Latin lesson plan
:Advanced Mathematics (I)
1) Complex functions 2) Variational calculus 3) Sturm-Lioville equations and eigen value and eigen function analysis 4) Partial differential equations of different types 5) Fourier and Laplace transform and their applications 6) Greens functions and their applications 7) Orthogonal and orthonormal functions and their applications and basics of functional analysis
: Seminar
: 1) Proposal 2) Scientific Papers 3) Research Method 4) Endnote 5) Thesis Writing

لاتین
: Hydrodynamic Instability
: 1) Traditional perturbation method 2) Homotopy perturbation method 3) Instability analysis 4) Rayleigh instability analysis 5) Orr-Sommerfeld instability analysis 6) Coeutte-Taylor instability analysis 7) Plane Poiseuille instability analysis 8) Energy gradient method 9) Review of the recent publications on instability analysis 10) Plane jet instability analysis
: Two Phase Gas-Solid Flow
: 1) Introduction: Multiphase Flow, Classification of Multiphase flows, Flow Regimes and Flow pattern maps, volume fraction, mass velocity, superficial velocity, non-dimensional numbers. 2) Local Instantaneous Governing Equations: Conservation laws and jump conditions at phase interfaces 3) Averaging of Governing Equations: Different averaging methods, Volume averaging , the mathematical operation on averaged fields, Volume average Governing Equations, 4) Mixture Model: Application and restrictions,One-Fluid formulation, Mixture Properties, Drift velocity and drag force, slurry and nanofluid models, Mixture model in FLUENT 5) Eluerian method: Two-fluid model, Phase interaction, Drag, Lift, Virtual mass, Wall lubrication, Surface tension, Turbulent dispersion,Interfacial Area Reconstruction, Two fluid model in FLUENT 6) VOF: Volume fraction equation, Doner-Accepter method, CICSAM Method, Graphical method, Free surface flows, VOF in FLUENT
: **Two Phase Gas-Solid Flow**
: 1) Introduction

2) Key concepts of multiphase flows
3) Gas-liquid flows in circular conduits
4) Solid-liquid flows in conduits
5) Governing equations - Eulerian approaches
6) Averaged equations
7) Numerical simulation - Eulerian approaches
8) Key concepts – particles
9) Governing equations - Lagrangian approaches
10) Fluid-particle interactions
11) Particle-particle interactions
12) Particle boundary conditions

: Non-Newtonian Fluid Mechanics

:

1) FundamentalsRheology, A historical background, Newtonian Fluid, Hookean Solid, Non-Newtonian Fluid, General classification of non-Newtonian behavior, Some Examples of non-Newtonian behavior, An introduction to viscoelasticity: Stress relaxation, Creep and recovery
2) A brief review of continuum mechanics (1): Tensor Notation, Stress, Strain, Configuration and displacement, Velocity Gradient tensor, Rate of Deformation Tensor, Shear rate
3) Governing Equations of fluid flow: Continuity equation, Cauchys Flow Equation, Navier-Stokes Equations,Cylindrical and Spherical Coordinates, Constitutive equations
4) Material Functions, Viscosity and standard flows in Rheolog: Viscosity, First and second normal stress difference, Simple shear flow, Shear free flows, Steady and Transient Material Functions
5) Viscometry: Cone and plate viscometer, Parallel plate viscometer, Capillary viscometer, Rotational Couette viscometer
6) Generalized Newtonian Fluids (GNF): Definition, Shear thinning, Shear Thickening, Apparant viscosity and viscosity function, Power-law fluid, Carrue-Yasuda fluid, Cross fluid, Gravitational flow of power-law fluid, Non-isohermal flow of GNF fluids
7) Viscoplasticity: Yield phenomenon in fluids, Measuring Yield stress, Bingham model, Casson model, HB model, Flow in circular pipes, Transition to turbulent, Turbulent pipe flow of time independent fluids, Regularization concept, Variational methods
8) Linear Viscoelasticity (1): Fading memory and elastic behavior, Relaxation time and Deborah number, Stress relaxation, Creep and recovery, LASOS
Linear Viscoelasticity (2): Mechanical models, Spring and dash-pot element, Maxwell Fluid, Jeffereys fluid, Generalized Maxwell Model and its material functions, Integral models, Generalized Viscoelastic model, Memory function,Relaxation function
9) Non linear viscoelasticity: Limitations of linear viscoelastic models, Frame invarince and objectivity, Infinity small strain tensor, Finite strain tensor, Polar decomposition, Finger and Cauchy strain tensor
Non-linear Viscoelasticity (2): Cauchy and finger strain tensors in solid body rotation, Finite strain tensor in simple shear and shear free flows, Lodge integral model and its behavior in shear and elongation
Non linear Viscoelasticity (3): Convected Derivates, UCM fluid and its b

: Advanced Heat Transfer (Conduction)

:

1) Foundations of Heat Transfer- Formulation (Lumped, Integral and Differential Formulations)
2) Steady One-Dimensional Problems
3) Steady Two- and Three-Dimensional Problems
4) Unsteady Problems

: Advanced Heat Transfer (Radiation)

1) Definition of black body, black body radiation, Planks distribution function,definition of non black

body radiation,Relations between radiation parameters
2) Electromagnetic theory of radiation properties,prediction of thermal radiation properties by electromagnetic wave propagation, radiation in an enclosed surface
3) Radiation between small elements, shape factor in radiation, calculation of shape factor between different surfaces, methods of shape factor calculation
4) Radiation between diffuse and non gray surfaces
5) Radiation between non diffuse and non gray surfaces, application of Monte Carlo method in thermal radiation
6) Combine radiation and conduction or convection, basic principles of emission and absorption of radiation by solid and gases
7) Extinction of radiation in participating media, thermal radiation properties of participating media
8) Equation of transfer in participating media with absorption and emission
9) Gray gas definition, approximate solution methods of equation of transfer
10) Net radiation method for enclosure filled with isothermal gas
11) Calculation of mean absorption and transmission coefficient for all wavelength, mean beam length for different geometries
12) Radiation heat transfer between gas and enclosure by use of mean beam length
13) Calculation of total radiation heat transfer by integration on all wavelengths
14) Radiation of non isotherm gas , use of Mote-Carlo method for absorbing and emitting gas
15) Consideration of radiation properties of matters, radiation heat transfer for non steady state conditions. Radiation heat transfer in medium with scattering and absorption

: Advanced Heat Transfer (Convection)

1) Chapter one: Fundamental Principles
2) Chapter two: Laminar Boundary Layer Flow
3) Chapter three: Laminar Duct Flow

: Numerical Simulation of Turbulent Flows

1) Introduction
2) The equations of fluid motion
3) Mean flow equations
4) Turbulence: a short review
5) Reynolds-Averaged-Numerical-Simulation (RANS)
6) Large Eddy Simulation (LES)
7) Spectral description, modeling, and simulation
8) An introduction to Probability Density Function (PDF) method

: Advanced Air Conditioning

1) Design of Steam piping
2) Design of heating and cooling panels
3) Design of CAV systems in airconditioning
4) Design of VAV systems in airconditioning
5) Building air simulation
6) Indoor air quality

: Advanced Fuel & Combustion

1) Introduction
2) Combustion thermodynamics
3) Combustion kinetics
4) Governing equations

5) Laminar premixed flames
6) Laminar diffusion flames
7) An Introduction to turbulent combustion

: Selected Topics-Numerical Optimization Methods

1) Introducing the class, evaluation process, topics and course structure
2) Review of selected linear algebra topics
3) Introducing and analysis of the optimality condition for various types of problem formulation
4) Classical optimization methods for various problems
5) Classical optimization methods for various problems (continued)
6) Modern optimization methods

: Turbulence

1- Introduction to turbulence
2- Introduction to the equations of motion
3- Averaging and reynolds stresses
4- Mean energy and turbulence
5- Looking statistically to mean energy and turbulence
6- Energy cascade
7- Lenghts and their relations
8- Measuring methods in turbulence
9- Modeling based on reynolds averaging
10- Modeling turbulence- prandtl
11- One equation K model
12- Two equation energy and dissipation modeling
13- Multi equations modeling
14- Coherent structure and direct method
15- Large eddy simulation model
16- Seminar and discussions

: Direct Energy Conversion

1) Introducing energy conversion and direct energy conversion
2) Crystalline structure of semiconductor materials, intrinsic and doped semiconductors ,statistics of electrons and holes
3) Solar cell, photoelectric effect,general consideration of solar cell, p-n junction (abrupt and gradual)
4) Calculations regarding efficiency of solar cells and parameters affecting the efficiency
5) Methods of solar cell fabrications
6) Thermoelectric energy conversion, thermoelectric effects and their relations
7) Thermoelectric generators and thermoelectric coolers
8) Calculation of performance of thermoelectric coolers and efficiency of thermoelectric generators
9) Optimization and considerations of properties change with temperature
10) General consideration of magnetohydrodynamics energy conversion and problems involve

: Advanced Fluid Mechanics

: Boundary Layers Theory

1- Understanding laminar and turbulent boundary layer phenomena and their mathematical modeling

: Advanced Measurement Method

1- Introduction
2- Definition of Terms (Readability, Sensitivity, Hysteresis, Accuracy, Calibration, ...)
3- The General Measurement System
4- Technical Report Writing
5- Analysis of Experimental Data (Analysis of Errors, Uncertainty Analysis, .Evaluation of Uncertainty for complicated Data, ...)
6- Flow Visualization Techniques (Qualitative Techniques, Quantitative Techniques, Global Flow Field Mapping Techniques, Aerodynamics, Wind Tunnel, Classification of Flow Visualization, Wall Tracing Method, Tuft Method, Direct Injection, Chemical Reaction Tracing, Optical Methods, ...)
7- Mechanical Measurement for Velocity and Flow Techniques (Popular Electro-Mechanical Devices)
8- Temperature Measurement (By Mechanical Effects, By Electrical Effects, ...)
9- Pressure Measurements (Mechanical and Electro-mechanical Devices, ...)
10- Special Topics
11- Scientific Field Trips during the Semester (one to three Trips if be possible)

: Power Plant Engineering Advanced Thermodynamics

: Computational Fluid Dynamics (CFD)

1- Introduction, an overview of CFD, brief introduction of finite difference
2- One dimensional linear wave equation
3- Modified equation
4- Stability and accuracy analysis
5- One dimensional nonlinear wave equation
6- Introduction to finite volume discretization
7- Higher order methods
8- Diffusion equation
9- Source term
10- Curvilinear grids
11- Midterm exam
12- Classification of partial differential equations
13- Methods for compressible flow
14- Incompressible fluid flow, pressure-velocity coupling
15- Unstructured grids
16- Advanced methods
17- Programming guidelines

: Compressible CFD

1- Governing equations of fluid motion for inviscid and viscous flows (continuity, momentum, energy PDE's and the equation of state); conservative and non-conservative forms of the governing PDE's and advantages of each
2- why for steady problems we choose unsteady solution algorithms!!; shock capturing and shock fitting solutions; rotational flow behind the bow shocks and the Crocco theorem
3- initial conditions, physical and numerical boundary conditions over the bodies at inflow or outflow boundaries; sub/super sonic inflow/outflow boundary conditions; boundary conditions for shock fitting problems
4- Types of the PDEs; elliptic, hyperbolic and parabolic PDEs; behavior of the equations in sub/super sonic problems
5- Continued: Types of the PDEs; elliptic, hyperbolic and parabolic PDEs; behavior of the

equations in sub/super sonic problems
6- Stability Analysis
7- Grid mapping to generalized coordinates
8- Deriving the governing equations in generalized coordinates
9- Solution to the equations in generalized coordinates using finite-difference method, and in physical coordinates using finite-volume method
10- Principles of upwinding, eigenvalues and the direction to propagating the information
11- Principles of the FDS and FVS schemes
12- Central and upwind numerical schemes like MacCormack,
13- Continued: L-W, Jameson, S-W, van Leer, Roe, AUSM,
14- Continued: MUSCL method in higher order spatial extrapolation, problems in high resolution schemes, TVD, flux limiter and ENO methods.
15- Projects (Hinting students with some of their 1D and 2D problems)- during the term

: Fuel Cell Systems

1- Energy cycle, Status of renewable of energies, and fuel cells, various applications of fuel cells
2- Fuel cell under reversible operation
3- Fuel cells under actual operations (containing the losses)
4- Principles of fuel cells designs, and flow field design basis
5- Fuel cell systems
6- Fuel cell lab

: Advanced Numerical Methods

1- Introduction Numerical methods and the art of problem solving in engineering, Programming and Software, Truncation error and Taylor series, Round of Error
2- Interpolation Lagrange Polynomial Interpolation, Cubic Spline Interpolation, Curve Fitting and Regression
3- Numerical Differentiation Finite Differencing Formulas and Taylor series, Pade Approximation, non-Uniform Grids
4- Numerical Integration Trapezoidal and Simpson's Rules, Romberg Integration and Adaptive Quadrature, Gauss Quadrature, Improper and Multiple Integrals
5- Numerical Solution of ODEs Initial Value Problems and Euler methods, Numerical Stability, Runge–Kutta Methods, Stiffness and Multi-Step Methods, System of ODEs, Boundary Value Problems
6- Root Finding Bisection method, False-position method, Newton-Raphson method, Polynomial root finding
7- Numerical Solution of PDEs Classification of Second Order PDEs, Elliptic PDEs: Discretization and Iterative methods, Parabolic PDEs: Implicit vs. Explicit, Stability Analysis
8- Special Functions Gamma and Beta Functions, Bessel Functions

: Hydro Power Plan

1- Water In nutral
2- Dams and hydraulic strucrtures
3- Turbomachineiy

: Advanced Hydraulics

: Advanced Gas Dynamics I

: Advanced Internal Combustion Engines

: ENERGY METHODS

1-General Concepts and Principle: of mechanics
2-Elastic Beams and Frames
3- Method of Calculus of Variations
4- Deformable Bodies
5- Theory of Plates and Shells
6- Hamilton s Principles and its Equations of Lagrange and Hamilton
7-Theory of vibrations

: Continuum Mechanics (I)

1- Introduction: Continuum Theory
2- The Indicial Notation
3- Vectors and Tensors
4- Transformation between Coordinate Systems
5- Tensors Calculus
6- Kinematics of a Continuum
7- Strain Tensor
8- The Rate of Deformation Tensor and the Spin Tensor
9- Stress
10- Newtonian Viscous Fluid/ the Elastic Solid

: ENERGY METHODS

1- Basic facts about nonlinear systems
2- Time-dependent dynamical systems
3- Chaotic dynamics
4- Bifurcations of equilibria
5- Near equilibrium dynamics
6- Nonlinear dynamical systems on the plane

: Special Topics- Heat and Mass Transfer in Porous Media

: Special Topics- Biofluid Mechanics

: Parallel Processing Methods in Numerical Analysis

1- Introductory materials and history of parallel processing
2- Introduction to Linux
3- Processor architecture
4- Software considerations
5- Shared memory processing
6- Using OpenMP to implement computational algorithms on shared memory machines
7- Introduction to distributed memory machines
8- Using MPI to implement computational algorithms on distributed memory machines
9- Computational algorithms in parallel linear algebra
10- Class works (distributed in the semester)

: Special Topics- Micro-Nano-Fluidics

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: Advanced Computer Aided Design & Manufacturing

:

1) Introduction to CAD /CAM
2) Hardware and Sofware of a CAD System
3) Various Data Base and Data Structure
4) Product Data Exchange
5) Introduction to 3D Geometric Modelling
6) 3D Wire-Frame, Surface, Solid and Solid Surface Modelling
7) Introduction to Curve Equations
8) Cubic Spline, Hermit and Bezier Curves Equations
9) B-Spline and NURBS Curves Equations
10) Geometric Transformation
11) CAM and G-Code Generation
12) CNC Control Strategies
13) CAPP systems
14) Adaptive Control
15) Application of CAD/CAM in Rapid Prototyping and Rapid Tooling
16) Cubic Spline, Hermit and Bezier surface Equations
17) B-Spline and NURBS surface Equations
18) Improving the productivity of CNC machine tools
19) Computer aided design and manufacture of dies and molds

: Advanced Non Destructive Testing

:

: Advanced Heat Treatment

:

1) Introduction-applications of heat treatment processes
2) Study of nucleation and growth mechanisms of phases in metal- Example: review of age hardening
3) Austenite decomposition and its products
4) Investigation of mechanical properties of some selected steels in relation with their micro-structures
5) Study of effect of environmental conditions on mechanical properties of metal

: Grinding Technology

:

1) The grinding process- introduction
2) Grinding wheels: composition and properties
3) Wheel truing, dressing and topography
4) Grinding geometry and kinematics
5) creep feed grinding
6) Grinding mechanisms
7) Heat and Thermal damage
8) Cylindrical grinding
9) Surface texture and tolerance
10) Case studies----Student seminars

: SURFACE FINISHING TECHNIQUES

1) Surface Texture Analysis & Surface Integrity
2) Surface Roughness Measurement
3) Surface Finish Characterization
4) Material Removal Mechanisms
5) Barrel Finishing
6) Roller Burnishing
7) Grinding
8) Honing
9) Lapping
10) Polishing Electrochemical
11) Ion beam Polishing
12) Magnetic Abrasive Finishing
13) Magnetorheological finishing
14) Magnetic Fluid Finishing
15) Abrasive Flow Machining
16) Chemical Mechanical polishing
17) Chemical Mechanical polishing
18) Monitoring & Control of surface finishing processes

: Mechatronics (I)

1) What is Mechatronic
2) Pneumatic & Hydraulic Actuators
3) Final Project Description
4) PLC Programming
5) Sensors
6) Principles of Precision Eng
7) Virtual Instrumantaion

: Application of Finite Element in Manufacturing Engineering

1) Direct Finite Element Method
2) Elastic Plastic Analysis in Finite Element
3) Variational Finite Element method
4) Finite Element Modelling of Manufacturing and Production processes

: Design and Analysis of Multi-Stage Forming Tools

1) Differences between multistage and single stage forming processes
2) Classification of tooling setup in multi and single stage forming
3) Introduction of different multi-stage forming processes
4) Governing equations in multistage forming
5) Damage and wear in multistage forming
6) Fatigue and wear in multistage forming process
7) Fracture mechanics in multistage forming
8) multistage forming in extrusion process
9) Preform design using reverse velocity field in gear forming
10) Backward deformation of turbine disk forging

: Computer Aided Process Planning (C. a. P. P)

1) Computer Integrated Systems
2) Computer Aided Process Planing Systems
3) Logical Design of a process plan
4) Machining Accuracy

5) Interpretion of Engineering Drawings (Geometric , Dimensional Tolerances and Surface Roughness)
6) Tolerance Control
7) General Selection of Primary Production Process
8) Selecting detailed methods of production
9) How to select a machine for the job
10) The Selection of Depth of cut and Feedrate for Turning Operations
11) The Selection of cutting speed for Turning Operations
12) The Selection of cutting tool fot Turning Operations.)
13) Turning Operation (How to select Jig and Fixture)
14) Milling Operation
15) Hole Making Procedure
16) General Procedure of Process Planing

: MACHINE TOOL ELEMENTS & CONSTRUC. DESIGN

1) Design of Guide-ways and Power Screws
2) Design of Spindles and Spindle Supports
3) Calculation of Machining Power Requirements and Cutting Forces
4) Regulation of Speed and Feed Rate in Machine Tools
5) Design of Machine Tool Structure

: Machining & Tooling Systems

1) Basics of Production Management
2) Decision Making
3) Forecasting
4) Planning (Long range, Medium range and Short range planning)
5) Executing (Project, Purchasing and Inventory management)
6) Just-in-Time / Kanban
7) Quality Control (Quality Assurance, TQC and TQM)
8) Quality Control Tools
9) Continuous Improvement and Business Process Redesign

: Advanced Numerical Control Machines

1) Difference between old and new machine tools
2) Machine Power Unit
3) Speed Control Unit
4) Controlling Line of Movement
5) Tool/work Movement Mechanism
6) Tool/Work Holding Device
7) Linking Structure
8) Positional Transducer
9) Tool Monitoring
10) Controller, PLC, Adaptive control
11) Group Technology, Part family programming
12) Geometric & Parametric programming
13) Preventive Maintenance

: Welding

1) Introduction
2) Welding processes-a
3) Material engineering

4) Weld defects
5) Weldability
6) Welding processes-b
7) Welding processes-c
8) Weld inspection
9) Welding residual stresses
10) Welding distortions
11) FEM analysis in welding
12) Design of welds
13) Welding WPS
14) Brazing
15) Materail testing of welds

: Metallurgical Manufacturing Processing

1) Steels Microstructure &Properties; Honey Comb R.W
2)
3)
4)
5) anisotropy
6)
7) fracture toughness
8)
9)
10)
11)
12) Microstracture-perperties correlation of dual phase steels, Thermo-mechanical & Heat Treatment Process

: Metal Forming

1) Metal Forming Concepts, Anisotropy
2) Mechanical Behavior, Super Plasticity
   Metallurgy of Metal Working Process: Rolling, Forging, Extrusion, Drawing & Sheet Forming, Friction & Lubrication
3) Metallurgy of Metal Working Process: Rolling, Forging, Extrusion, Drawing & Sheet Forming, Friction & Lubrication
4) Thermo-mechanical Process
5) Slab Method Analysis
6) Drawing

: Machine Tool Control & Test Systems

1) References: VDI/VGQ 3441 VDI/VDE 2617 part 3 International Standard ISO 230- part 1 to 5 International Standard ISO 10791-1,3,4,5,6,7 ISO/TC 39/SC2/WG3 BS4656-38 BS 3800-3
2) Machine Tools Testing and their Quality Control 1- Introduction 1.1- Factors affecting product quality Human Errors (this is decreasing by further automation) Machine Errors Material inconsistencies Manufacturing method and procedure
3) mbient conditions (Temp.; Pres.; humidity; Magnetic, Electrical and electromagnetic Emissions; coolant; etc.)(better condition monitoring and compensations and also more perfection in protections are reducing the influences) Clamping and fixing of the tool and workpiece Tool preset and tool wear…. 1.2-What is Machine Tool Calibration? 1.3-Why measure machine performance? 1.4-Statistics
4) mbient conditions (Temp.; Pres.; humidity; Magnetic, Electrical and electromagnetic Emissions; coolant; etc.)(better condition monitoring and compensations and also more perfection in protections are

reducing the influences) Clamping and fixing of the tool and workpiece Tool preset and tool wear
5) 1.2-What is Machine Tool Calibration? 1.3-Why measure machine performance? 1.4-Statistics ….
6) 1.2-What is Machine Tool Calibration? 1.3-Why measure machine performance? 1.4-Statistics ….
7) 2.1.2-Controller Errors: Hysteresis Servo mismatch Stick-Slip Feed rate Reversal spikes.
8) 2.3- Environment 2.4-Geometry 2.5-Structure 2.6-Dynamic Behavior of Machine 2.7-Human Factors.
9) 3- Machine Tool Testing Methods: 3.1-Static (No load or no process). 3.1.1-Positional
10) 3.1.1.1-Linear axis positioning - Direct old Method using length bar, dial indicator, slip gage & rotation stop plate on screw - Indirect old Method using length bar, dial Indicator, slip gage & rotation stop plate on spindle - Microscope & Scale - Michelson Laser Interferometer (e.g. Renishaw) - Two frequency Laser Interferometer (e.g. HP)
11) 3.1.1.1-Linear axis positioning - Direct old Method using length bar, dial indicator, slip gage & rotation stop plate on screw - Indirect old Method using length bar, dial Indicator, slip gage & rotation stop plate on spindle
12) - Microscope & Scale - Michelson Laser Interferometer (e.g. Renishaw) - Two frequency Laser Interferometer (e.g. HP)
13) 3.1.1.2-Indexing or interpolating rotary axis positioning - Auto collimator & precision polygon - Laser straighter & precision polygon - Renishaw laser, angular reflector & Precision rotary table - Precision electronic level & precision rotary table.
14) 3.1.2-Geometrical 3.1.2.1- Out of straightness of guides & motions 3.1.2.2- Angular deviations of straight motions 3.1.2.3- Out of flatness of tables 3.1.2.4- Out of alignment 3.1.2.5- Out of co-axiality
15) 3.1.2.6- Out of parallelism 3.1.2.7- Out of squareness 3.1.2.8- Bed torsion 3.1.2.9- Axial play of spindle, center or rotary table 3.1.2.10- Run out of spindle, centre or rotary table
16) 3.1.2.11- Caming of spindle or rotary table 3.1.2.12- Spindle cone run-out and angular deviations 3.1.2.13- Angular play 3.1.2.14- Leveling
17) 3.2- Dynamic (Loaded or in process) 3.2.1-On-Line 3.2.1.1-Simulation of operation by static or dynamic load or by motion - Deflection under force and/or torque
18) - Induced vibrations - Dynamic geometrical simulation - Double ball bar of Telescopic LVDT or scale type (Renishaw or Heidenhain) - Laser ball bar (Optodyne) - Stanimuc Method
19) 3.2.1.2-Actual operation - Repeatabilities in x, y & z directions: a- Tool change b- Spindle head change c- Tool adaptor change
20) d- Workpiece change e- Workpiece adaptor or pallet change f- Tool measuring probe g- Workpiece measuring probe …
21) - Deflections measurement under force and/or torque - Vibrations a- Under no load while machine is on b- Under load of operation
22) - Noise a- Under no load while machine is on b- Under load of operation
23) - Feed rate a- Linear axis b- Rotary axis
24) - Feed acceleration and deceleration a- Linear axis b- Rotary axis - Spindle speed -Spindle acceleration and deceleration
25) -Field emissions a- Magnetic b- Electromagnetic c- Electric -Dust and particle generation
26) -Fume and chemical gas or vapor generation -Liquid and solid chemical residues -Dry run repeat cycles at least for 8 hours -Power test -Safety and limit switches operation
27) -Machine response to any failure 3.2.2-Off-Line 3.2.2.1- NAS test
28) 3.2.2.2- Test Machined Part - Flatness - Roundness – Cylindercity
29) - Screwing - Parallelism 3.2.2.3- Actual Part Machined
30) Measuring Equipment Metrological Requirements

: Electrophysical Processess

1) References: Morgan Piezoelectric Tamura Piezoelectric Vibration Theory Ultrasonic Engineering and Applications
2) Electro-strictive Transducers Magneto-strictive Transducers Nontraditional Manufacturing Processes Advanced Machining Methods Electro-chemical Machining
3) ULTRASONIC TRANSDUCERS THEORY AND APPLICATIONS: Introduction Waves History of Ultrasonic Vibration of Simple Discrete Mechanical Systems
4) Equivalent Electrical Oscillating Systems Mechanical- Electrical Power of the systems Power

Balance in a Continuous System without loss Power Balance in a
5) Sound Pressure Level and Intensity Level Electrical and Mechanical Theories of Ultrasonic Transducers and attachments Equation of vibration in transmitters Cylindrical Transmitters
6) Cylindrical Transmitters Step Transmitters Exponential Transmitters Conical Transmitters

7) Theory of Magnetic systems Design of Ultrasonic magneto-strictive transducers Piezoelectric Properties, behaviors as sensor and actuator Piezoelectric Parameters
8) Effects of heat on Piezoelectric Properties Efficiency of Piezoelectric s as sensor and actuator Equivalent electrical elements for a continuous piezoelectric rod, Vibrating at resonance frequency Design of Ultrasonic electro-strictive transducers

: Sheet Metal Forming Analysis

1) Different sheet metal forming processes
2) plasticity: plastic work , Tensile unstability
3) plasticity: Yield criteria
4) Analysis of Bend process- Spring back in bending
5) Bending under Tension, Bending & Unbending
6) Membrane Analysis in deep drawing
7) Analysis of deep drawing process
8) Elastic wrinkling of sheet metal in deep drawing process
9) Plastic wrinkling of sheet metal in deep drawing process
10) Analysis of hydro bulging
11) Analysis of stretch forming/ hole expansion
12) Analysis of hydro Forming
13) Using the FEM in Sheet Metal forming analysis
14) Sheet Metal formability study
15) FLD Theoretical & experimental determination of FLD

: Metal Forming Analysis

1) Different Bulk metal forming processes
2) Stress states, Strain & flow rules
3) Yield criteria,Constitutive equations, strain hardening & … Mechanical properties
4) Ideal work Analysis in metal forming (extrusion & wire drawing)
5) Slab Analysis method,: sheet drawing
6) Application of Slab Analysis in Wire drawing & Forging
7) Application of Slab Analysis in sheet rolling
8) (Upper Bound Method (UBM)
9) Application of UBM in extrusion & forging
10) Slip line field Methods
11) Application of Slip line field Method in Extrusion & Forging
12) Drawing of Slip Line Field
13) Finite element Method (preface)
14) Application of FEM in metal forming Analysis

: Metal Coating

1- Principles of corrosion in metals and methods of preventing
2- Met5allic Coatings
3- Nonmetallic coating
4- Methods of testing of coatings

: Automation in Production

1- Modeling and design of the components of a servo mechanism
2- Industrial actuators and sensors
3- PLC
4- Types of industrial robots
5- Strategies and technologies of industrial automation
6- Implementation of an automation cell with the laboratory equipments

: Advanced Hydraulics & Pneumatics

1- Introduction
2- Applications, and Concepts
3- An Introduction to Fluid Properties
4- Hydraulic Pumps
5- Hydrostatic Actuation
6- Pump-Controlled Hydraulic Systems
7- Hydraulic Control Valves
8- Hydraulic Control Systems

: Creep, Fatigue & Fracture

1- Creep Analysis in solid objects
2- Creep Analysis in pipes
3- Creep Analysis in vessels
4- Fatigue is solids
5- Fatigue in structures
6- Fatigue in pipes
7- Fracture in solids
8- Brittle fracture
9- Ductile Fracture
10- Finite Element Modelling of Creep, Fatigue and Fracture

: ADVANCED ROBOTICS

1- Introduction
2- Spatial Descriptions and Transformations
3- Kinematics; Forward & Inverse
4- Jacobians: Velocities and Static Forces
5- Dynamics
6- Trajectory Generation & Path Planning
7- Position Control
8- Force Control

: Selected Topics-Micro Eletromechanical Systems

1- Introduction: What is MEMS, History of MEMS
2- Introduction: MEMS Applications, MEMS Market, MEMS Design Methodology, Overview of MEMS Processes, Properties of Silicon, Materials
3- Microfabrication: Photolithography
4- Microfabrication: X-ray and E-beam Lithography, Etching
5- Microfabrication: Surface Micromachining, PVD, CVD, MUMPS
6- Microfabrication: Bulk Micromachining
7- Setup for Course Projects
8- Microfabrication: LIGA, CMOS

9- Clean Rooms, Safety Rules, Fire, Toxicity, Acids and Basis
10- Review of Essential Electrical and Mechanical Concepts
11- Scaling Effects4 (pp. 535-579) • Mechanical Resonance, Electrostatics, Electromagnetic Actuators, Applications
12- Electrostatic and Magnetic Sensors and Actuators
13- Thermal Sensors and Actuators
14- Thermal Sensors and Actuators

: Fracture Mechanics

1- Introduction
2- General aspects
3-Theoretical bases
4-Theoretical bases
5-Linear elastic fracture mechanics
6-Nonlinear fracture mechanic
7- ...

: Artificial Intelligence & Expert Systems

: Engineering of Nuclear Power Plants

1- Other related issues in NPP engineering
2- Student projects
3- Fundamentals in NPP
4- Light water NPP
5- Other types NPP
6- Fuels and waste Management
7- NPP in the world
8- General
9- Heavy water NPP
10- Safety issues in NPP
11- Safety analyses in NPP
12- Introduction to fabrication of reactors

: Special Topics (Stress-Analysis & Design of Welded Structures)

1- Fundamental of structural design
2- Stress analysis-1
3- Stress analysis-2
4- Weld design for static loads
5- Weld design for fatigue loads-1
6- Weld design for fatigue loads-2
7- Fracture analysis of welded structure
8- Design of welds of resistance welding
9- Simulation of weld processes
10- Student projects
11- General views
12- Stress analysis-3

:

: Advanced Heat Transfer in WeldingEngineering

1- Introduction to energy conservation law and heat transfer
2- Heat transfer equation and normalization techniques
3- Heat conduction transfer in weld joint
4- Investigation of temperature distribution in electric arc
5- Solution by separation of variables
6- Solution by laplace transform
7- Solution by approximate method
8- Solution by perturbation method
9- Solution by lamped method
10- Phase change problem and finding temperature distribution around the heat source
11- Numerical solution
12- Finite element method
13- Fundamental of heat convection in weld area
14- Empirical equations in heat convection and their use in weld area
15- Radiation transfer in welding
16- Heat exchange between grey bodied

: Inspection & Quality Control in Welding

1- Overview - NDT/NDE methods - Imperfections and defects - Destructive testing - Acceptance criteria - Inspection and test plan
2- Visual inspection of welds - Introduction - Welding inspection personnel - Condition for visual inspection - Visual inspection duties
3- Weld defects and causes - Weld technique - Weld geometry, shape and dimensions - Cavities - Cracks - Solid inclusions - Lack of fusion or penetration
4- Weld acceptance criteria
5- Advanced methods of weld assessment

: Welding

1) Introduction
2) Welding processes-a
3) Material engineering
4) Weld defects
5) Weldability
6) Welding processes-b
7) Welding processes-c
8) Weld inspection
9) Welding residual stresses
10) Welding distortions
11) FEM analysis in welding
12) Design of welds
13) Welding WPS
14) Brazing
15) Materail testing of welds

: Special Topics (Residual Stresses & Deformations Due to Welding)

: Advanced Mathematics (I)

1- Delta function Greens function Application of Greens function in differential equations Calculus of variation Problems with fix boundaries Problems with moving boundaries Problems with corner

Conditional functional Direct methods Orthogonal functions Transformations Application of transformations

: ADVANCED ROBOTICS

1- Introduction to robots
2- robots applications
3- robots kinematics
4- robots dynamics
5- path planning
6- robot control
7- senors in robotics

: Composite Technology, Forming Processes & Lab

1- PART 1—FUNDAMENTALS OF CONSTITUENTS FOR COMPOSITES MANUFACTURING. Introduction Examples of Products Made Using Different Manufacturing Techniques General Characteristics of Manufacturing Using Composites Functions of the Constituents of Composites. Matrix Materials. Introduction Different types of Matrix Materials and Their Prominence Thermoset Matrix Materials Thermoplastic Matrix Fillers, Colorants and Other Resin Modifiers Ceramic Matrices Metal Matrix
2- . Reinforcements—Fibers. General Individual Filaments Tows Fabrics and Other Reinforcement Forms Deformation of a Bed of Fibers
3- Part 2—TECHNIQUES FOR COMPOSITES MANUFACTURING. Hand Laminating (or Wet Lay-up) and the Autoclave Processing of Composites Hand Laminating (or Wet Lay-Up) Autoclave Processin
4-Filament Winding and Fiber Placement Filament Winding Fiber Placement Process
5-. Pultrusion General Materials Combination of Other Processes with Pultrusion Factors Affecting the Pultrudability of a Composite Component
6-. Liquid Composite Molding Introduction Materials Mold Filling In-Mold Cure
7-. Long Fiber Thermoplastic Matrix Composites. Introduction Materials Preliminary Material Combinations (PMCs) Fabrication of the Final Product
8- Lab reports

: Special Topics- Mechanics of Cellular Solids

1- intoduction to cellular solids
2- Structure of cellular solids
3- Mechanics of Honeycombs
4- Introduction to Foams and their properties
5- Mechanics of Foams
6- Strain rate, temperature and anisotropy effects
7- Energy absorption in foams
8- Strain rate, temperature and anisotropy effects
9- Fracture mechanics in foams
10- Finite element modelling of foams
11- Design and properties of sandwich structures
12- Chancellous Bone

: Special Topics (Dynamics of Structures)

1- Introduction: getting to know to structural dynamics problem
2- Review of vibrations of continuous systems
3- Eigenvalue and mode shapes solving algorithms
4- Damping in Structural Dynamics

5- Analysis of Forced vibration response (temporal or time) in multi-degree and continuous system
6- Analysis of frequency response in multi-degree and continuous system
7- Analysis of accidental vibration response in multi-degree and continuous system
8- Use modal analysis, forced

: Continuum Mechanics (I)

1- Analysis of Cartesian tensors
2- Kinematics of deform-able bodies
3- Deformation measures
4- Conservation Laws
5- Constitutive equations
6- Fundamentals of fluid mechanics
7- General rigid body motion
8- Transformation of frames

: Robust Control

1- An overview on Classical Control
2- An overview on Linear algebra and Linear systems
3- Norms and H2 and H? Spaces
4- Basic Concepts
5- Performance Specification and Limitations
6- Uncertainty and Robustness
7- m and m Synthesis
8- Controller Parametrization
9- Algebraic Riccati equation
10- H2 and LQ optimal control
11- H? control
12- Design Example

: Mechanics of Heterogeneous Materials

1- (Linear Elasticity (Kinematics, Force, Material Behavior and Geometry
2- Constitutive Equations
3- Principle of Minimum Complementary Potential Energy
4- Homogenization a la Hill
5- Classical Reuss and Voigt Bounds
6- Duality Transformation
7- Strain Concentration Tensor
8- Rank-1 laminates and their applications
9- Eshelby Inclusion Problem
10- Applications of Eshelby Solution
11- (Differential Scheme (or Iterated Homogenization
12- Hashin-Schtrikman Variational Principle
13- Thermoelastic Response of a Composit

: Advanced Numerical Methods

1- An introduction to numerical methods- error analysis
2- Non-linear algebraic equations methods (general eq)
3- Non-linear algebraic equations methods (polynomial eq)
4- System of linear and nonlinear equations plus eigenvalue problems direct and iterative methods
5- Interpolation and extrapolation methods (Spline – Bezier – B-spline - Least squares)
6- Interpolation and extrapolation polynomials (Newtonian and Lagrangian)

7- Numerical integration and differentiation first and higher order estimates
8- Numerical integration using approximate functions + composite integration formulas
9- Numerical integration using Gaussian quadratures
10- Numerical solutions for ordinary differential equations (IVP) single and multi-step methods
11- Numerical solutions for ordinary differential equations (BVP) shooting method and finite difference
12- Numerical solutions for partial differential equations (elliptic eq.)
13- Numerical solutions for partial differential equations (parabolic eq.)
14- Numerical solutions for partial differential equations (hyperbolic)
15- Other solution methods for PDEs in literature (FEM - DQ - GDQ - EKM - ....)
16- Introduction to finite element method

: Advanced Automatic Control

1- Introduction
2- State Space Modeling Analysis ,State Space Description: Non Linear and Linear Systems ,Linearization and State Variable Selection ,Solution of State and Output equations Realization Theory
3- Realization Theory
4- Compensator Design,Disturbance Rejection ,Tracking Systems ,Noise Elimination where to place the poles
5- Optimal Control Design ,Formulation of Optimal Control Problem ,Formulation of Optimal State Feedback Control: A Solution Based on The Riccati Equation Optimal Observers: The Kalman Filter
6- Stability Analysis ,Basic Stability Definitions ,Lyapunov: The First Method (Linearization and Stability),Lyapunov: the Second Method Lyapunov

: Advance Dynamics

1- Coordinate Systems
2- Rotation of Coordinate Frame
3- Relative Motion
4- System of Particles
5- Linear and Angular Momentums
6- Linear and Angular Momentums
7- Constraints and Configuration Space
8- Virtual Displacement and Work
9- Principle of Virtual Work
10- Lagrange Equations
11- Kinematics of Rigid Body
12- Dynamics of Rigid Body
13- Hamiltonian Equations

: Elasticity (I)

1- Theory of Deformation
2- Theory of Stress
3- Three Dimensional Equations of Elasticity
4- Uniqueness Theorem for Equilibrium Problem of Elasticity
5- Fundamentals of Thermoelasticit
6- Plane Theory of Elasticity in Rectangular Cartesian Coordinates
7- Plane Theory of Elasticity in Polar Coordinates

: Vibration of Continuous Systems

: Vibration of Continuous Systems

1- Review of the Newtonian Dynamics
2- Calculus of Variation
3- Review of the Analytical Dynamics
4- Lagranges Equations of Motion
5- Hamiltonians Principle
6- The Boundary-value Problem for Strings, Rods and Shafts
7- The Boundary-value Problem for Beams in Bending

: Optimal Control

1- Introduction to optimization
2- Dynamic Programming
3- Variational Calculus
4- linear optimal Systems
5- Nonlinear Optimal Systems

: Selected Topics-Advanced Engineering Acoustics

: Special Topics (Design for manufacture and assembly)

1- Design Goals for Manufacture and Assembly
2- Principals of Product Design for Manual Assembly
3- Principals of Product Design for Automatic and Robotic Assembly
4- Processability of metals and non-metals
5- Process Capability Evaluation of Manufacture and Assembly for Risk Control
6- ISO-GD&T - Concepts of MMC, LMC , RFS , DRF- Virtual Lines- Dimensional and Geometrical Tolerances of all types for Accuracy and Precision
7- Datum Reference Frames for Location and Positional Tolerances of Groups of Holes and Profiles
8- Direct Linear Method for Kinematic Feature Analysis of Assemblies -Tolerance Allocation for Minimum Cost
9- Part Design for Machining
10- Part Design for Sand Casting
11- Design for Sheet Metal Forming
12- Design for Metal Die-Casting
13- Design for Metal Powder Pressing and Sintering
14- Design for Hot Forging
15- Designing Polymeric Components for Injection Molding

: Experimental Stress Analysis

1- Principles of elasticity
2- Strain gages
3- The application of strain gages and sensors
4- Photoelasticity
5- Photoelasticity coating
6- Moire techniques
7- Holographic
8- Stress relaxation measurement
9- Modeling laboratory samples
10- Computer data acquisition

: Finite Elements

1-Finite Element Formulation for one-Dimensional Problems
2- Finite Element Formulation for Multidimensional Scalar Field Problems
3- Finite Element Formulation for Multidimensional Scalar Field Problems
4- Finite Element Formulation for Vector Field Problems - Linear Elasticity
5- Introduction to Finite Element Method
6-Direct Approach for Discrete Systems
7- Strong and Week From for one-Dimensional Problems
8-Beam Element
9-Plate Element
10-Approximation of Trial Solutions, Weight Functions and Gauss Quadrature for one-Dimensional Problems
11-Strong and Weak Forms for Multidimensional Scalar Field Problems
12-Approximation of Trial Solutions, Weight Functions and Gauss Quadrature for Multidimensional problems
13-Modelling with Commercial Finite ElementProgram

: Plasticity

: Thermoelasticity

: FINITE ELEMENTS (II)

: Mechanical Behavior of Materials

: Viscoelasticity

1-Viscoelastic Responses
2- Viscoelastic Models
3- Integral Transforms
4- Hereditary Integral Representation of Stress and Stress (Stieltjes Integral)
5- Tensor Representation
6- Correspondence Principle
7- Boundary Value Problems in 2 and 3 dimensional spaces

: Adaptive Control

: Random Vibration

1- Basic mathematics of random functions and proceses
2- Response of single degree vibrating systems to random excitation
3- Response of two degrees freedom of vibrating systems to random excitation
4- Response of multi degrees freedom of vibrating systems to random excitation
5- Response of continuouse vibrating systems to random excitation

: Modal Analysis in Mechanical Systems

: Reliability of Mechanical Systems

1- Definition and Concepts of Reliability and its criteria
2- Probability Theory - Permutations and Combinations - Venn Diagram - Probability Rules - Frequency Distributions and Probability Density Functions - Expected Value and Standard Deviation
3- Binomial Distribution and its Engineering Applications : Economic Assessment, Effect of Redundancy, Derating, One unit in Reserve, Non identical Capacities
4- Network Modeling and Evaluation of Simple Systems : Series Systems, Parallel Systems, compound systems, Partial Redundancy, Standby Redundancy with Perfect Switching and Imperfect Switching
5- Network Modeling and Evaluation of Complex Systems : Conditional Probability and Cut Set Methods, Tie Set Method, Approximate Evaluation , Comparison of Techniques, Connection Matrix Technique, Event Tree, Fault Tree, Quantitative Assessment of a Top Event, Multi Failure Modes
6- Probability density functions and experimental data analysis
7- Reliability evaluation of engineering systems based on probability distributions for all types of component and network dependencies MTTF Spare part and wear out impact on system reliability

: Theory of Plates & Shells

Introduction to plate-bending theory, including: stress-curvature relation,equiblibrium;governing equqtion for deflection of plates, Circular plates : Annular plates, Rectangular plates, Plates of various geometrical forms, Plates under lateral and direct loads, Membrane theory of shells, Bending theory of shells, General bending theory of cylindrical ansshells of revolution, Edge solution

: Impact Mechanics (I)

Elastic stress waves in long cylindrical bars, Application of stress wave theory, Elastic stress wave theory-more general considration, Elastic-plastic stress waves in bars, High speed normal impact of brs with rigid anvil, Plastic bending of thin flat plates, Collapse of cylindrical tubes, Impulsive loading of beams

: Composite Materials

1- mechanical properties of fibrous composites : stress-strain curves of constituents, a simple theory for long fibers,strength mechanism of long fiber, short fiber and its mechanism of strength, random orientation of composites, compression, failure modes of composite structures
2- mechanical properties of fibrous composites : stress-strain curves of constituents, a simple theory for long fibers,strength mechanism of long fiber, short fiber and its mechanism of strength, random orientation of composites, compression, failure modes of composite structures
3- Anisotropic Elasticity (Elastic stiffness and compatibility matrices in anisotropic materials, Elastic symmetry of materials, Physical meaning of elastic tensor factors in an orthotropic material, thermal and hygrothermal properties of composite materials).
4- Anisotropic Elasticity (Elastic stiffness and compatibility matrices in anisotropic materials, Elastic symmetry of materials, Physical meaning of elastic tensor factors in an orthotropic material, thermal and hygrothermal properties of composite materials)

: Advanced Design of Mechanical Components

Machine elements design - gearbox and selected mechanical systems

: Behavior of Composite Structures Under Impact Loads

: Nonlinear Vibration

1- phase plane
2- fixed points
3- stability
4- classification of linear and nonlinear systems
5- classification of linear and nonlinear systems
6- limit cycle
7- free vibration of nonlinear conservative systems
8- free vibration of nonlinear conservative systems
9- forced vibration of nonlinear conservative systems
10- forced vibration of nonlinear conservative systems
11- free vibration of nonlinear damped systems
12- free vibration of nonlinear damped systems
13- forced vibration of nonlinear damped systems
14- forced vibration of nonlinear damped systems
15- subharmonic و superharmonic

: Advanced Heat Treatment

: Selected Topics-Micro Eletromechanical Systems

15- Introduction: What is MEMS, History of MEMS
16- Introduction: MEMS Applications, MEMS Market, MEMS Design Methodology, Overview of MEMS Processes, Properties of Silicon, Materials
17- Microfabrication: Photolithography
18- Microfabrication: X-ray and E-beam Lithography, Etching
19- Microfabrication: Surface Micromachining, PVD, CVD, MUMPS
20- Microfabrication: Bulk Micromachining
21- Setup for Course Projects
22- Microfabrication: LIGA, CMOS
23- Clean Rooms, Safety Rules, Fire, Toxicity, Acids and Basis
24- Review of Essential Electrical and Mechanical Concepts
25- Scaling Effects4 (pp. 535-579) • Mechanical Resonance, Electrostatics, Electromagnetic Actuators, Applications
26- Electrostatic and Magnetic Sensors and Actuators
27- Thermal Sensors and Actuators
28- Thermal Sensors and Actuators

: Digital Control Systems

1- Review of continiouse classic and modern control systems
2- Transfer function in digital systems
3- Steady Ststate error in digital systms
4- Jurry stability analysis of digital systems
5- Root lucus diagram of digital systems
6- Frequency response function of digital systems
7- State space analysis of digital systems
8- Controller design in digital systems
9- Compensators in digital systems
10- Digital controllers in state space

: Design of Experiments & Reliability Evaluation

1- Statistical inference and confidence interval
2- Hypothesis Test and two sample comparison
3- Single and Multiple Regression and Correlation Analysis
4- Simple and Multiple Analysis of Vaiances
5- Randomized Blocks and Latin Square
6- The 2K Factorial Desiign
7- Blocking , Confounding and Two Level Factorial Factorial Design
8- Taguchi Method and its Special Lx Arrays
9- Taguchi Method for Evaluation of ◌Factors Main and Interaction Efffects
10- Facorial Design in the Design of Product
11- Managing the Uncontrollable Factors in Design of Experiments
12- Interference Theory for Reliability Modeling in Mechanical Design
13- Loading, Stress and Deflection as Random Variables
14- Statistical Consideration of Static and Fatigue Failiures
15- Experimental Study in Reliability Evaluations
16- Accelerated Life Test and Experimental Reliability Evaluation
17- Application of Factorial Design for Reliability Improvement

: Optimum Design of Mechanical Components

1- Introduction to design optimization
2- Optimum design problem formulation
3- Graphical solution method and basic optimization concepts
4- Optimum design concepts: optimality conditions
5- Linear programming methods for optimum design
6- Unconstrained optimum design for nonlinear problems
7- Constrained optimum design for nonlinear problems

: Dynamics of Multi-Body Systems

1- Linear Transformation
2- Rigid Body Rotation
3- Coordinate Transformation
4- Rotation Matrix
5- Motion and Constraints
6- Mechanisms and Degree of Freedom
7- Screw Theory
8- Kinematics of Rigid Body
9- Spatial Newtonian Dynamics of Rigid Bodies
10- Joint Constraint Equations
11- Joint Constraint Matrix
12- Natural Orthogonal Complement Method
13- Mechanism Dynamics Based on NOC
14- Lagrange Equations
15- Constrained Lagrange Equations
16- Elastostatics and Stiffness Analysis
17- Elastodynamics
18- Finite Element Methods in Mechanisms

: Fracture Mechanics

1- Introduction
2- General aspects
3-Theoretical bases

4-Theoretical bases
5-Linear elastic fracture mechanics
6-Nonlinear fracture mechanic
7- ...