

**REVISED SEMESTER WISE SCHEME OF STUDIES FOR B.SC. MECHANICAL  
ENGINEERING (SESSION 2022 & ONWARD)**

**1st Semester (18)**

22

Course No.	Title	Credit Hrs		Pre-Requisite
		Th	Lb	
HU 111 L	Communication Skills	0	1	
MA 113	Calculus and Analytic Geometry	3	0	
PHY 119	Engineering Physics	2	0	
CS 103 & CS 103 L	Introduction to Computer Programming for Data Science	2	1	
ME 111 & ME 111 L	Thermodynamics-I	3	1	
ME 121(22) & 121(22) L	Engineering Graphics and Drawing	1	1	
ME-123(22)	Engineering Mechanics-I	2	0	
QT-101	Translation of Holy Quran-I	1	0	
<b>Total:</b>		<b>14</b>	<b>4</b>	

**2nd Semester (18)**

Course No.	Title	Credit Hrs		Pre-Requisite
		Th	Lb	
IS 101	Islamic and Pak Studies-I	3	0	
ME 131(22) & ME 131(22) L	Materials and Manufacturing -I	3	1	
ME 124(22)	Engineering Mechanics-II	2	0	
HU 221 L	Technical Writing & Presentation Skills	0	1	
MA 225	Differential Equations and Transforms	3	0	
EE 101(22) & EE 101(22) L	Electrical Engineering and Electronics	2	1	
ME 100 L	Workshop Practice	0	1	
ME-122(22) L	Engineering Mechanics	0	1	
<b>Total:</b>		<b>13</b>	<b>5</b>	

**3rd Semester (16)**

Course No.	Title	Credit Hrs		Pre-Requisite
		Th	Lb	
IS 201	Islamic and Pakistan Studies -II	3	0	
ME 231(22) & ME231(22) L	Materials and Manufacturing - II	2	1	ME 131(22)
ME 251 L	Computer Aided Drawing	0	1	
ME 221 & ME 221 L	Mechanics of Materials-I	3	1	
ME 211(22) & ME 211(22) L	Fluid Mechanics-I	3	1	
QT-201	Translation of Holy Quran-II	1	0	QT-101
HU-003	International Language	0	0	
<b>Total:</b>		<b>12</b>	<b>4</b>	

**4th Semester (18)**

Course No.	Title	Credit Hrs		Pre-Requisite
		Th	Lb	
ME 272	Engineering Project Management	2	0	
ME 212 & ME 212 L	Thermodynamics-II	3	1	ME 111
ME 213(22) & ME 213(22) L	Fluid Mechanics-II	3	1	ME 211(22)
ME 222 & ME 222 L	Mechanics of Materials-II	3	1	ME 221
MA-241	Applied Engineering Statistics	2	0	
ME 273 & ME 273 L	Engineering Entrepreneurship	1	1	
<b>Total:</b>		<b>14</b>	<b>4</b>	

*M.A.M.*

## 5th Semester (17)

Course No.	Title	Credit Hrs		
		Th	Lb	
ME 321(22) & ME 321(22) L	Mechanics of Machines	3	1	
ME 312(22) & ME 312(22) L	Heat and Mass Transfer	2	1	
ME 341(22)	Instrumentation and Control	2	0	
ME 322(22)	Machine Design -I	3	0	
ME-351 L	Computer Aided Design -I	0	1	
ME 381	Health Safety & Industrial Environment	2	0	
ME-399 L	Semester Design Project	0	1	
QT-301	Translation of Holy Quran-III	1	0	QT-201
<b>Total:</b>		<b>13</b>	<b>4</b>	

## 6th Semester (18)

Course No.	Title	Credit Hrs		
		Th	Lb	
ME 342 & ME 342 L	Robotics and Automation	2	1	ME 341(22)
ME 382 & ME 382 L	Engineering Data Analytics & AI	2	1	
ME 323(22)	Machine Design II	2	0	ME 322(22)
ME 352 L	Computer Aided Design-II	0	1	
ME-332	Metrology and Quality Assurance	2	0	MA 241
ME 361(22)	Energy Resources and Utilization	2	0	
ME 353 & ME 353 L	Computational Engineering-I	2	1	
ME 371	Professional Ethics in Engineering Practices	2	0	
<b>Total:</b>		<b>14</b>	<b>4</b>	

## 7th Semester (18)

Course No.	Title	Credit Hrs		
		Th	Lb	
ME 461	Energy Conservation and Management	2	0	ME 361(22)
ME 478	Engineering Economics	2	0	
ME 453 & ME 453 L	Computational Engineering-II	2	1	ME 353
ME 411 & ME 411 L	IC Engine	2	1	ME 212
ME 496 L	FYDP-I	0	3	
ME 4 --	Elective-I	2	0	
QT-401	Translation of Holy Quran-IV	1	0	QT-301
ME 471	Production & Operations Management	2	0	
<b>Total:</b>		<b>13</b>	<b>5</b>	

## 8th Semester (17)

Course No.	Title	Credit Hrs		
		Th	Lb	
ME 415(22)	Power Plants Engineering	2	0	ME 212
ME 464 L	Energy & Power Systems	0	1	
ME 412(22) & ME 412(22) L	Refrigeration and Air Conditioning	2	1	ME 312(22)
ME 421(22) & ME 421(22) L	Mechanical Vibrations	3	1	ME 321(22)
ME 472	Supply Chain Management	2	0	
ME 497 L	FYDP- II	0	3	ME 496L
ME 4 --	Elective-II	2	0	
<b>Total:</b>		<b>11</b>	<b>6</b>	
<b>Grand Total:</b>		<b>105</b>	<b>35</b>	

*MAD*

**DETAIL OF COURSES FOR B.SC. MECHANICAL ENGINEERING**  
**(SESSION 2022 ONWARD)**

**IS 101                      Islamic Studies                      3(3,0)**

It is a university level course. The contents are designed by the Department of Islamic Studies.

**IS 201                      Pakistan Studies                      3(3,0)**

It is a university level course. The contents are designed by the Department of Islamic Studies.

**HU 003                      International Language                      0 (0,0)**

It is a university level course. The contents are designed by the Department of Humanities.

**HU 111 L                      Communication Skills                      1(0,1)**

It is a university level course. The contents are designed by the Department of Humanities.

**HU 221 L                      Technical Writing & Presentation Skills                      1(0,1)**

It is a university level course. The contents are designed by the Department of Humanities.

**CS 103 & 103 L                      Introduction to Computer Programming for Data Science 3(2,1)**

It is a university level course. The contents are designed by the Department of Humanities.

**PHY 119                      Engineering Physics                      2(2,0)**

Mechanics: Coordinate systems, Force vectors, Rectangular components, Cartesian vectors, position vectors, Equilibrium of a particle, conditions for equilibrium of a particle, Free body diagram and coplanar force systems, Motion under constant acceleration, Newton laws and their applications, Uniform circular motion. Vortex Motion, Frictional forces, friction, types of friction, dry friction, applications of friction.

Work and energy. Potential energy, energy conservation, energy and our environment, fundamental of heat transfer, Modern materials and energy transfer

Atomic nucleus, Mass energy relation, Binding energy, Nuclear forces and fundamental forces, Exponential decay and half-life

Electrostatic and magnetism: Coulomb's law, Gauss's law, Electric field around conductors, Dielectrics. Magnetic fields. Magnetic force on current. Semiconductor Physics: Energy levels in a semiconductor, Hole concept, Intrinsic and extrinsic regions, Law of mass action, P-N junction, Transistor.

Modern Physics: Electron microscope, Zeeman effect,

**Recommended Books:**

1. Fundamentals of Physics by Halliday, Resnick and Walkers.
2. Applied Physics (University Physics) by Zears, Zemansky and Young
3. Physics for scientist and Engineers with Modren Physics by Douglas C. Giancol,

*M. J. S. W.*

**MA 113                      Calculus and Analytic Geometry                      3(3,0)**

**Contents:** A review of differentiation: Geometrical interpretation of a derivative; Infinitesimal; Differential coefficient; Derivatives of higher order; Indeterminate forms and L. Hopital's rule; Asymptotes; Curvature; Increasing and decreasing functions; Maxima and minima of a function. Approximation and error estimates.

Further techniques of Integration; Integration by reduction formula; Fundamental Theorem of Integral Calculus; Definite integral and its properties; Area enclosed between curves; Arc length; Volume of a solid; Volume of a solid of revolution; Area of surface of revolution; Moments; Centroids.

Cartesian, cylindrical and spherical coordinates; The ratio formula; Equations of a straight line in  $R^3$ ; Direction ratios and direction cosines; Angle between two straight lines, Distance of a point from a line; Equations of a plane; Angle between two planes; Shortest distance between two skew lines; The sphere; Directional derivatives.

The concept of limit, continuity and differentiation in functions of several variables; Geometric interpretation of partial derivatives; Total differential; Chain rule; Implicit differentiation; Maxima and minima of functions of two independent variables. Taylor's and Maclaurin's series for functions of two variables.

Double Integration; Fubini's Theorems; Change of order; Geometrical Interpretation of double integral; Applications to find volumes and areas.

**Recommended Books:**

1. "Calculus" by Thomas & Finny
2. "Mathematics for Engineers and Scientists" by Muhammad Iqbal Bhatti and Muhammad Nasir Ch
3. "Advanced Engineering Mathematics" by E. Kreyszig
4. "Calculus" by Howard Anton.
5. "Calculus" by Swokowski.

**MA 225                      Differential Equations and Transforms                      3(3,0)**

**Contents:** Formation of differential equations; Solution of several types of first order differential equations; Orthogonal trajectories, Application in physical problems. Linear differential equations of second order, Complementary function and integral. Solution of non-homogeneous linear differential equations of second order and higher by (i) the method of undetermined coefficients (ii) the method of variation of parameters and (iii) the method of power series; Application of second order differential equations; System of differential equations.

Formation of partial differential equations; Equations reducible to ordinary differential equations; Equations of the form  $Pp + Qq = R$ ; Solution by the method of separation of variables. Wave, heat and Laplace equations.

Introduction to Laplace transform: Laplace transform of elementary functions, Laplace transform theorems, Inverse Laplace transform, applications to the solutions of initial value problems, Convolution theorem and applications.

Periodic functions. Even and odd functions. Fourier series of functions of period  $2\pi$  and arbitrary period; Half range series; Complex Fourier series, Fourier transform and applications

**Recommended Books:**

1. "Mathematics for Engineers and Scientists" by Muhammad Iqbal Bhatti and Muhammad Nasir Ch,
2. "Advanced Engineering Mathematics" by E. Kreyszig,

MA 225

3. Elementary Differential Equations and Boundary Value Problems, by Boyce and Diprima,
4. "Advanced Engineering Mathematics by H.K. Dass,
5. "Ordinary Differential Equations" by N.A. Shah,

**MA 241 Applied Engineering Statistics 2(2,0)**

Introduction & role of statistics in engineering. Population & samples, Variables, Methods of displaying data sets, Stem & leaf display, Histogram, Histogram shapes, Boxplot, Bar chart, Pareto diagram, Dot diagram, Frequency distributions & their graphs, Outlier. Mean, Median, Quartile, Percentile, Range, Deviation from mean, Sample variance, Sample standard deviation, Coefficient of variation.

Probability, Concepts & definitions, Basic theorems of probability, Law of total probability, Bayes theorem, Discrete and continuous random variables and their probability distributions, Density and distribution functions; Expectation.

Mean & variance of discrete & continuous random variables, Binomial distribution, Poisson distribution, Normal distribution, t-distribution, Chi-square distribution, F-distribution.

Sampling techniques and sampling distribution; Point estimation and interval estimation of parameters, Least square linear & polynomial regression, Linearization of nonlinear models, Correlation, Design of experiments, Analysis of variance.

**Recommended Books:**

1. Applied Statistics for Engineers & Scientists by Devore/Farnum. Thomas.
2. Probability and Statistics for Engineers and Scientists by Ronald E. Walpole.
3. Probability and Statistics for Engineering and Sciences by CENGAGE Learning.
4. Advanced Engineering Mathematics by Erwin Kreyszig.
5. Applied Statistics and Probability for Engineers by Montgomery, Runger,
6. Probability and Random Variables and Stochastic Processes, by Papoulis Athanasios
7. Introduction to Statistical Theory by Muhammad Shehzad and Sher Muhammad,

**ME 382 & ME 382 L Engineering Data analytics and AI 3(2,1)**

Data science concepts, types of data, continuous data, categorical data, qualitative data, data summarization and basic statistics, dendrograms, Statistical Techniques for forecasting, Interpolation/ Extrapolation, correlation analysis, Hypothesis Testing, data distribution types, error in estimation, round off error, truncation error, confidence intervals, linear transformations,

Design of experiments, hyper-space, single factor experiments, multi factor experiments, full factorial designs, partial factorial designs, linear regression, nonlinear models and related diagnostics, generalized linear model; exponential families, response surface methodology, analysis of variance, pareto of coefficients, contour plots

An Introduction to artificial intelligence and its applications towards knowledge-based systems; Introduction to reasoning and knowledge representation, human neural networks, network diagrams an imitation of human neural networks, artificial neural networks, supervised learning, unsupervised learning, multilayer perceptron, gradient decent algorithm, recent trends in AI and applications of AI algorithms for mechanical engineering problem solving (for complex engineering problem)

**Recommended Books:**

*M.A.S.M.*

1. Head first statistics by Griffiths, Dawn!
2. Numerical methods for engineers. By Chapra, Steven C., and Raymond P. Canale.
3. Design and analysis of experiments by Montgomery, Douglas C.
4. Neural networks and learning machines by Haykin, Simon
5. First Data Analysis: A learner's guide to big numbers, statistics, and good decisions. " by Milton, Michael. Head
6. "Artificial Intelligence. A Modern Approach" by Russell, S. and Norvig, P.

**EE 101(22) & EE 101(22) L                      Electrical Engineering and Electronics                      3(2,1)**

Introduction to DC circuits, series and parallel circuits and analysis, AC current, resistance, inductance and capacitance in AC circuits, power factor, single and polyphase circuits, power and power factor measurement, current and voltage relationship in phase and line circuits, introduction to AC/DC motors and generators, transformers, losses and efficiency, introduction to semiconductors, diode, power amplifiers, transistors, relays, signal conditioning, operational amplifier.

**Recommended books**

1. Electrical Power Technology, by Theodore Wildi
2. Electric Machinery Fundamentals, by S. Chapman
3. Electric Circuits, Basic Electricity, Schaum's Series
4. Electronic Devices, by Floyd,
5. Electronic Principles , by Malvino, A.Paul

**ME 100 L                      Workshop Practice                      1(0,1)**

Machine Shop: Detailed study of center lathe and accessories. Plain and Taper turning. Basic lath operations including turning, facing, simple screw cutting/treading, knurling, Grooving (Drilling and Boring), cutting tools and their grinding. Brief Introduction of shaper, milling Shaper and Surface Grinding Machine. Assigning of Practical Jobs.

Fitting and Fabrication Shop: The use and care of fitter's tools. Marking out of job. Practice in Metal filing. Sawing, Drilling, dieing, Tapping and reaming. Brief introduction and use of power Hack Saw, Arbor Press, Sheet Shaper Machine, Sheet Rolling Machine, Punching Machine and Drilling Machine. Assigning of practical Jobs.

Carpentry Shop: The use and care of tools. Type of Timber, its defects and preservation methods practice in planning and sawing. Different types of wood joints. Study of sawing, planning, turning mortise and tenon machines. Assigning of Practical Jobs.

Electrical Shop: Electric shocks and treatment. The use and care of tools used by Electrician. Types and uses of cable and electrical accessories for house wiring, practice in simple house wiring, testing methods. Switch gear used on domestic installation and DB system. Earthing System. Assigning of Wiring arrangements practical.

**Books recommended:**

1. Workshop Technology part-1, by W.A.J Chapman.
2. Electrical Wiring , by Richter and Schwan
3. Wiring Manual , by Pak Cables Limited.

**ME 111 & ME 111 L                      Thermodynamics-I                      4(3, 1)**

Thermodynamics, system, continuum, properties, state, thermodynamic equilibrium, state postulate and its conclusions, process, cycle, zeroth law of thermodynamics, forms of energy,

*M.A.S.*

energy transfer by heat, energy transfer by work, moving boundary work and other forms of work, properties of pure substances, phase change processes of pure substance, critical and triple point, property diagrams for phase change processes, use of property tables, ideal gas equation, specific heats, Joule's law, internal energy, enthalpy and specific heats of perfect gases, liquids and solids, first law of thermodynamics, first law of thermodynamics applied to non – flow processes, continuity equation, first law of thermodynamics applied to flow processes, steady flow energy equation and steady flow engineering devices, uniform state and uniform flow processes, second law of thermodynamics, statements, corollaries, thermodynamic temperature scale, reversible and irreversible processes, entropy and its application to non-flow and flow processes, temperature-entropy and enthalpy-entropy diagrams, generation of steam through boilers, classification, configurations and applications of boilers, boiler efficiencies, energy analysis of boilers, boiler Draughts, Boiler fuels, boiler efficiencies, rating, and heat balance sheet, concept of steam condenser and its types,

**Recommended Books:**

1. Thermodynamics, An Engineering Approach, by Y. A. Cengel and M. A. Boles
2. Applied Thermodynamics for Engineering Technologists, by T.D. Eastop, A. McConkey
3. Basic Engineering Thermodynamic, by Rayner Joel
4. Fundamentals of Engineering Thermodynamics, by Moran, Shapiro

**ME 121(22) & ME 121(22) L      Engineering Graphics and Drawing      2(1, 1)**

Introduction, types of lines, projections, types of projections, orthographic projections, plane of projections, four quadrants, projection of points, projection of straight lines, examples with different quadrants, traces of a line, true length of a line, inclination of line to both reference planes, projection of perpendicular and oblique planes, loci of points and generated curves, Loci of points and straight lines, cycloid, epicycloid, involute, Archimedean spiral, types of solids, poly-hedra, solids of revolution, prism, pyramid, cylinder, cone, sphere, projection of solids, projection of various solids in simple position and inclined positions, section of solids, true shape of section on auxiliary plane of various solids.

Introduction, lettering, dimensioning, use of pencil and drawing instruments, planning of drawing sheet, projections, types of projections, orthographic projections, plane of projections, four quadrants, Isometric and pictorial projections of solids/machine parts, making of freehand sketches from solid objects and from orthographic projections, sections of joints, screw thread systems, nuts and bolts, keys and cotter, coupling and simple bearings

**Recommended Books**

1. Engineering Drawing and Graphics by N.D Bhatt and V.M.Panchal
2. Technical Graphics Communication, by Bertoline Wiebe, Miller Mohler, Irwin
3. Practical Geometry and Engineering Graphics ,by Abbot.
4. Engineering Graphics by , Craft, Meyers and Boyer
5. Engineering Drawing, by A. C. Parkinson
6. Engineering Drawing from Beginning, by M.F. Cousins
7. Engineering Drawing, by N.D. Bhatt
8. Machine Drawing, by K.L. Narayana
9. Engineering Drawing, by A.W.Boundy

*MKS*

**ME 131(22) & ME 131(22) L      Materials and Manufacturing -I      4 (3, 1)**

Engineering materials and their types, Atomic bonding and atomic structure of materials, crystal systems, structure property relationship, metals and alloy systems, iron-iron carbide phase diagram, types of steels, corrosion of metals anti-corrosive coatings and paints, heat treatment,

Non-Metals: Composition, structure of plastics, rubber, ceramics, fiberglass and introduction to composite materials. Polymers: Molecular structure, properties, bonding and classification of polymers, forming of thermosetting or thermoplastic polymer.

Types of casting, expendable and nonexpendable mold casting, sand casting, bulk deformation processes, rolling, roll mills, thread rolling, gear rolling, ring rolling, roll piercing, forging, open die and impression die forging, forging dies, hammers and presses, upsetting extrusion, types of extrusion, drawing, sheet metal working

Joining processes (welding) types of welding, oxyfuel gas welding, arc welding, SMAW, GMAW, GTAW, resistance welding, resistance spot and seam welding, weld quality, defects, inspecting and testing of welds, brazing, soldering, types of weld joints, types of welds, features of welded joints

Sheet metal forming/working, bending operations, drawing, roll bending and forming, mechanical assembly, threaded fasteners, washers, rivets and eyelets, press fitting, shrink and expansion fits, snap fits, retaining rings, cotter pins,

Shaping processes for plastics, extrusion, injection molding, compression molding, blow molding, thermoforming, introduction to rapid prototyping

**Recommended books**

1. Material Sciences and Engineering, William D. Callister
2. Fundamentals of Modern Manufacturing, Materials, Processes and Systems, Groover
3. Process and Materials of Manufacturing, Lindberg
4. Materials and Processes in Manufacturing, E.P Degarmo
5. Manufacturing Engineering and Technology, Kalpakjian, Shmid
6. Processes and Materials of Manufacture, Lindberg
7. Materials and Processes in Manufacturing, Degarmo, Black, Kohser
8. Introduction to Physical Metallurgy, Avner
9. Manufacturing Engineering by Ostwald

**ME 123(22)      Engineering Mechanics-I      2(2, 0)**

Force System, force, rectangular components, moment, couples, resultant of forces, moments and couples (two and three-dimensional systems), equilibrium, Equilibrium of Rigid Bodies mechanical systems, isolation and equilibrium equations for two and three-dimensional systems., two forces and three force members, ,plane trusses, method of joints, method of sections, frames and machine analysis, distributed forces, flexible cables, Centroids and Centers of Gravity, Free body diagram Analysis of Structures, Moments of Inertia , Forces in Beams, Parallel Axis theorem, friction, types of friction, dry friction, applications of friction

**Recommended Books:**

1. Engineering Mechanics, Statics, by J.L. Meriam and L.G. Kraig,
2. Engineering Mechanics, Statics, by R.C. Hibbeler and S.C. Fan
3. Vector Mechanics for Engineers: Statics, by Beer, F. and E. Johnston.,

*MAK*



**ME 124(22)                      Engineering Mechanics-II                      2 (2, 0)**

Kinematics of Particles: Introduction to dynamics and kinematic quantities, rectilinear kinematics (continuous and erratic motion), curvilinear motion (using rectangular and normal & tangential coordinates components).

Kinetics of particles: Force, mass and acceleration, Newton's second law of motion, Equation of motion for a particle (using rectangular coordinates and normal & tangential coordinates). Work of a force, Principle of work and energy, Power and efficiency. Introduction to principle of linear impulse and momentum. Introduction to planer kinematics and kinetics of rigid bodies.

**Recommended Books:**

1. Engineering Mechanics, Dynamics, by J.L. Meriam and L.G. Kraig
2. Engineering Mechanics, Dynamics, by R.C. Hibbeler and S.C. Fan,

**ME 122(22) L                      Engineering Mechanics                      1 (0, 1)****ME 221 & ME 221 L                      Mechanics of Materials-I                      4(3, 1)**

Stress-Strain and Mechanical Properties: Stress, Normal Stress, Normal Stress Distribution, Shear Stress, Shear Stress Equilibrium, General State of Stress, Deformation, Strain, Normal Strain, Shear Strain, Tension and Compression Test, Stress-Strain Diagram, Elastic and Plastic Deformation, Stress-Strain Diagram for Ductile and Brittle Materials, Strain Energy, Resilience, Toughness, Hardness, Creep, Fatigue, Hooke's Law, Poisson's Ratio, Elastic Modulus, Shear Modulus, Bulk Modulus, Saint-Venant's Principle, Relationship between Mechanical Properties, Allowable Stresses and Factor of Safety, Thermal Stresses, Stress Concentrations.

Section Properties: Centroid of Simple and Composite Sections, Radius of Gyration, Parallel Axis Theorem, Section Modulus, First Moment of Area of Simple and Composite Structural Shapes, Second Moment of Area of Simple and Composite Structural Shapes.

Bending of Beams: Simple Bending Theory, Pure Bending of Symmetric Members and Composite Members. Flexure Formula. Shear Force and Bending Moment Diagrams. Graphical Method for Constructing Shear Force and Bending Moment Diagram. Shear Force and Bending Moment Diagrams for Beams carrying Concentrated Loads only, Uniformly Distributed Loads, Combined Concentrated and Uniformly Distributed Loads, Applied Moments,

Torsion of Shafts: Simple Torsion Theory, Torsional Deformation of Circular Shaft, Torsion Formula, Angle of Twist, Power Transmission for Solid and Hollow Shafts, Torsion of Solid Non-Circular Shafts.

Buckling of Columns: Critical Load and Equilibrium, Buckling, Ideal Column with Different Supports, Euler's Formula for Buckling of Columns.

Deflection in Beams: The Elastic Curves, Slope and Displacement by Integration, Method of Superposition.

**Recommended Books**

1. Mechanics of Materials by Russell C. Hibbeler
2. Mechanics of Materials by Ferdinand Beer, E. Johnston, John DeWolf and David Mazurek
3. Mechanics of Materials by James M. Gere & Barry J. Goodno
4. Mechanical Engineering Design by Richard Budynas and Keith Nisbett

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**ME 211(22) & ME 211(22) L      Fluid Mechanics-I      4(3, 1)**

Introduction, continuum concept of fluid, properties of fluids, no-slip condition, no-temperature jump condition, Classification of fluid flows: Viscous versus Inviscid Regions of Flow, Internal versus External Flow, Compressible versus Incompressible Flow, Laminar versus Turbulent Flow, Natural versus Forced Flow, Steady versus Unsteady Flow, 1D, 2D, System and Control Volume, Fundamental Concepts of Mathematical Modelling of Fluid Mechanics Problem, Properties of Fluids: Density and specific gravity, Vapor pressure and cavitation, Energy and specific heats, Coefficient of Compressibility, Viscosity, Surface tension, Capillary Effect

Pressure: Pascal's Law, The Manometer, The barometer and Atmospheric Pressure, Fluid Statics: hydrostatic forces on submerged plane and curved surfaces, Buoyancy, Fluids in rigid body motion, Fluid Kinematics: Lagrangian and Eulerian descriptions, Deformation of Fluid Elements, The Reynolds Transport Theorem, The Boundary Layer Theory, The Bernoulli's Equation: Unsteady and Compressible Flow, Static, Dynamic and Stagnation Pressure, Hydraulic Grade Line, Application of Bernoulli's Equation

**Recommended Books**

1. Fluid Mechanics, Fundamentals and Applications, by Yunus A. Cengel, John M. Cimbala
2. Engineering Fluid Mechanics, by Clayton T. Crowe, Donald F. Elger, John A. Roberson
3. Fluid Mechanics, John F. Douglas, by Janusz M. Gasiorek, John A. Swaffield
4. Fundamentals of Fluid Mechanics, by Munson, Young and Okiishi
5. Fluid Mechanics, by F.M. White
6. Fluid Mechanics, by Irving H. Shames

**ME 231(22) & ME 231(22) L      Materials and Manufacturing -II      3 (2, 1)**

Introduction to rapid prototyping Powder metallurgy, techniques to prepare powders, preforms and sintering. Principles of metal cutting, lathe machine tools, Types of Lathes, working principle of lathe machines, lathe processes, lathe tools, cutting tools nomenclature, geometry and materials, and their effects on machining, cutting speed, feed and depth; Types of drilling machine and drills, speed, feed calculations; Milling machine classifications, milling processes, milling cutters and related mechanics, speed, feed, depth of cut, calculations; grinder, and its types, grinding processes, grinding wheel structure; working principles, Shaper, planer, slotter; working principle, introduction to CNC Machining, CNC Machining center and Turning center, Non-Conventional machining processes (Ultrasonic, EDM, Laser machining, water-jet, plasma cutting), Additive Manufacturing Operations (RP, 3DP, FDM, EBM ), Hybrid Manufacturing

**Recommended Books:**

1. Machine Tools Practice by Kibbe, Meyer, Neely, White
2. Technology of Machine Tools by Krar, Gill, Smid
3. Manufacturing and Machine Tool operation by Pollack
4. 3D P and Additive Manufacturing: Principles and Applications, by Chu
5. Additive Manufacturing of Metals: The Technology, Materials, Design and Production, by Yang

## 6. Fundamentals of Modern Manufacturing, Materials, Processes and Systems by Groover

**ME 251 L**                      **Computer Aided Drawing**                      **1 (0, 1)**

**ME 272**                      **Engineering Project Management**                      **2(2, 0)**

Introduction to project management, The Need for Projects, General Project Characteristics, Why are Projects Important, Project Life Cycles, Determinants of Project Success, Developing Project Management Maturity, Employability Skills of Project Managers, Project Elements. Project Selection, Approaches to Project Screening and Selection, Checklist Model, Simplified Scoring Models, Limitations of Scoring Models, Analytical Hierarchy Process, Profile Models, Financial Models, Choosing a Project Selection Approach, Project Portfolio Management, Objectives and Initiatives, Portfolio Selection Process, Developing a Proactive Portfolio, Keys to Successful Project Portfolio Management, Problems in Implementing Portfolio Management. Successful Projects Need Leaders, Leaders Versus Managers, How the Project Manager Leads, Traits of Effective Project Leaders. Scope Management, Conceptual Development, Statement of Work, Project Charter, Scope Statement, Work Breakdown Structure and its Purpose, Organization Breakdown Structure, Responsibility Assignment Matrix, Work Authorization, Scope Reporting, Control Systems, Configuration Management, Project Closeout, Project Management and Sustainability, Managing Projects for Sustainability. What is Project Risk, Risk Management: A Four-Stage Process, Risk Identification, Risk Breakdown Structures, Analysis of Probability and Consequences, Risk Mitigation Strategies, Use of Contingency Reserves, Other Mitigation Strategies, Control and Documentation, Project Risk Management: An Integrated Approach, Cost Management, Cost Estimation, Creating a Project Budget, Developing Budget Consistencies. Project Scheduling, Key Scheduling Terminology, Developing A Network, Constructing the Critical Path, Lags in Precedence Relationships, Gantt Charts, Crashing Projects. Agile Project Management, Theory of Constraints and Critical Chain Project Scheduling, Critical Chain Solutions

**Recommended books**

1. Project Management: Achieving Competitive Advantage by Jeffrey K. Pinto
2. A Guide to the Project Management Body of Knowledge (PMBOK), PMI, PMBOK® Guide
3. Project Management: A Strategic Managerial Approach by Jack R. Meredith, Scott M. Shafer, Samuel J. Mantel Jr
4. Project Management: A Systems Approach to Planning, Scheduling and Controlling by Harold Kerzner

**ME 212 & ME 212 L**                      **Thermodynamics-II**                      **4(3, 1)**

Non-reacting gas mixtures: Composition of a gas mixture, mass & mole fraction, mixture of perfect gases, Dalton's law and the Gibb's Dalton law, Exergy, Amagat's law, properties of ideal gas mixtures, adiabatic mixture of perfect gases real gas mixture, gas vapor mixtures, wet cooling towers,

Mixture with chemical reaction: Fuels and types of fuels, combustion, theoretical and actual combustion processes, calorimeter, simple reaction equation, stoichiometric chemical reaction, rich and lean air-fuel ratio mixture, enthalpy of formation and combustion reaction, first law analysis of reacting system, adiabatic flame temperature. third law of thermodynamics,

Compressors: classification and working principles, single stage and multistage rotary and reciprocating compressors, inter-cooling, efficiencies and P-V diagrams of all compressors,

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Nozzles: Introduction to air/gas nozzles, flow through steam nozzle, their classification, working principles and efficiencies, jet propulsion.

Turbines: Steam turbine, their classification and working principles. comparison of reaction & impulse steam turbines, efficiencies of turbine

Vapor Power Systems: Rankine Cycle, Improving Performance-super heat, re-heat and supercritical, Gas Power Systems: Air-Standard Otto, Diesel and Brayton Cycle. Gas Turbine-Based Combine Cycle.

#### Recommended Books

1. Fundamentals of Engineering Thermodynamics, by Moran, Shapiro
2. Thermodynamics, An Engineering Approach, by Y.A. Cengel and M.A. Boles
3. Applied Thermodynamics for Engineering Technologists, by T.D. Eastop, A. McConkey
4. Fundamentals of Thermodynamics, by Sonntag, Borgnakke, Van Wylen
5. Basic Engineering Thermodynamic, by Rayner Joel

ME 213(22) & ME 213(22) L

Fluid Mechanics-II

4(3, 1)

Mass and Energy Equations: Conservation of mass, Mechanical Energy and Efficiency, Conservation of Energy, Energy Analysis of Steady Flows, Momentum Analysis: Conservation of Momentum, Body and surface forces, The Linear Momentum Equation, Rotational Motion and Angular Momentum, The Angular Momentum Equation, Dimensional Analysis: Dimensional Analysis and Similarity, Buckingham Pi Theorem, Flow in Pipes: Laminar Flow in Pipes, Turbulent Flow in Pipes, Pipe Losses, Flow rate and velocity Measurements – Flow meters, Differential Analysis of Fluid Flows: Continuity Equation, The Stream Function, Cauchy's Equation, The Navier-Stokes Equation, Approximate Solution of the Navier-Stokes Equation

Flow over bodies: Drag and Lift, Friction and Pressure Drag, Drag coefficients of common geometries, Parallel Flow Over Flat Plates, Flow Over Cylinders and Spheres, Compressible Flow: Stagnation properties, Speed of Sound - Mach number, Isentropic Flow, Adiabatic Flow, Open Channel Flow: Uniform and Varied Flow, Pumps and Turbines, Introduction to Computational Fluid Dynamics

#### Recommended Books

1. Fluid Mechanics, Fundamentals and Applications, by Yunus A. Cengel, John M. Cimbala
2. Engineering Fluid Mechanics, by Clayton T. Crowe, Donald F. Elger, John A. Roberson
3. Fluid Mechanics, by John F. Douglas, Janusz M. Gasiorek, John A. Swaffield
4. Fundamentals of Fluid Mechanics, by Munson, Young and Okiishi
5. Fluid Mechanics, by F.M. White
6. Fluid Mechanics, by Irving H. Shames

ME 381

Health Safety and Industrial Environment

2(2, 0)

Introduction of Health and Safety, Industrial Safety: Objectives of Safety, Importance of Safety in an industry, Engineering Controls, Personal Protective Equipment, Industrial accidents, Effects of accidents, Types of accidents incidence of fire. Fire prevention and control. Principles of accident prevention, hazard analysis. Legal, humanitarian and economic reason for action. Safety inspection procedures. Emergency Preparedness, Information and Training ,

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Chemical Hazards, Hazardous Chemical Waste Disposal, Physical Hazards, Hazardous Material Shipping, Hazardous Material Control, Importance of clean environment, Scale of Environmental Pollution. Environmental Act. Health and Safety Act. Atmospheric Pollution: Types of Atmospheric pollution, Their Causes and Effects on Human Health, Available Technologies for Controlling Pollution. Industrial Waste: Solid Waste, Industrial Effluents and Waste Gases, waste treatment plants. Noise Pollution: Measurement of Noise level, Effect of excessive noise on human health. Remedial Measures.

Introduction to ISO Standards for Safety and Health and Environment, ISO 14000, Introduction to OHSAS 18001 standards, National OHS policy draft, National OHS Act, Punjab OHS Act 2019

**Recommended Books:**

1. Safety at Works, by John Ridley
2. International Health and Safety at Work: The Handbook for the NEBOSH International General Certificate by Hughes, Phil, and Ed Ferrett.
3. Emergency Response Guidebook (ERG)
4. Factory & Production Management, by K. G. Lockyer,
5. Environmental Pollution and Control, by J. Jeffrey Peirce, Ruth F. Weiner and P. Aarne Vesilind

**ME 322 (22)                      Machine Design - I                      3(3, 0)**

Introduction to Mechanical Engineering Design: Mechanical Engineering Design, Design process. Problem formulation and calculation. The engineering models. Computer-Aided Design and Engineering. Dimensions and Tolerances.

Standards and Codes: Introduction to International design codes and standards. International organization of Standardization (ISO), British Standards (BS), American National Standards Institute (ANSI), Japanese Industrial Standards (JIS), German Institute for Standardization Standards (DIN), Pakistan Standards and Quality Control Authority (PSQCA). International design codes and standards related to Mechanical Engineering Design.

Failure Prevention: Design factor and Factor of safety. Failures resulting from Static loading. Fatigue failure resulting from Variable loading.

Shafts and Shaft Components: Introduction to shafts, Shaft materials, Shaft layouts. Shaft design for stress. Deflection considerations. Critical speeds for shafts. Miscellaneous shaft components. Limits and fits.

Screws and Fasteners: Thread Standards, Mechanics of power screws, Threaded fasteners. Joints-fastener stiffness, Joints-member stiffness. Bolt strength, Tension joints, Bolt torque and bolt tension, Statically loaded tension joint with preload. Gasketed joints. Fatigue loading for tension joints. Bolted and Riveted joints in Shear.

Welding, Bonding and Permanent Joints: Welding symbols, Butt and Fillet Welds. Stresses in welded joints in torsion and bending. Strength of welded joints. Statically loaded joints, Fatigue loaded joints. Resistance welding. Adhesive bonding.

Flexible Mechanical Elements: Belts, Flat and Rounded belt drives, V belts, Timing Belts. Roller Chains. Wire rope. Flexible shafts.

**Recommended Books**

1. Mechanical Design: An Integrated Approach by R. L. Norton
2. Shigley's Mechanical Engineering Design by R. G. Budynas and J. K. Nisbett
3. Machine Elements in Mechanical Design by R. L. Mott

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## 4. Design of Machine Elements by M. F. Spotts, T. E. Shoup and L. E. Horberger

ME 351 L	Computer Aided Design-I	1 (0, 1)
ME 352 L	Computer Aided Design-II	1 (0, 1)
ME 273 & ME 273 L	Engineering Entrepreneurship	2(1,1)

Evolution of the concept of entrepreneur, Characteristics of an entrepreneur, Distinction between an entrepreneur and a Manager, Economic Development, Factors affecting entrepreneurial growth (economic, Non-Economic and Government factors), Critical factors for starting a new enterprise. Ingredients for a successful new business. Self-assessment and feedback, Personal entrepreneurial competencies. Goal setting. Creativity and sources of new business ideas, the difference between ideas and opportunity and creativity. Assessing business opportunities in Pakistan. Screening and evaluating opportunities Product planning and development process. Creating parallel competition by developing a similar product or service, Product life cycle, finding sponsorship. Acquiring a going concern, E-Commerce and business start-up and growth. Marketing as a philosophy, marketing management: Creating a marketing plan, Analyze the environmental situation and the market opportunity, setting marketing objective, formulating a marketing strategy. The business plan as selling document, reasons for writing a business plan your company

**Recommended Books:**

1. Entrepreneurship, by Rober D. Hisrich and Michael P. Peter
2. Engineer to Entrepreneur: Success Strategies to Manage Your Career and Start Your Own Firm by Rick De La Guardia
3. Entrepreneurship for Scientists and Engineers by Kathleen R. Allen
4. Entrepreneurship for Engineers, by Helmut Kohlert, Dawud Fadai and Hans-Ulrich Sachs

**ME 321(22) & ME 321(22) L Mechanics of Machines 4(3, 1)**

Introduction and application to mechanisms and machines. Kinematics of Mechanisms. Kinematics of links and its analysis using translating and rotating frame of references. Lower and higher pair joints, kinematic chain, degrees of freedom, connectivity and mobility, inversion, Grashof rules. Techniques of Mechanism Analysis Velocity and acceleration analysis in mechanisms.

Dynamics of machines: Belt drives for power transmission: Gear trains: Simple and compound gear trains, reverted gear train, epicyclic gear train and their tabular analysis. Time Ratio, Timing Charts, Design of Slider Crank Mechanism, Design of Crank Shaper Mechanism, Mechanism to Move a Link Between Two Positions Cam Design: cam profile design. Balancing: balancing of rotating and reciprocating masses, balancing of in-line engines, V-engines and radial engines, balancing machines Flywheels: moment of inertia, design calculation methods, Gyroscope: working principle and applications.

**Recommended Books**

1. Theory of Machines and Mechanisms, by John J. Uicker, Gordon R. Pennock, Joseph E. Shigley
2. Kinematics and Dynamics of Machinery, by Charles E. Wilson, J.Peter Sadler

3. Design of Machinery, by Robert L. Norton
4. Engineering Mechanics, Dynamics, by R.C. Hibbeler and S.C. Fan,

**ME 312(22) & ME 312(22) L                      Heat and Mass Transfer                      3(2, 1)**

Basics of Heat Transfer & Introduction to various modes of heat transfer: Fourier's law of conduction, Newton's law of cooling and Stefan Boltzmann's law. Thermal conductivity, heat conduction/diffusion equation in Cartesian, Cylindrical and Spherical coordinates; one dimensional steady state heat conduction through a slab/plane wall and composite wall, cylinders and spheres with and without heat generation sources, Insulation, critical radius/thickness of insulation, The overall heat transfer co-efficient, Temperature distribution in solid cylinders & spheres, Thermal contact resistance; Conduction-convection systems, Fins, effectiveness and efficiency of fins, and heat transfer through fins; Unsteady-state conduction—Lumped-heat-capacity system and the criteria of its applicability, Biot and Fourier numbers; Principles of Convection—Viscous flow, Boundary-layer flow regimes and Laminar boundary layer on a flat plate, Energy equation of the boundary layer, The integral energy equation of the thermal boundary layer, The relation between fluid friction and heat transfer, Turbulent boundary layer (TBL) heat transfer, eddy viscosity and mixing length, The turbulent shear stress and velocity distribution in TBL. Heat transfer in laminar tube flow and the temperature distribution, non-dimensional parameters related to convective heat transfer and their applications, shear stress; Empirical and practical relations for forced convection heat transfer—empirical relations for pipe and tube flow; Radiation heat transfer – Thermal radiation, radiation properties, black body radiation, absorptivity, reflectivity, transmissivity, Wien's law, Kirchoff's law, Grey body radiation, Radiation shape factor and relations between shape factors, Reciprocity theorem, Heat exchange between non-blackbodies, Infinite parallel planes, Radiation shields; Heat exchangers – The overall heat transfer co-efficient, fouling factors, types of heat exchangers, The log mean temperature difference (LMTD), Effective-NTU method, Compact heat exchanger, Heat exchanger design considerations; Mass transfer—Fick's law of diffusion, diffusion in gases, diffusion in liquids and solids, analogy between momentum, heat and mass transfer; simultaneous heat and mass transfer, Evaporation processes in the atmosphere.

**Recommended books**

1. Heat Transfer, by J. P. Holman
2. Heat Transfer: A Practical Approach, by Yunus A. Cengel
3. Engineering Heat Transfer, by William S. Janna
4. Fundamentals of Heat and Mass Transfer, by Incropera and Dewitt
5. Principles of Heat Transfer, by Frank Kreith, Raj M. Manglik, Mark S. Bohn

**ME 341(22)    Instrumentation and Control Systems                      2(2,0)**

Instrumentation, Basic concepts of instrumentation system, Static and dynamic characteristics of measuring instruments. Different transducers for measuring and indicating, temperature, pressure, flow and level. Measurement errors. Calibration of measuring instruments  
Basic tools in modeling, analysis and design for linear feedback control systems. Modelling of mechanical, electrical, and electromechanical systems as differential equations, transfer functions and state equations. stability of open loop and closed-loop systems, time responses and frequency responses of low order systems.

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Bode plots for designing PID and lead/lag controllers. automatic control theory to real engineering problems with Matlab. state-space control techniques, nonlinear control, robust control and system identification.

**Recommended Books:**

1. Measurement and Instrumentation Principles by Alan S. Moris
2. Mechanical measurement by Bechwith
3. Automatic Control System by B.C.Kuo
4. Control Systems Engineering, by N.S.Nise,

**ME 222 & ME 222 L                      Mechanics of Materials - II                      3(2, 1)**

Plane Stress and Strain: Plane stress transformation, General Equation of Plane transformation, Stresses in Shaft Due to Axial Load and Torsion, Absolute Maximum Shear Stress, Plane Strain, General equation of Plane Strain Transformation, Mohr's circle for stress and strain, Material Properties Relations, Principal Stresses and Principal strains, Theories of failure, Yield criteria. Strain Rossets

Stress in Cylinder: Types of cylinders, Thin and thick curved bars. Thin walled pressure vessels, Thin Cylinder, stresses in thin cylinders, thick cylinders, Stresses in thick cylinders

Transverse Shear Stress: Shear in Straight Members, Shear Formula, Shear Stresses in Beams, Shear Flow in Built-up Materials, Analysis of statically indeterminate beams, Macaulay's method, Virtual work principle, energy methods, Castigliano's theorem.

**Recommended Books**

1. Mechanics of Materials, by F.P. Beer, E.R. Johnston.
2. Mechanics of Engineering Materials, by P.P. Benham and R.J. Crawford.
3. Advanced Theory and Applications, by J. Alexander and J.S. Gunasekra

**ME 342 & ME 342 L                      Robotics and Automation                      3(2,1)**

Robot definition and its types. Robot kinematics. 2D and 3D spatial relationships in Cartesian coordinate systems. Body fixed and space fixed transformations. Velocity and acceleration analysis of robot manipulators. Manipulate robot arms: kinematic chains, forward and inverse kinematics, differential kinematics. Eulerian angles and quaternions. Robot kinetics. Program and navigate mobile robots: robot and map representations, motion planning.

Automation of industrial control systems. Role of discrete control in manufacturing industries. Input/output devices for discrete data systems. Sensors and actuators. Analog to digital converters. Digital to analog converters.

Computer control/Embedded control (PLC) architecture. Programming in ladder logic or flow charts. Usage of subroutines, counter, timers, memory section and I/O scanning in PLCs. Scan cycle of PLC. Interacting of PLC to PC or human machine interface (HMI) for data analysis and control aspects. Case studies for different machining and assembly processes using a PLC. Industrial communications and its protocols. Sensor Bus (RS 485, ASI, HART Multidrop), Device Bus (ModBus, ProfiBUS-DP, CANopen, DeviceNet). Control network (Ethernet ). Introduction to SCADA (supervisory control and data acquisition systems). Interfacing of PLC or control devices to NC, CNC or robot to form a single station FMS.

**Recommended Readings:**



1. Introduction to Robotics, Mechanics and Control, by Craig,
2. Industrial Automation and Robotics: An Introduction ,by A.K. Gupta and S.K. Arora,
3. Robotics and Manufacturing Automation by C Ray Asfahl.
4. Automation, Production Systems, and Computer-Integrated Manufacturing by Mikell P. Groover
5. Manufacturing Automation: Metal cutting machines, Machine Tools, Vibrations and CNC design. By Yusuf Altintas.
6. PLC application manuals from Siemens, by Mitsubishi and Allen Bradley

**ME 323 (22)                      Machine Design – II                      2 (2, 0)**

**Mechanical Springs:** Introduction to several types of springs. The terminology used for helical compression, helical extension, helical torsion and Belleville spring. Spring Materials for above four types. Stresses and Deflection in springs for above four types. Design of helical compression, extension and torsion springs for static and fatigue loading. Design of Belleville spring for static loading.

**Bearings:** Introduction to several types of rolling-element bearings. Failure of rolling-element bearings. Selection of rolling-element bearings. Rolling-element bearing mounting details.

Introduction to lubricants and sliding contact bearings. Types of lubrications. Hydrodynamic lubrication theory. Materials for sliding contact bearings. Design of sliding contact bearings.

**Gears:** Introduction to several types of gears. Nomenclature of the gear tooth. Conjugate action and Involute properties. Interference and undercutting. Determination of gear tooth and gear mesh parameters. Gear manufacturing. Geometry and nomenclature of Spur, Helical, Bevel and Worm gears. Force analysis of Spur, Helical, Bevel and Worm gears. Stress and Strength equations for Spur, Helical, Bevel and Worm gears. Analysis and Design of gear mesh for Spur, Helical, Bevel and Worm gears.

**Clutches and Brakes:** Introduction to several types of clutches and brakes. Clutch and brake materials. Static Analysis of clutches and brakes. Design of Disk clutches. Design of Disk and Drum Brakes. Coupling. Flywheels.

**Recommended Books**

1. Mechanical Design: An Integrated Approach by R. L. Norton
2. Shigley's Mechanical Engineering Design by R. G. Budynas and J. K. Nisbett
3. Machine Elements in Mechanical Design by R. L. Mott
4. Design of Machine Elements by M. F. Spotts, T. E. Shoup and L. E. Horberger

**ME 332                      Metrology and Quality Assurance                      2 (2, 0)**

Introduction to Quality, Quality Control, Quality Assurance, Dimensions of quality, Quality function deployment, Product liabilities, Computer & quality control, Quality standards, Lean Enterprise, Types and Categories of Waste, lean implementation, 5S, SMED, VSM, Six sigma and DMAIC, SPC Tools (Pareto Chart, Cause & Effect, Scatter Plot, Histogram, Check Sheets), Data & data types, accuracy & precision, measurement of central tendency, population and sample, normal curve, tests for normality, control charts for variables, control charts for attributes, process capability, Process state of control, experimental design basics, Comparators, Gauges, Taylor's theory of gauging systems, Design of limit gauges, CMM, Profile projector, 3D laser scanner, metal fits and tolerances, standards of fits and tolerances, surface finish, surface analyzer.

**Recommended Books:**

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1. Quality Improvement, by Dale H. Besterfield,
2. Fundamentals of Dimensional Metrology, by Doston, Harlow, Thompson
3. Introduction to Statistical Quality Control, by Douglas C. Montgomery

**ME 361 (22)                      Energy Resources and Utilization                      2(2, 0)**

Introduction to energy & energy resources, renewable versus sustainable - fundamentals; Mineral Energy resources, Fossil Fuels in solid, liquid and gaseous state; Oil, Gas and Coal reserves, production technologies and trends, consumption trends, global warming & ocean acidification, Technologies for storage and conversion for heat and/or electricity.

Solar radiation—extraterrestrial solar radiation, components of radiation, geometry of the earth and sun, geometry of collector and the solar beam, latitude, season and daily insolation, effects of the earth's atmosphere and air-mass-ratio, measurements of solar radiation; Solar Thermal Applications: Types of solar Collectors, Solar water heating, calculation of heat balance, uncovered solar water heaters – progressive analysis, improved solar water heaters, systems with separate storage, selective surfaces, passive heaters and thermosyphon, evacuated collectors, social and environmental aspects; Air heaters, energy-efficient buildings, crop driers, space cooling, water desalination & solar ponds. Solar CSP systems,

Solar PV: Photovoltaic generation: the silicon p–n junction, photon absorption at the junction, solar radiation absorption, maximizing cell efficiency, solar cell construction, and types & adaptations of photovoltaic; Hydro-power— Principles of hydro-power, Advantages and disadvantages, assessing the resource for small installations; jet velocity, nozzle size, and shape number of hydro power systems; Power from the wind – wind energy conversion system (WECS), types & commonly used terms; linear momentum and basic theory, drag machines, dynamic matching and blade element theory; The photosynthetic process & Biomass and biofuels – biofuel classification, biomass production for energy farming, pyrolysis, alcoholic fermentation, anaerobic digestion for biogas, and vegetable oils and biodiesel, digester sizing & working digesters; Wave power – wave motion, wave energy, wave power and patterns; Tidal power – the cause of tides, enhancement of tides, tidal current/stream power, and tidal range power; Ocean thermal energy conversion (OTEC) & geothermal energy, Energy systems, storage and transmission: biological storage, chemical storage, heat storage and fuel cells.

**Text and Reference books:**

1. Renewable Energy Resources by John Twidell, Tony Weir
2. Renewable Energy: Power for a Sustainable Future by Godfrey Boyle
3. Energy Resources, Utilization and Technologies by Anjaneyulu Yerramilli and Francis Tuluri
4. Renewable Energy Sources for Electricity and Fuels, by T. B. Yohansson, H. Kelly, A. K. N Reddy, and R.H. Williams.
5. New Renewable Energy Resources, World Energy Council: by Kogan Page
6. Biomass energy in developing countries, by S.C. Bhattacharya and P. Abdul Salam,
7. Fundamentals of Renewable Energy Processes, by Aldo V. Da Rosa,

**ME 371                      Professional Ethics in Engineering Practices                      2(2,0)**

Morals and ethics, comparison of ethics and engineering ethics, ethics at personal and student level, The concept of professions, The importance of ethics in science and engineering, The role of codes of ethics, Professional responsibilities of engineers, The concept of morality, The importance of core values, Moral/ethical dilemmas and hierarchy of moral values, Factors affecting moral responsibility, and degrees of responsibility, Overview of ethical theories and applications, Basics of ethical analyses and decision-making, The importance if intention,

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Truth (personal and social), The concept of whistleblowing, Ethical leadership in engineering and society, Conflicts of interests, Ethics in the workplace, Fairness (personal and social), Ethics in the electronic and digital age, Responsible conduct of research, Intellectual property and society, Sustainable engineering, PPRA regulation, Engineering Practices code and regulation in Pakistan, NAB Regulation,

**Recommended Readings:**

5. Fundamental of Ethics for Scientists and Engineers, by Seebauer, E.G. and Barry, R.L.
6. Ethics in Engineering – Practice and Research, by Whitbeck, Caroline.

**ME 399L Semester Design Project 1(0,1)**

**ME 411 & ME 411 L IC Engines 3(2, 1)**

Introduction and historical perspective, classifications, operating cycles, components and operations of Reciprocator and Rotary IC engines. Stratified-Charge engines.

Ideal models of Engine Cycles, Processes and Thermodynamic Relations, analysis of ideal gas and fuel-air cycles, comparison with real engine cycles. Working principle of (2-stroke, 4-stroke) SI and CI engines. Engine design and operating parameters, Geometrical properties and performance characteristics of SI and CI engines under variable conditions of load and speed. Calculation of engine power and other parameters. Ignition/Injection timing advance. Variable Valve timing.

Fuel metering and carburetion. Electronic Fuel Injection (EFI) in SI and CI engines. Octane number and Cetane rating.

Combustion in SI and CI engines, Thermodynamics analysis, abnormal combustion (knocking) in SI and CI engines. Conventional and alternative fuels, fuel additives. Fuel injection and combustion in DI (Common Rail) and Gasoline direct injection (GDI) engines. multi-spray systems, analysis of cylinder pressure data, heat release analysis, fuel spray analysis, ignition delay.

IC Engine testing and control, exhaust gas analysis, regulated and unregulated emissions, controlling of emissions using in-cylinder and out-cylinder (after treatment) techniques, implications of exhaust gas recirculation (EGR) system, thermal reactor and catalytic converters.

Forced induction in IC Engines. Working principle of Turbocharging and Supercharging, its performance characteristics and comparison with naturally aspirated (NA) engine of equal power;

Engine Coolants and Cooling Systems. Types and Grades of Engine Lubricants and lubrication systems of the Engines. Latest developments in IC Engines.

**Recommended Books**

1. Internal Combustion Engine Fundamentals, by J.B. Heywood
2. Introduction to I. C. Engines, by Richard Stone
3. Engineering Fundamentals of the Internal Combustion Engine, by Willard W. Pulkrabek
4. Internal combustion Engines, by C. R. Ferguson and A. T. Kirkpatrick

**ME 478 Engineering Economics 2(2, 0)**

Principles of Engineering Economy, Engineering Economy and Design Process, Cost terminology: Fixed, Variable, Incremental, Direct, Indirect and Standard costs, Cash cost versus Book cost, Sunk cost, Opportunity cost, Life-cycle cost. General economic

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environment: Consumer and producer goods and services, Measures of economic worth, Necessities, Luxuries, and Price demand, Competition, Total revenue function, Cost, Volume, and Breakeven point relationships. Cost-Driven design optimization. Time value of money, Simple interest, Compound interest, Concept of equivalence, Notation and Cash-flow diagrams and Tables. Relationship between present and future equivalent values of single cash flows. Relating a uniform series or annuity to its Present and Future equivalent values. Interest formulas and Relationships for discrete compounding. Deferred Annuities, Equivalence calculations involving multiple interest formulas. Nominal and Effective interest rates. Evaluating a Single Project: Minimum Attractive Rate of Return (MARR), Present Worth method, Future Worth method, Annual Worth method, Internal Rate of Return (IRR) method, Payback Period method. Concepts for comparing alternatives: Investment and Cost alternatives, Ensuring a Comparable Basis, Study Period, Useful Lives, Equivalent Worth Methods, Rate of Return Methods, Unequal Useful Lives among Alternatives. Depreciation and Income Taxes, Price Changes and Exchange Rates, Cost Benefit Method, Breakeven and Sensitivity Analysis

#### Recommended Books

1. Engineering Economy by William G. Sullivan, Elin M. Wicks & C. Patrick Koelling.
2. Fundamentals of Engineering Economics by Chan S. Park
3. Engineering Economic Analysis by D. G. Newnan, T. G. Eschenbach, J. P. Lavelle & N. A. Lewis
4. Fundamentals of Economics for Applied Engineering by M. D. Sarder & S. Kant V.

ME 461

Energy Conservation and Management

2(2,0)

Fundamentals of Energy Management: Concepts of Energy conservation & Management, Energy Units and Calculations, Energy Benchmarking, Engineering Economic Analysis, Energy Auditing, Energy Performance Models, Electricity Tariffs  
 Energy Conservation in Electrical Systems: Introduction to Electrical Systems, Power Factor Upgrade, Power Quality Issues and Harmonics, Energy Conservation Opportunities in Motors, Variable Speed Drives, Energy Conservation Opportunities in Lighting Systems  
 Energy Conservation in Thermal Systems: Introduction to Boilers, Combustion Reactions and Stoichiometry, Energy Conservation Opportunities in Boilers & Steam Networks, Introduction to Cooling Equipment and Chillers, Energy Conservation Opportunities in Chilled Water Systems, Thermal Energy Storage  
 Energy Conservation in Compressors, Pumps, Heat Recovery & CHP: Introduction to Compressors and Compressed Air Systems, Energy Conservation Opportunities in Compressors, Introduction to Pumps, Energy Conservation Opportunities in Pumps, Waste Heat Recovery Opportunities, Cogeneration Options  
 Energy Management System ISO 50001: Introduction to ISO 50001, Benefits of ISO 50001, ISO 50001 Approach & Methodology, Requirements of Energy Management System (EnMS), Energy Policy & Energy Planning, Implementation & Operation of EnMS, Energy conservation standards: Pakistan building energy code, NEECA, PEECA

#### Recommended Books:

1. Energy Management and Conservation Handbook, by Frank Kreith and Yogi Goswami
2. Energy: Management, Supply and Conservation by Clive Beggs.
3. Energy Conservation Guidebook by Dale R. Patrick, Stephen W. Fardo, Ray E. Richardson, Brian W. Fardo.
4. Plant Engineers and Managers Guide to Energy Conservation Albert Thumann, Scott Dunning

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5. Inside Energy: Developing and Managing an ISO 50001 Energy Management System  
by C.H. Eccleston, F. March T. Cohen

**ME 471                      Production and Operations Management                      2(2, 0)**

Functions of management, production systems, the inputs to a production system and their relationship with the cost of production. Organizational structure. Selection of plant location and factors affecting industrial development in Pakistan. Productivity and factors contributing to productivity of organizations. Implementation of productivity based comprehensive continuous improvement system in production systems. Job production, intermittent batch production, continuous production, group technology. Inventory management techniques. Demand Forecasting using various time series techniques incorporating seasonality, growth trends and randomness. Regression based demand forecasting. Production planning and scheduling and capacity planning. Introduction to push and pull based manufacturing systems, Plant Maintenance strategies, their costing and relation to cost of production, total productive maintenance, RAMS. Computer applications, Case studies

**Recommended Readings:**

1. Operations Management by Jay Heizer, Barry Render, Jagdish Raja shekhar
2. Industrial Management by M.H. Zuberi and Nasir Hayat
3. Work Systems: The Methods, Measurement and Management of by Mikell P. Groover

**ME 415 (22)                      Power Plant Engineering                      2(2,0)**

Introduction to conventional and non-conventional power plants, Fuels and combustion, Fuels handling systems, Rankine cycle, steam power plants, Feed water treatment, Steam generators, Steam Turbines, steam condenser, Power plant air and water circulation systems, Brayton cycle, gas turbine power plants, Combined cycle power Plant, Application of gas turbines in aircraft industry, ram jets, jet propulsion, propulsive thrust, turbojet engines, turboprop engines and their performance characteristics Diesel Engine power plant, Nuclear power plants, Hydroelectric power plant, Power from Renewables / Non-conventional sources, Codes and Standards for Power Plant Design and Operation, power plant abnormal operating condition, Power plant Risk and reliability analysis, Power plant maintenance, Instrumentation and equipment in Power station, power plant site selection, power plants economics. Power plant environmental aspects, Emission control systems,

**Recommended Books**

1. Power Plant Engineering by R.K.Hedge
2. Power Plant Engineering by A.K.Raja
3. Thermal power plant design and operation by D. Sarkar
4. Thermal Power Plant Performance Analysis by G Fancisco

**ME 412 (22) & ME 412 (22) L                      Refrigeration and Air Conditioning 3(2, 1)**

Definition and basic terminology, refrigeration cycle, vapor compression cycle, COP, introduction to pressure-enthalpy chart, types of refrigerants, air cycle refrigeration, vapor

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absorption refrigeration and air conditioning, working principle of thermally driven cooling machines, single, double and triple effect absorption chiller, adsorption chiller, desiccant evaporative cooling, ejector cycle.

Cooling and heating: Indoor and outdoor air conditions, comfort air conditions and comfort zone, indoor air quality, psychrometry, psychrometric chart and psychrometric properties, central air conditioning system, essential components of central air conditioning plant, water chiller and water heater, air handling unit, chilled water and hot water re-circulating system, return air supply system, fresh air supply system and air mixture chamber, supply fan, air dust cleaning and bacteria removal, air supply and air return terminals, diffusers, dampers, grillers and registers,

Air-conditioning system design: CFM rating and tons of air conditioning of central air conditioning plant, cooling and heating loads, calculation procedures, duct sizing and piping design, pumps and fans selection, air ventilation, calculation of fresh air supply of multi-story buildings, air handling units for treatment of fresh and return, forced convection-based air ventilator design, Indoor air quality: Dust and bacteria removal methods.

Cooling towers: Types of cooling towers, performance of cooling tower, hydronic terminal units

#### Recommended Books:

1. Air Conditioning Principles and Systems, by Edward G. Pita,
2. Principles of Refrigeration. By Dossat, R. J
3. Ventilating, and Air-Conditioning Analysis and Design, by W. F. Stoecker,
4. Heating and Cooling of Buildings, by Ed. Kreider, Curtiss & Rabl,
5. HVAC Systems Design Handbook, by Haines, Roger W. Wilson, Lewis,
6. Handbook of Air Conditioning and Refrigeration. by Shay n K. Wang,

ME 421 (22)

Mechanical Vibrations

4(3, 1)

Fundamentals of Vibration: Basic concepts of vibration, Classification of vibration, Vibration analysis procedure, Spring elements, Mass or inertia elements, Damping elements, Harmonic motion, Harmonic analysis.

Free Vibration of Single-Degree-of-Freedom Systems: Free vibration of an undamped translational system, Free vibration of an undamped torsional system, Free vibration with viscous damping, Graphical representation of characteristic roots, Parameter variations and root locus representations, free vibration with Coulomb damping, free vibration with Hysteretic damping.

Harmonically Excited Vibration: Response of an undamped system under harmonic force, Response of a damped system under harmonic force, Response of a damped system under harmonic motion of the base, Response of a damped system under rotating unbalance, forced vibration with Coulomb damping, forced vibration with Hysteretic damping, Self-excitation and Stability analysis, Transfer-function approach, Solutions using Laplace transform, Frequency transfer functions.

Two-Degree-of-Freedom Systems: Equations of motion for forced vibration, Free vibration analysis of an undamped Translational system, Free vibration analysis of an undamped Torsional system, Coordinate coupling and Principal coordinates, Forced-vibration analysis, Self-excitation and Stability analysis.

Determination of Natural Frequencies and Mode Shapes: Dun Kerley's Formula, Rayleigh's Method

*MAA*

Vibration Measurement and Applications: Transducers, Vibration Pickups, Frequency-measuring instruments, Vibration exciters, Signal analysis, Dynamic testing of machines and structures, Experimental modal analysis, Machine-condition monitoring and Diagnosis.

**Recommended Books**

1. Mechanical Vibrations, by S. S. Rao.
2. Mechanical Vibrations: Theory and Applications, by S. G. Kelly
3. Theory of Vibration with Applications, by W. T. Thomson and M. D.

**ME-472**

**Supply Chain Management**

**2(2, 0)**

Key Concepts of SCM: introduction to SC and SCM. Supply Chain Drivers, Responsiveness, Efficiency, Vertical Integration, Supply Chain Structure. Supply Chain Operations; Planning & Sourcing. Forecasting Variables, Forecasting Methods, Aggregate Planning, Promotions, Types of Inventory, Economic Order Quantity (EOQ), Procurement Activities, Credit and Collections, Supply Chain Operations; Making & Delivering. Product Design and Supply Chain, Production Scheduling, Facility Management, Economic Lot Size (ELS), Run-out Time, Order Management, Delivery Scheduling, Outsourcing. New Technology in SCM, Cloud Computing, Data Transmission, Databases and Business Analytics, SC Application Systems, E-business and Supply Chain Integration. Metrics for Measuring SC Performance, Markets and Required Performance, Measurement Categories, Dashboards, Performance Metrics & Diagnostics, Data Sharing. SC Coordination, Bullwhip Effect, Synchronized SC, Collaboration Framework. SC Opportunities. SC for Competitive Advantage. Real-Time SC

**Recommended Books:**

1. Essentials of Supply Chain Management by Michael H. Hugos
2. Supply Chain Management: Strategy, Planning, and Operation by Sunil Chopra & Peter Meindl
3. Principles of Supply Chain Management: A Balanced Approach by Joel D. Wisner
4. Global Supply Chain and Operations Management by D. Ivanov, A Tsioulanis & J Schönberger

**ME 353 & ME 353 L**

**Computational Engineering-I**

**3(2,1)**

Round-off errors, floating point arithmetic, convergence, solution of non-linear equations for locating roots: bracketing methods – bisection and false position methods, open methods - Newton Raphson; and Secant methods, finite difference: forward; backward; and central difference, numerical differentiation, approximating the derivative, numerical integration: trapezoidal; Simpson's rule; composite trapezoidal and Simpson's rules, solution of differential equations: Euler's method; Runge Kutta methods, solution of linear simultaneous equations: Jacobi's method; Gauss-Seidel method; LU decomposition, solution of partial differential equations: hyperbolic equations; parabolic equations, elliptic equations, explicit and implicit schemes, stability of transient solutions, CFL number, applications in fluid dynamics and heat transfer problems.

**Recommended Books:**

1. "Numerical Methods for Engineers" by Raymond Canale and Steven C. Chapra,
2. "Numerical Analysis" by Richard L. Burden, J. Douglas Faires and Annette M. Burden,
3. "Essential Computational Fluid Dynamics" by Oleg Zikanov,

*AMS*

ME 453 & 453 L

Computational Engineering-II

3(2,1)

Introduction: Review of matrix operations; Solution methods – direct methods, variational methods, weighted residual methods; 8 steps of FEA; Types of elements used; Practical applications of FEA; Review of various types of FEA software.

FEA of 1-Dimensional Structural Problems: Solution of spring elements by direct stiffness and variational methods; Solution of plane- and space-trusses, beams, frames and grids – interpolation functions, transformation matrices, local and global stiffness matrices, boundary conditions, calculating stresses and deformations, FEA vs exact solution.

FEA of 2-Dimensional Structural Problems: Solution of plane-stress and plane-strain problems – interpolation functions for constant strain triangle, local and global stiffness matrices, boundary conditions, calculating stresses and deformations.

FEA of 1-Dimensional Non-structural Problems: Introduction to one-dimensional heat transfer and fluid dynamics problems.

**Recommended Textbooks**

1. A First Course in the Finite Element Method by, Daryl L. Logan, Cengage Learning
2. Concepts and Applications of Finite Element Analysis by, Robert D. Cook
3. Finite Element Analysis – Theory and Applications with ANSYS, by Saeed Moaven

ME 464 L

Energy & Power Systems

1(0, 1)

ME 496 L

FYDP-I

3(0, 3)

ME 497 L

FYDP-II

3(0, 3)



## ELECTIVES

ME 416

Gas Dynamics

2(2,0)

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

### Recommended Books

1. "Modern Compressible Flow with Historical Perspective", by John D & Anderson
2. "Elements of Gas Dynamics", by Liepmann HW and Roshko A.
3. "The Dynamics and Thermodynamics of Compressible Flow", by Shapiro A.
4. "Compressible fluid flow", by Oosthuisen P & Carscallen W.

ME 417

Environment and Pollution control

2(2, 0)

Introduction to environmental engineering and environmental legalization, clean and polluted air, water and pollution effect. Air, water, land, noise and thermal pollution. Sources and nature of pollution, industrial furnaces automobiles, aircrafts, thermal power plants, industrial waste, accidental and shortage leakage of hydrocarbon. Pollution control; pre-pollution control of air and water, improvement in combustion process, industrial waste treatment. Post pollution control, air pollution control technologies, water pollution control technologies. Thermal and noise pollution control, Nuclear power plants pollution, ISO 14000, pretreatments, post treatment, EPA, Recycling,

### Recommended Books:

1. Fundamentals of Environmental Engineering by Danny D. Reible
2. Environmental Engineering by Weiner, Mathews, Aarne

*AS*

**ME 418      Aerodynamics and Aerospace Structures      2(2,0)**

Introduction to aerodynamic and aerospace structures, Compressible Aerodynamics, Analysis and design of compressible, inviscid flows; isentropic flow, shock waves, Prandtl-Meyer expansions, supersonic nozzles and diffusers. Airfoils in compressible flow and small perturbation theory, introduction to hypersonic-flow theory.

Incompressible Aerodynamics, Dynamics of vector fluid flow fields. Ideal fluid flow. Introduction to viscous boundary layers. Airfoil Theory. Finite-wing theory.

Experimental aerodynamics, aerodynamic testing and instrumentation. Supersonic and low-speed wind tunnel testing including shock waves, aerodynamic forces, pressure distribution on an airfoil and boundary layers, application of schlieren optics, thermal anemometry and laser doppler velocimetry, Aerospace structures, Torsion of thin-walled beams. Flexural shear flow. Thermal analysis of aerospace structures. Introduction to composite materials. Buckling of plates.

**Recommended Books:**

1. Aerodynamics for Engineers by J. J. Bertin and R. M. Cummings
2. Aircraft Structures for Engineering Students by T. H. G. Megson

**ME 422      Fatigue & Fracture Analysis      2(2,0)**

Introduction to fracture and fracture mechanics, principles of linear-elastic and elastic-plastic fracture mechanics, micro-structural effects on fracture in metals, ceramics, polymers, thin films, biological materials and composites, toughening mechanisms, crack growth resistance and creep fracture, failure assessment diagram and quantitative analysis of fracture.

Introduction of fatigue and fatigue damage, fatigue classification, stress and strain-life approach to fatigue, dislocation sub-structures in single crystals, fatigue crack growth models and mechanisms, variable amplitude fatigue, corrosion fatigue, predicting failure loads on flawed structures, predicting time to failure due to fatigue loading on cracked and uncracked structures, designing to prevent failure, analysing stress corrosion cracking, and conducting ASTM standard tests and case studies of fracture and fatigue in structural, bio-implant, and microelectronic components.

**Books:**

1. Fatigue and Fracture: Understanding the Basics, by F.C Campbell
2. Fatigue of Materials. by Suresh, S
3. Fracture Mechanics. By Anderson, T. L. CRC Press,
4. Deformation and Fracture Mechanics of Engineering Materials. by Hertzberg, R. W

**ME 423      Advanced Mechanics of Materials      2(2, 0)**

Three-dimensional stress at a point, stress equation of equilibrium, laws of stress transformation, principal stresses, displacement and strain, equations of strain transformation, principal strains, compatibility. inelastic bending and torsion, Thick cylinders, axial stresses in thick cylinders, compound cylinders, plastic deformation of thick cylinders, thin circular plates, beams on elastic foundation.

**Recommended Books**

1. Mechanics of Engineering Materials by R.J. Crawford and P.P. Benham.
2. Advanced Mechanics of Materials by Arthur P. Boresi, Richard J. Schmidt

**ME 424      Design Ergonomics      2(2,0)**

*M. J. S.*

Fundamental concepts of Ergonomics, types of Ergonomics (Physical Ergonomics, Cognitive Ergonomics, and Industrial Ergonomics), Fitting man to job and fitting job to man concepts (Human Centered Design Thinking), Anthropometry and Ergonomic Design, Designing for 5<sup>th</sup> and 95<sup>th</sup> percentiles, Inclusive Design (Design for All),

Ergonomics workplace design, Design for Sitting and Standing work, Principles of Motion Economy and role of Ergonomics, Ergonomic principles for maintaining Illumination, Noise, Vibration and Temperature standards at workplace, Ergonomics workplace risk assessment and design of interventions for safety and productivity,

Role of Ergonomic Design in complex Industrial Systems, Human-Machine Interaction (HMI) Model, Digital Human Modelling (DHM) based design assessment, Organizational Ergonomics and work performance

#### Recommended Books

1. Ergonomics in Design: Methods and Techniques (Human Factors and Ergonomics) by Marcelo M. Soares and , Francisco Rebelo
2. Human Factors and Ergonomics in Practice: Improving System Performance and Human Well-Being in the Real World by Steven Shorrock, Claire Williams
3. Introduction to Human Factors and Ergonomics by R. S. Bridger,

#### ME 431                      Fundamentals of Tool Design                      2(2,0)

Introduction to tool design, Design process, Economics of tool design, Cutting Tool Material, Cutting Tool Design, Factors effecting tool design, Tool wear, Cutting Forces and Tool Life Calculations, Nomenclature of single and multi-edge cutting tools, Locating and Work holding Principles, Locating and Clamping types and methods, Clamping principles, non-mechanical & power clamping, Jig design, Jig design principles, fixture design, classification of fixtures, fixture principles, fixture forces, Die Design, die operations, die forces, progressive and compound dies, power presses, Modular and Automated Tool Handling, Tool design for Inspection and Gaging, Tool Design for Joining Processes, Computer aided modular fixture design, Form feature classification, fixture setup planning, layout design, computer aided die design.

#### Recommended Books:

1. Integrated Process & Fixture Planning, Theory, Application & Practice, by Awais A. Khan,
2. Fundamentals of Tool Design, by John G. Nee
3. Jigs and Fixture Design by Edward G. Hoffman,
4. Advanced Computer Aided Fixture Design, by Rong

#### ME 432                      Computer Integrated Manufacturing                      2(2,0)

Introduction to CIM -Type of Manufacturing System -Elements of CIM -Automation and CAD/CAM Concurrent Engineering. Manufacturing System -Group Technology (GT) -Process Planning -Production Planning and Control. Fundamental of CAM -Numerical Control (NC) -Control Systems of the NC Machine Tool -Adaptive Control -Sensors for Computer-Controlled Machine Tool -NC Part Programming. Material Handling and Storage -Automated Material Handling -Analysis for Material Handling System -Automated Guided Vehicle System -Automated Storage System -Automated Storage/Retrieval System -Applications. Flexible Manufacturing Systems -FMS Workstation -Material Handling and Storage System -

*M. J. Swartz*

Computer Control System -Planning the FMS -Analysis Methods for FMS -Applications. Numeric Control and Robots -Numerical Control -Industrial Robotics -Programmable Logic Controllers. Material Requirements Planning (MRP) -Objectives of MRP -Basic Concepts and Inputs to MRP -Bill of Material (BOM) -How MRP works. Shop Floor Control (SFC) - Functions of SFC System -Operation Scheduling -Priority Rules for Job Sequencing. Just-In-Time (JIT) -Introduction -Prerequisites for JIT -Elements of JIT -Toward Eliminating Inventories in JIT System. Implementation of CIM

**Recommended Readings:**

1. Automation, Production Systems, and Computer-Integrated Manufacturing, by Mikell P. Groover,
2. Computer Integrated Manufacturing by James A. Rehg , Henry W. Kraebber
3. Computer Integrated Manufacturing, by N. Venkateshwaran
4. Systems Approach to Computer-Integrated Design and Manufacturing, by Nanua Singh

**ME-433                      Micro and Nano Manufacturing                      2(2, 0)**

Basics PCB manufacturing process, basic semiconductor manufacturing process, Introduction of Top-down approaches, Introduction of Bottom-up approaches, Lithography, etching basics, Thin-film deposition methods, evaporation, sputter deposition, Chemical vapor deposition, Physical Vapor Deposition, Molecular Beam Epitaxy. Introduction to nanotechnology and nanomanufacturing, Taxonomy and geometry of nanostructures, Techniques for characterizing nanostructures, Electronic and optical properties of nanostructures, Mechanical properties of nanostructures, Thermal properties of nanostructures, Nanoparticle synthesis in solution, Self-assembly of monolayers and multilayers

**Recommended Books:**

1. Fundamentals of semiconductor manufacturing and process control. By May, Gary S., and Costas J. Spanos.
2. Nanomanufacturing handbook. by Busnaina, Ahmed. ,

**ME 434                      Engineering Tribology                      2(2, 0)**

Basic principles of tribology--the study of friction, wear, and lubrication--including the importance of materials, surfaces, design, operating conditions, environment, and lubrication on friction, wear, and surface damage in any system. Hydrodynamic lubrication, Hydrostatic lubrication, Elasto-hydrodynamic lubrication, Lubricants, Surface modification, Application of tribological theories, concepts, techniques, and approaches to design, research, development, evaluation, and problem-solving. Thin Films and ceramic coatings for tribological applications, mechanical properties of the ceramic coatings, frictional performance of ceramic coatings, wear performance of ceramic coatings, Toxicology and chemical analysis of ceramic coatings for bio medical applications,

**Recommended Books:**

1. Engineering Tribology, by John A. Williams,
2. Tribo-physics and Design of Tribological Systems by Suh, N. P. Englewood Cliffs,
3. Tribology, Principles and Design Applications, by Arnell
4. Fundamentals of Machine Elements, by Hamrock, Jacobson, and Schmid

*MA*

ME 435

Product Development

2(2,0)

Product Design Philosophy: introduction Multiple sources, user friendliness, human factors and ergonomics, sense of proportion, safety factors, Design Psychology: introduction, colour, aesthetics, emotions, structure and concept of space, Design and Planning: problem statement, customer, needs, product design specifications; product design planning, project plan; Gantt chart, critical path method, Principles of Design: basic design parameters; understanding product design specifications, product design process, flow and the implementation of its principles; product packaging, universal principles of design Engineering Design: conceptual and detailed engineering design; establishing product functions; functional decomposition, concept creation, concept selection, computer aided design (CAD) modelling, design simulation, manufacturing documentation, engineering drawings, Design for Manufacturing and Assembly: Factors influencing process selection; fabrication guidelines; design for manufacturing; design for assembly Sustainable Product Design: product reuse; recyclability; green design; design for disassembly (product life cycle), reliability and failure; risk assessment; preliminary hazard analysis, failure modes and effects analysis, energy efficient and environment friendly product design; eco-friendly systems; green economy, Intellectual property and patents

**Recommended Books:**

1. Product Design and Development by K. Ulrich, K.T. Ulrich, S.D. Eppinger, and M.C. Yang.
2. The Design Thinking Playbook: Mindful Digital Transformation of Teams, Products, Services, Businesses and Ecosystems by M. Lewrick, P. Link, and L. Leifer.
3. Universal Principles of Design, Revised and Updated: 125 Ways to Enhance Usability, Influence Perception, Increase Appeal, Make Better Design Decisions, and Teach Through Design by W. Lidwell, K. Holden, J. Butler, and K. Elam.
4. Product Design: Techniques in Reverse Engineering and New Product Development. By K.N. Otto and K.L. Wood.
5. The Mechanical Design Process by D. Ullman.

ME 452

Computational Fluid Dynamics

2(2,0)

Introduction to CFD, advantages and disadvantages of numerical prediction, continuum, Eulerian and Lagrangian description of fluid, substantial derivative, Reynolds transport theorem, equations for conservation of mass; momentum; energy and chemical species, governing equations in conservative forms, boundary conditions, classification of partial differential equations, numerical discretization of domains, introduction to finite element; finite difference; and finite volume methods, time and space discretization in finite difference methods, truncation error, higher-order approximation of derivatives, discretization of mixed derivatives, numerical dissipation, up-winding, implementation of boundary conditions, implicit and explicit techniques for solution of difference equations, round-off error discretization, stability analysis of implicit and explicit schemes, solution algorithms for incompressible flows, role of pressure, co-located and staggered grids, Poisson equation solvers, the Projection method, SIMPLE algorithm, finite volume methods, integral formulation, boundary conditions, introduction to turbulence, turbulence modeling

**Recommended Books:**

1. "Essential Computational Fluid Dynamics" by Oleg Zikanov,
2. "Computational Fluid Dynamics: The Basics with Applications" by John D. Anderson,

3. "A first course in Computational Fluid Dynamics" by H. Aref and S. Balachandar,  
**ME 465                      Clean Coal Technology                      2(2, 0)**

Introduction to Clean Coal Technologies: Role of coal in the overall energy situation, History of energy production from coal, Indigenous coal reserves, Recent advances in clean energy generation from coal, Coal Preparation for clean energy generation: Coal preparation methods including fine coal treatment, Properties of coal and impurities in relation to preparation (emphasis on Thar coal), Wash ability studies and evaluation of coal for different uses, Breaking and crushing; screening, wet concentration methods of coarse coal; wet concentration methods of fine coal, Status & scope of coal preparation by flotation, Dust collection in coal processing and handling Clean coal gasification: Coal gasification basics/types, Coal gasifier designs/Reaction kinetics, Direct blowing & reverse blowing concepts, Air separation and gas cleanup, Syngas cleanup/ CO<sub>2</sub> capture for CCS.

Underground Coal Gasification (UCG): Technology Description , Geological aspects in UCG/ coal seam, overburden and water table , Thar coal UCG case study, Process flow diagrams, Channel formation b/w injection & production wells, Process parameters/Coal & Rock properties, Economics of UCG, Coal to liquid (CTL): Direct coal liquefaction, Process description, Process parameters & flow sheet diagrams, Single stage & two stage liquefaction, DCL catalytic reactors/ overview, Commercial Plants, Environmental considerations

Indirect coal liquefaction (Fischer Tropsch Process): Process Description/ Process Flow diagrams, FT Process/ Reaction mechanism & kinetics, FT process parameters, Catalyst Preparation & Characterization, FT Reactor core concepts/Process control, Energy analysis/ Heat exchanger network optimization in FT synthesis, Products refining Integrated gasification combined cycle (IGCC) : Process description, Thermodynamic cycle of IGCC, Development of process flow diagram, CO<sub>2</sub> pre combustion capture & storage, Energy requirements

**Recommended books:**

1. Clean Coal Engineering Technology, by Bruce G. Miller,
2. Coal Gasification and Its Applications, by Brian F. Towler, David Bell, and Maohong Fan
3. Carbon Capture and Storage, by Stephen A. Rackley,
4. Integrated Gasification Combined Cycle (IGCC) Technologies, by Ting Wang Gary Stiegel

**ME 466                      Nuclear Power Plant                      2(2, 0)**

Role and importance of nuclear energy, Particle wavelength, Excited states and radiation, Nuclear stability and radioactive decay, Nuclear reaction, Binding energy, Radioactive decay, Interaction of radiation with matter: Neutron interaction, Cross-sections, Neutron attenuation, Neutron flux, Neutron cross-section data, Energy loss in scattering collision, Fission,  $\gamma$ -ray interaction with matter

Nuclear reactor: Fission chain reaction, Nuclear reactor fuel, Nuclear power plants  
 Nuclear Reactor Systems and components: Steam generator, Pressurizer, Steam supply system, Reactor Containment, Turbine, Cooling Tower; Nuclear reactor theory: Neutron flux, Fick's law, Equation of continuity, Diffusion equation, heat Removal from reactor, Heat generation in reactors, Conduction, Convection, Two Phase Flow, Boiling Heat transfer, Nuclear reactor safety: Reliability, Risk, Safety, Case studies of Nuclear power plant accidents,

**Recommended Books:**



1. Introduction to Nuclear Engineering, by J. R. Lamarsh and A. J. Baratta .
2. Fundamentals of Nuclear Reactor Physics, by E. E. Lewis.
3. Nuclear Energy: An introduction to the concepts, systems, and applications of nuclear processes, by R. L. Murray.
4. Nuclear Engineering Theory and Technology of Commercial Nuclear Power, by R. A. Knief

**ME 467                      Hydroelectric Power Plant                      2(2, 0)**

Hydroelectric power plant includes topics Hydropower Resources, Hydropower Sites, categories of hydropower Plant, large Hydropower Plants: Dams and Barrages, run-of-river Scheme, Flow duration curve, estimation of gross energy, by-pass channel, Dam and Reservoir, Dam types, Hydropower Turbines, Impulse Turbines, Reaction Turbines, Francis turbine, Propeller and Kaplan Turbines, Deriaz Turbine, Generators, Small Hydropower, Environmental Considerations, Environmental Assessment, Resettlement, Biodiversity, Geological Effects, Sedimentation and Downstream, Effects, Greenhouse Gases, Interregional Effects, Hydropower and Intermittent renewable Generation and Cost of Electricity Generation from Hydropower Plants.

**Recommended Books:**

5. Hydropower, by Paul Breeze
6. Introduction to Hydro Energy Systems, by Wagner, H.J. and M. Jyotirmay.

**ME 468                      Rail Motive Power Systems                      2(2,0)**

Locomotive Systems Power, Locomotive Systems, Introduction to electric railway traction including traction mechanics, rail systems, electrical drives, and power supplies, Electric Traction by Electric Railways for Ordinary Service. Electric Traction for Special Situations. Electric Traction in Routine Use for Trains for Economic Reasons. DEMUs (diesel multiple units), EMUs (electric multiple unit), Incomes and Mileage of Railways Operating Electric Trains. Introduction of Internal Combustion engine structure and sub-systems. Engine cycles, combustion. Engine emissions and control strategy. Advanced engine design and introduction to advanced engine technologies.

**Recommended Books:**

1. Electric Traction for Railway Trains by Edward P. Burch, Forgotten Books,
2. Introduction to internal combustion engines by Richard Stone, , Basingstoke: Palgrave Macmillan,

**ME 469                      Energy Storage Technologies                      2(2,0)**

Intro to Energy Storage: Introduction to the traditional bulk power system, its operation, layout and control. Design tradeoffs of applying energy storage solutions throughout the transmission, sub-transmission and distribution networks. System impacts and effects of distributed generation on the operation and control of the bulk power system.

Electrochemical Energy Storage: Batteries, Introduction to battery storage including lead acid, lithium ion, flow, and emerging battery technologies. Comprehensive analysis of design considerations and application specific needs. Impacts on system cost in terms of life cycle, environmental, and reliability of the end solutions. Ultra-Capacitors: Introduction to ultra-capacitors including operation, applications, and emerging technologies. Topics include the usage in mobile applications and proximity to renewable energy sources. Discussion of primary target market usage in today's energy and power sectors

*M. S. M.*

Super Conducting Magnetic Energy Storage: Introduction to Super Conducting Magnetic Energy Storage (SMES) operation, theory of usage and emergent research. Case study large utility scale energy storage facilities

Mechanical Energy Storage: Pumped hydroelectric energy storage, Models for pumped hydro capacity and availability, System cost, capacity, conversion efficiency,

Compressed Gas: Models for compressed gas capacity, efficiency, and availability. System cost, capacity, conversion efficiency, and siting will be discussed along with barriers to adoption. Possible applications in carbon capture and sequestration

Flywheel: Models for flywheel capacity, availability, efficiency, and self-discharge. Applications in transportation, uninterruptible power supply (UPS), pulse power, and bulk storage. Selection and design of flywheels for safety and availability in various applications.

Thermal: Introduction to thermal storage with an emphasis on residential and utility scale applications including molten salts, cold reservoirs, and phase change materials. Analysis of design considerations, material selection, and application specific constraints. Applications in renewable energy particularly utility scale solar and geothermal power production.

#### Recommended Books:

1. Energy Storage for Power Systems, by Ter-Gazarian, A.G. ,
2. Energy Storage, by Huggins R.A.
3. Thermal Energy Storage; Systems and Applications, by İbrahim Dincer, Marc A. Rosen ,
4. Sustainable Thermal Storage Systems: Planning, Design, and Operations, by Lucas B. Hyman
5. Large Energy Storage Systems Handbook by Frank S. Barnes, Jonah G. Levine

ME 460

Energy Economics and Planning

2(2,0)

Energy and Resource Economics - Economic theories and management of energy resources, Evaluation of external effects of energy use; Modeling energy and resource use; Using energy mix in devising sustainable development strategies and plans, econometric models. Energy Challenges, Pricing and Macro Economy-Concepts - Energy pricing, Measures to reduce energy import bill, Role of energy resources in economic development, analyze the impact on different economies.

Energy Tariffs, Taxation and Subsidies - Types of tariffs, current tariff system, Taxation and Subsidies, Need for comprehensive reforms for pricing system, Energy contracts, levelized cost of electricity, energy audits, asset management.

The Economics of Climate Change - Energy and Climate Change, Clean Development Mechanism Estimation of damage costs from climate change; evaluation of climate change mitigation options; problems of international cooperation on climate change policy; distributional implications of climate change and climate change policy. Energy Management - Project management, Demand side management; Electrical Systems load scheduling/shifting, Energy modeling and forecasting; Financing energy conservation programs.

Optimal planning of resources, logistics, distribution and storage in the end to end energy value chain from upstream natural gas production through mid-stream transportation and storage to downstream power generation, utility distribution and consumption. Smart Grid Optimization. Supplier and customer relationship management, contracts management. Lean-Six Sigma energy system process design. Power systems reliability and control, preventive maintenance, predictive maintenance, process and service quality control. Future Readiness: Key Trends, Business Opportunities and Challenges, Future Scenario Planning



**Recommended Books:**

1. Energy Economics: Concepts, Issues, Markets and Governance. by Bhattacharyya, S.C.
2. Energy Engineering and Management, by Chakraborti, A.
3. Energy Management Handbook, by Turner, W.C. and S. Doty
4. Environmental and Natural Resource Economics, by Thomas Tieten berg.
5. Resource Economics, by Jon M. Conrad,

**ME 473                      Industrial Management Systems                      2(2,0)**

Quality Management System, implementation planning, documentation planning, defining organizational processes, quality practices, refinement, deployment, continual improvement, ISO 9001 standards, environmental management system, introduction and importance, typical plan, do, check and act processes of environmental management system, familiarization with ISO 14000 standards, Energy Management System: Energy policy, planning, implementation, operation, auditing, reporting, Familiarization with ISO 50001 standards, occupational health and Safety management system, management responsibility, identifying and analyzing workplace hazards, developing and implementing safety based procedures, workforce involvement, familiarization with OHSAS 18001 standards, IT Management System, introduction, supply chain management system, introduction

**Recommended Books:**

1. Quality Management System Handbook for Product Development Companies by V. Nanda
2. Installing Environmental Management Systems: A Step-by-Step Guide by C. Sheldon and M. Yoxon
3. Inside Energy: Developing and Managing an ISO 50001 Energy Management System by C.H. Eccleston, F. March T. Cohen
4. Energy Management Handbook by W.C. Turner and S. Doty
5. Occupational Health and Safety Management: A Practical Approach by C.D. Reese

**ME 474                      Total Quality Management                      2(2,0)**

Introduction to Quality, Total quality concept, Quality management system, Evolution of quality concepts and quality paradigms, Cost of Quality, TQM principles and strategies, Contributions of Deming, Juran and Crosby - Barriers to TQM, Organization for total quality, process management, Quality teams and teamwork processes, Basic problem solving tools for quality improvement, Leadership and empowerment, Performance Measures for TQM, Quality standards, Global quality awards (Deming Prize, Malcolm Baldrige), Quality improvement: Six sigma, Lean, kaizen, 5S, SPC, Quality through planning and design: QFD, policy deployment, Quality through innovation, Quality through IT, TQM implementation and case studies

**Recommended Books:**

1. Quality Management, by Goetsch and Davis,
2. Quality Management Essentials, by Hoyle,
3. Quality planning and analysis: from product development through use, by Gryna,
4. Total Quality Management, by D. H Besterfield,
5. Total Quality Management by John Oakland

*MJS*

**ME 475 Risk and Reliability Engineering (2,0)**

Uncertainty modelling and propagation; learning models, applicable reliability, risk and safety standards). Time-dependent risk, safety and reliability; System failure analysis (FMECA, FTA; Hazard Analysis; RBD, Mathematical methods for reliability; Monte Carlo, Bayesian Networks); risk, safety and reliability analysis of binary and multistate systems; Dependence in systems; Network reliability analysis; Physically-based system models; Component importance measures and system sensitivity analysis; Problems). Basic decision analysis (with given information); Utility theory; Influence diagrams; Decision analysis with varying information; Value of information; Problems).

**Recommended Books:**

1. Risk Assessment: Theory, Methods, and Applications by Marvin Rausand.
2. Engineering Decision Making and Risk Management by Jeffrey W. Herrmann.
3. Handbook of RAMS in Railway Systems: Theory and Practice by Qamar Mahboob and Enrico Zio.
4. Reliability Engineering - Theory and Practice by Alessandro Birolini.

**ME-476 Operations Research 2(2,0)**

Introduction, Overview of How Operations Research and Analytics Professionals Analyze Problems, Introduction to Linear Programming, Solving Linear Programming Problems: The Simplex Method, The Theory of the Simplex Method, Duality Theory, Linear Programming under Uncertainty, Other Algorithms for Linear Programming, The Transportation and Assignment Problems, Network Optimization Models, Dynamic Programming, Integer Programming, Nonlinear Programming, Metaheuristics, Game Theory, Decision Analysis, Queueing Theory, Inventory Theory, Markov Decision Processes, Simulation

**Recommended Books:**

1. Introduction to Operations Research by Frederick Hillier and Gerald Lieberman
2. Operations Management by Gerard Cachon and Christian Terwiesch

**ME-477 Organizational Behaviour 2(2,0)**

Introduction to Organizational Behaviour, Managing Demographic and Cultural Diversity, Understanding People at Work: Individual Differences and Perception, Individual Attitudes and Behaviours, Theories of Motivation, Designing a Motivating Work Environment, Managing Stress and Emotions, Communication, Managing Groups and Teams, Conflict and Negotiations, Decisions Making and Creativity, Leading People Within Organizations, Power and Influence in the Workplace, Organizational Structure and Change, Organizational Culture, case studies and Exercises

**Recommended Books:**

1. Organizational Behavior By Steven McShane and Mary Von Glinow
2. Organizational Behavior: Improving Performance and Commitment in the Workplace by Jason Colquitt and Jeffery LePine
3. Organizational Behavior and Management by Robert Konopaske and John Ivancevich

**ME 481 Bio Engineering 2(2, 0)**

Introduction to Bioengineering: Introduction to some major diseases/biological systems and the engineering used in current treatments. Regulatory and ethical issues in the design and development of medical devices.

*M. Amin*

**Biomaterials and Manufacturing Processes:** Introduction to Biomaterials, Current clinical applications of biomaterials. Nano-biomaterials manufacture, characterization and use as biomaterials. Case studies on the design and manufacture of both external and internal implants (e.g. prosthetics for amputees, joint replacements, tissue scaffolds, etc.). Manufacturing processes used to biomaterials.

**Biomechanics:** Muscles and movement. Skeletal biomechanics, Introduction to Biomechanics of human movement, human hand and foot biomechanics, functional biomechanics of the spinal column. In-vivo musculoskeletal diagnostic technique.

**Biofluid Mechanics:** The application of experimental techniques and computational fluid dynamics (CFD) to the study of medical and biological problems. Mechanics of heart valves, Pulsatile flow in large arteries. Flow and pressure measurements. The computational modelling of artificial heart pumps and assistive devices.

#### **Recommended Books**

1. An Introductory Text to Bioengineering, by S. Chien, P.C. Y. Chen, Y. C. Fung.
2. Biomaterials Science: An Introduction to Materials in Medicine, by B. D. Ratner, A. S. Hoffman, F. J. Schoen and J. E. Lemmon.
3. Biomaterials: Principles and Practices, by J. Y. Wong, J. D. Bronzino, D. R. Peterson.
4. Introductory Biomechanics: From Cells to Organisms, by C. R. Ethier and C. A. Simons.
5. Fundamentals of Biomechanics, by D. Knudson.
6. Biofluid Mechanics, by J. Mazumdar.
7. Biofluid Mechanics in Cardiovascular Systems, by L. Waite.
8. Applied Biofluid Mechanics, by L. Waite and J. Fine.

**ME 482**

**AI Application in Mechanical Engineering**

**2(2,0)**

Artificial intelligence in data visualization, self-organizing feature maps, Machine vision, Machine Learning, Expert System, Pattern recognition, Deep Learning, Integration of AI with automation and Robotics, Supervised and Unsupervised learning, Function approximation through continuous predictors, classifiers, radial basis function, convolutional neural networks (CNN), testing for measures of goodness of fit for AI process models, testing for robustness, Monte Carlo technique, significance analysis, paired interaction analysis techniques

AI application: data collection, data Preparation, case study on AI application for strategic level operations in industry, case study on AI application for systems level operations in industry, case study on AI application for component level operations in industry, case study on AI application in mechanical engineering design (product development), case study on AI application for process development

#### **Recommended Books:**

1. Artificial Intelligence and Machine Learning Applications in Civil, Mechanical, and Industrial Engineering, by Gebrail Bekdas
2. Artificial Intelligence in Mechanical and Industrial Engineering, by Kaushik Kumar
3. Neural networks and learning machines, by Haykin, Simon.

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