G.P
**DYNAMIC PROGRAMMING:** Multistage decision process, principles of optimality, examples, conversion of final problem to an initial value problem, application of dynamic programming, production inventory. Allocation, scheduling replacement.

**LINEAR PROGRAMMING**: Formulation – Sensitivity analysis. Change in the constraints, cost coefficients, coefficients of the constraints, addition and deletion of variable, constraints.
**Simulation**: Introduction – Types – Steps – application – inventory – queuing – thermal system.

**INTEGER PROGRAMMING**: Introduction – formulation – Gomory cutting plane algorithm – Zero or one algorithm, branch and bound method.
**STOCHASTIC PROGRAMMING:** Basic concepts of probability theory, random variables – distributions – mean, variance, Correlation, co variance, joint probability distribution – stochastic linear, dynamic programming.

**REFERENCES:**

1. Optimization theory & Applications/ S.S Rao/ New Age International
2. Introductory to operation research/Kasan & Kumar/Springar
3. Optimization Techniques theory and practice / M.C Joshi, K.M Moudgalya/ Narosa Publications.
4. Operation Research/H.A. Taha/TMH
5. Optimization in operations research/R.L Rardin
6. Optimization Techniques/Benugundu & Chandraputla/Person Asia
7. Optimization Techniques /Benugundu & Chandraputla / Pearson Asia

# DYNAMICS OF MECHANICAL SYSTEMS

**MTCM 041** **L T P**
**3 0 0**

**Basic concepts:** Inertial coordinate system, fundamental laws of motion, mechanics of particles and system of particles, principles of linear and angular momentum, work-energy principles.

**Lagrangian dynamics:** Degrees of freedom, generalized coordinates and generalized forces, holonomic and non-holonomic constraints, Lagrange's equation from d'Alembert's principles, application of Lagrange's equation for conservative and non-conservative autonomous systems with holonomic and non-holonomic constraints, applications to systems with very small displacements and impulsive motion; Hamilton principle from d'Alembert's principle, Lagrange equation from Hamilton's principle.

**Multi-body dynamics:** Space and fixed body coordinate systems, coordinate transformation matrix, direction cosines, Euler angles, Euler parameters, finite and infinitesimal rotations, time derivatives of transformations matrices, angular velocity and acceleration vectors, equations of motion of multi-body system, Newton-Euler equations, planer kinematic and dynamic analysis, kinematic revolute joints, joint reaction forces, simple applications of planer systems.

**Stability of motion**: Fundamental concept in stability, autonomous systems and phase plane plots, Routh's criteria for stability, Liapunov's method, Liapunov's stability theorems, Liapunov's function to determine stability of the system.

**Control system dynamics:** Open and close loop systems, block diagrams, transfer functions and characteristics equations, proportional integral and derivative control actions and their characteristics.

**Books:**


1. Ginsberg, J.H., "Advanced Engineering Dynamics", Harper and Row.
2. Meirovitch, L., "Methods of Analytical Dynamics", McGraw Hill Inc.
3. Harold Josephs and Ronald Huston, "Dynamics of Mechanical Systems", CRC Press.
4. Katsuhiko Ogata, "System Dynamics",4th Ed., Prentice Hall.
5. Robert L. Woods and Kent L. Lawrence, "Modeling and Simulation of Dynamic Systems", Prentice Hall.
6. Ramin S. Esfandiari and Bei Lu, "Modeling and Analysis of Dynamic Systems", CRC Press.
7. Dean C. Karnopp, Donald L. Margolis, and Ronald C. Rosenberg, "System Dynamics: Modeling and Simulation of Mechatronic Systems", 4th Ed., Wiley.

# ADVANCED MACHINE DESIGN

**MTCM 042** **L T P**
**3 0 0**

**Introduction:** Review of failure theories, their scope of applications under different loading and environmental conditions, Hertzian contact stresses and their effect on load carrying capacities of members, effect of small inelastic strains and residual stresses on load carrying capacity, theory of limit design; Machinery construction principles.

**Designing against Fracture:** Linear elastic fracture mechanics approach, theories of brittle fracture, fundamental aspects of crack growth and fractures, use of fracture in design.

**Designing against Fatigue and Creep:** Causes and interpretation of failures, influence of various factors, low cycle and high cycle fatigue, cumulative damage theories, acoustical and thermal fatigue, corrosion and fretting fatigue, pitting of gears, fatigue strength of joints, components and structures; creep behavior; the mechanical equation of state, an elastic and plastic creep, rupture theory, analysis of tensile creep data, creep in high temperature low cycle fatigue, creep analysis of thick walled cylinders and rotating discs.

**Design for Reliability:** Application of statistics to material properties, fatigue and reliability, early chance and wear out failures, reliability prediction against chance and wear out failures, probabilistic approach to design and its comparison with safety factor approach, reliability prediction of series, parallel and stand by systems.

**Books:**


1. Faupel, J.H., and Fisher, F.E., “Engineering Design”, Wiley-Interscience.
2. Burr, A.H., “Mechanical Analysis and Design”, Elsevier.
3. Smith, N., “Advances in Creep Design”, Applied Science.
4. Bazovsky, I., Reliability Theory & Practice, Courier Dover Publications.
5. Haugen, E.B., Probabilistic Approach Design, John Wiley.
6. Yotaro Hatamura and Yoshio Yamamoto, “The Practice of Machine Design” Oxford University Press.

# MECHANICS OF COMPOSITE MATERIALS

**MTCM 043** **L T P**
**3 0 0**

**Introduction:** Composite materials, characteristics, classification, advantages and typical problems.

**Unidirectional Lamina:** Introduction, longitudinal strength and stiffness, transverse strength and stiffness, failure modes, thermal expansion and transport properties.

**Short Fibre Composites**: Theories of stress transfer, modulus and strength of short fibre composites.

**Analysis of an Orthotropic Lamina:** Hook's law, stress-strain relation for lamina with an arbitrary orientation, strength of a lamina subjected to biaxial stress field.

**Analysis of Laminated Composites**: Classical lamination theory, thermal stress in laminates.

**Special Design Considerations:** Analysis after initial failure, inter-laminar stress, free edge effect, design of joints, elementary fracture mechanics concepts related to composite materials.

**Experimental Characterization:** Uni-axial tension test, compression test, inplane shear test, three and four point bending test, determination of interlaminar shear strength.

**Books:**


1. Agarwal, B.D. and Broutman, L.J., "Analysis and Performance of Fibre Composites", 3rd Ed., John Wiley & Sons.
2. Jones, R.M., "Mechanics of Composite Materials", Taylor & Francis.
3. Ashbee, K.H.G. and Ashbee, H.G., "Fundamental Principles of Fibre Reinforced Composites", 2nd Ed., CRC Press.
4. Daniel, I.M. and Ishai, O., "Engineering Mechanics of Composite Materials", 2nd Ed., Oxford University Press.
5. Christensen, R.M., "Mechanics of Composite Materials", Dover Publications.
6. Kaw, A. K., "Mechanics of Composite Materials", 2nd Ed., CRC Press.

## ELECTIVE V

## FLEXIBLE MANUFACTURING SYSTEMS

**MTME 051** **L T P**
**3 0 0**

**Flexibility And Automation**: Flexibility and automation, different types of flexibilities in manufacturing, volume variety relationships for understanding manufacturing systems, different types of FMS, building blocks of flexible manufacturing systems; work stations, storage retrieved systems, material handling systems and computer control system. Machining of FMS; Horizontal & vertical matching centers. Automatic storage and retrieved systems, FMS Control Systems.

**Group Technology And Cellular Manufacturing**: Part families formation, Selection of classifications and Coding Systems, production flow analysis, Cellular Manufacturing Computer aided process planning.

**Layout**: Layout consideration for flexible manufacturing, scheduling of flexible manufacturing systems.

**Fms Simulation**: Future developments in FMS, case studies on FMS.

**Books:**


1. Systems Approach to Computer Integrated Design and Manufacturing Automation, Production Systems – Nanua Singh
2. Automation, Production Systems and Computer Integrated Manufacturing – M.P.Groover
3. Flexible Manufacturing Systems – R.A. Maleki
4. Hand Book of Flexibile Manufacturing Systems – Nand K. Jha.

## ROBOTICS AND CONTROL

**MTCM 051** **L T P**
**3 0 0**

**Introduction:** Definition, Structure, Classification and Specifications of Robots, Industrial Robots.

**Robot Elements and Control:** Manipulators, Drives, Sensors, End Effectors, Configuration, Force/Torque Relationship, Trajectory Planning, Position Control, Feedback System, Digital Control

**Modeling of Robots:** Coordinate Frames, Mapping and Transformation; Direct Kinematic Model; Inverse Kinematics; Manipulator Differential Motion; Static Analysis; Jacobian **Manipulator Dynamics:** Acceleration of a rigid body, mass distribution, Newtons equation, iterative Newton Euler dynamic formulation, Lagrangian formulation of manipulator dynamics, Bond graph modeling of manipulators, Trajectory Planning.

**Linear and Non Linear Control of Manipulators:** control law partitioning, trajectory following control, multi input multi output control systems, Cartesian based control scheme.

**Force Control of manipulators:** hybrid position/force control

**Robot Programming:** Robot Programming for Manufacturing and Other Applications, Robot Integration with CAD and CAM.

**Books:**


1. Introduction to robotics: Mechanics & Control, Craig John J, Addison- Wesley.
2. Introduction to Robotics: Analysis, Systems, Applications, Niku Saeed B, PHI, New Delhi.
3. Fundamentals of Robotics Analysis and Control, Schilling R. J., Prentice Hall Inc.
4. Robotics and Control, Mittal R. K. and Nagrath I. J., Tata McGraw Hill.
5. Robotics: Fundamental Concepts and Analysis, Ghosal Ashitava, Oxford University Press.
6. Intelligent Mechatronic Systems: Modeling, Control and Diagnosis, Merzouki R., Samantaray A. K., Pathak P.M., Bouamama B. Ould, Springer.

## ADDITIVE MANUFACTURING & TOOLING

**MTME 053** **L T P**
**3 0 0**

Classification of additive manufacturing (AM) processes. AM based rapid prototyping (RP) Systems like Stereo-lithography, Fused Deposition Modeling (FDM), Selective Laser Sintering (SLS), Laminated Object Manufacturing (LOM), 3-D Printing, LENS etc.

Role of additive manufacturing and rapid prototyping in product design and development. Solid modeling techniques for additive manufacturing with comparison, advantages and disadvantages. Process planning for rapid prototyping, STL file generation Defects in STL files and repairing algorithms, Slicing and various slicing procedures.

Accuracy issues in additive manufacturing, Properties of metallic and nonmetallic additive manufactured surfaces, Stress induced in additive manufacturing (AM) processes. Surface roughness problem in rapid prototyping, Part deposition orientation and issues like accuracy, surface finish, build time, support structure, cost etc.,

Rapid tooling techniques such as laminated metallic tooling, direct metal laser sintering, vacuum casting etc.

**Books**:


1. Chua, C.K., Leong, K.F., Rapid Prototyping: Principles and Applications in Manufacturing, John Wiley and Sons Inc.
2. Pham, D.T., Demov, S.S., Rapid Manufacturing: The Technologies and Applications of Rapid Prototyping and Rapid Tooling, Springer- Verlag London Limited.
3. Hopkinson, N., Hague, R.J.M. and Dickens, P.M., Rapid Manufacturing and Industrial Revolution for the Digital Age, John Wiley and Sons Ltd, Chichester.
4. Gebhardt, A., Rapid Prototyping, Hanser Gardner Publications, Inc., Cincinnati
5. Noorani, R., Rapid Prototyping: Principles and Applications, John Wiley & Sons, Inc., New Jersey.
6. Gibson, I., Software Solutions for Rapid Prototyping, Professional Engineering Publication Ltd
7. Patri, K. V., and Weiyin, Ma, Rapid Prototyping – Laserbased and Other Technologies, Kluwer Academic Publishers, U.S.A.
8. Mortenson, M.E., Geometric Modelling, John Wiley and Sons, Inc.
9. Saxena, A., Sahay, B., Computer Aided Engineering Design, Anamaya Publishers, New Delhi.
10. Zeid, I., Mastering CAD/CAM, Tata McCraw Hill.

## MANUFACTURING SYSTEM ANALYSIS

**MTCM 052** **L T P**
**3 0 0**

**Introduction:** Definitions of manufacturing with input-output model, definition of system, basic problems concerning systems and system design procedure, modes of manufacturing – job/batch/flow and multi-product, small batch manufacturing.

**System Modeling Issues**: Centralized versus distributed control; Real-time vs. discrete event control; Forward vs. backward scheduling approaches with finite/infinite capacity loading; Modeling of absorbing states and deadlocks; Conflicts; Concurrency, and synchronization etc.

**System Modeling Tools and Techniques:** Introduction to mathematical modeling, optimization, and simulation; Issues related with deterministic and stochastic models; Continuous and discrete mathematical modeling methods - discrete event, monte carlo method; Basic concepts of Markov chains and processes; The M/M/1 and M/M/m queue; Models of manufacturing systems - including transfer lines and flexible manufacturing systems, introduction to Petri nets.

**Performance Analysis:** Transient analysis of manufacturing systems, analysis of a flexible machining center; Product flow analysis; Rank order clustering; Process flow charting; MRPI & II, kanban, OPT, JIT-pull and JIT-push, line of balance, effects of machine failure, set-ups, and other disruptions on system performance; Calculation of performance measures - throughput, in-process inventory, due dates, MTL, capacity, and machine utilization etc.; Critique of high inventory, long lead time systems; Shop floor control issues.

**Books**:


1. Modeling and Analysis of Manufacturing Systems Askin, R. G., and Standridge, C. R., John Wiley & Sons.
2. Manufacturing Systems Engineering, Gershwin, S., Prentice-Hall.
3. Manufacturing Systems Engineering, Hitomi, K., Taylor & Francis.
4. Performance Modeling of Automated Manufacturing Systems, Viswanadham N. and Narahari Y., Prentice-Hall.
5. Factory Physics : Foundation of Manufacturing Management, Hopp, W. J., and Spearman, M. L., McGraw Hill.