Department of Mechanical Engineering

Pakistan Institute of Engineering and Applied Sciences

Curriculum

For

Master of Science

In

Mechanical Engineering

2020

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LIST OF COURSES

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ME-521	Continuum Mechanics	3 + 0
ME-512	Computer-Aided Analysis	3 + 0
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Institutional Requirements		
CMS-501	Communication Skills	0+1
Fellowship Requirement		
NE-501	Fundamentals of Nuclear Engineering	3 + 0
NE-507	Radiological Engineering	3 + 0
NE-510	Nuclear Power Plant Systems	3 + 0
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ME-505	Mechanical Behavior of Materials	3 + 0
ME-507	Solar Devices and Renewable Energy	3 + 0
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ME-613	Hypersonic Aerodynamics	3 + 0
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MSME PROGRAM EDUCATIONAL OBJECTIVES (PEOS)

After achieving the MS Mechanical Engineering degree the graduates of MS Mechanical Engineering program will be able to:

- Apply the gained knowledge and skills in identifying, formulating and solving complex problems in the field of Mechanical Engineering.
- Effectively carry out the research activities as team member and as an individual in the field of Mechanical Engineering, under different working conditions and environments.
- Understand their professional and ethical responsibilities while applying their knowledge and skill to practical problems and sharing their results with the international scientific community.

OBJECTIVES OF THE LATEST REVISION OF MS MECHANICAL ENGINEERING CURRICULUM

- The current revision is as per HEC recommendations, i.e., there will be **eight (08)** courses to be studied by every student and carry out a Masters level thesis work.
- Following are the four (04) Core courses:
  1) Continuum Mechanics
  2) Computer Aided Analysis
  3) Applied Solid Mechanics
  4) Multiphase Heat Transfer & Fluid Flow
- The students will opt for **four elective courses** from the available ones.
- Those students who are on **fellowship program** will have to study following **three (03) courses** as **Fellowship Requirement**:
  1) Fundamentals of Nuclear Engineering
  2) Radiological Engineering
  3) Nuclear Power Plants Systems
- All students will study following course as **Institutional Requirement**:
  1) Communication Skills

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CORE COURSES

ME-521 Continuum Mechanics

Contact Hours:		**Credit Hours:**	
Theory	= **48**	Theory	= **3.0**
Practical	= **0**	Practical	= **0.0**
Total	= **48**	Total	= **3.0**

Prerequisite Course:

Course Learning Outcomes

Upon successful completion of the course, the student will be able to:

1	**INTERPRET** summation notation usage for various tensors encountered in solid and fluid mechanics.
2	**APPLY** tensor algebra and calculus for derivations of various physical phenomena related to mechanics.
3	**ANALYZE** linear elastic isotropic and anisotropic behaviors.
4	**ANALYZE** linear behavior of classical fluids.
5	**SUMMARIZE** non-linear material behaviors such as viscoelaticity.

Course Contents:

Introduction to continuum theory; summation notation, tensor and vector algebra, transformation of Cartesian tensors, principal values and directions, tensor fields and tensor calculus; Cauchy stress tensor, force and moment equilibrium, principal stresses and directions, deviator and spherical stress states, octahedral shear stress; Kinematics of deformation and motion, material and spatial descriptions, deformation gradients, finite strain tensors, infinitesimal deformation theory, rotation and stretch tensors, rate of deformation, vorticity, material derivative of line elements, areas, volumes; Fundamental laws and equations, continuity equation, momentum principles, Piola-Kirchhoff stress tensors, Lagrangian equations of motion, conservation of energy, the energy equation, entropy, constitutive equations; Elasticity, Hooke's law for isotropic and anisotrpic materials; Classical fluids, Stokesian and Newtonian fluids, Navier-Stokes equations, steady, irrotational & potential flow; Overview of linear viscoelasticity.

Recommended Texts:

1. GT Mase, RE Smeslar, GE Mase, *Continuum Mechanics for Engineers*, 3rd ed, CRC Press, 2010
2. WM Lai, E Krempl, D Rubin, *Introduction to Continuum Mechanics*, 4th ed, Elsevier, 2009
3. YC Fung, A first course in Continuum Mechanics, 3rd ed, Pearson, 2004
4. LE Malvern, Introduction to the Mechanics of a Continuous Medium, Pearson, 1977
5. GE Mase, Continuum Mechanics (Schaum's series), McGraw-Hill, 1970

ME-512 Computer-Aided Analysis

Contact Hours:
Theory = **48**
Practical = **0**
Total = **48**
Prerequisite Course:

Credit Hours:
Theory = **3.0**
Practical = **0.0**
Total = **3.0**

Course Learning Outcomes:

Upon successful completion of the course, the student will be able to:

1	**FORMULATE** structural response for a variety of loading conditions using available FEA software
2	**VALIDATE** FEA analysis result for design and evaluation purpose
3	**CREATE** parametric simulation, DOE, and optimization to reveal more and better Design solution(s).
4	**ASSESS** design of mechanical component, which is already published in recent research.

Course Contents:

Introduction to available finite element analysis software. The graphical user interface, files formats, modeling & meshing in 2D & 3D, detailed stress analysis, thermal analysis, structural elements, post-processing, presentation of results, the scripting language, dynamic analyses; modal Analysis, Harmonic Analysis, Transient Analysis; Non-linear Analysis, parallel/ distributed computing.

Recommended Texts:

1. Ansys Documentation V18.1, Ansys lnc.
2. H H Lee, Finite Element Simulations with ANSYS Workbench 18.
3. P. M. Kurowski, *Finite Element Analysis for Design Engineers*, 2nd ed, SAE international, 2017
4. Xianlin Chen, Yijun Liu, Finite Element Modeling and Simulation with Ansys Workbench, CRC Press, 2015
5. DThakore, Finite Element Analysis with Open Source Software, 2nded

ME-516 Applied Solid Mechanics

Contact Hours:		**Credit Hours:**	
Theory	= **48**	Theory	= **3.0**
Practical	= **0**	Practical	= **0.0**
Total	= **48**	Total	= **3.0**

Prerequisite Course:

Course Learning Outcomes:

Upon successful completion of this course, the student will be able to:

1	**DESCRIBE** the three-dimensional behavior of stress and strain in a mechanical component.
2	**APPLY** the fundamentals of theory of elasticity to advanced problems in mechanics of materials.
3	**ANALYZE** problems involving stress concentrations and contact stresses.
4	**EXPLAIN** various energy techniques used in stress analysis.

Course Contents:

Review of concepts of force, stress, strain & displacement; Stress & strain transformations, Mohr's circles in 3D, generalized stress-strain relations, equilibrium & compatibility; The plane elastic problem, Airy stress function, Prandtl's stress function for torsion; Shear flow; Torsion of thin-walled tubes, unsymmetrical bending of beams, composite beams; Beams on elastic foundations, bending of thin flat plates; Stress concentrations; Contacts; Energy methods in stress analysis; definition of homologous temperature and its importance in engineering, creep and relaxation; Cyclic stress strain behavior of materials, methods of obtaining stress strain hysteresis loops, cyclic strain hardening and softening, Coffin-Manson law, fatigue and its importance in design and damage analysis, low cycle fatigue, high cycle fatigue, effect of different types of wave shapes, environment, temperature, etc. on fatigue;

Recommended Texts:

1. RG Budynas, *Advanced Strength and Stress Analysis*, 2nd ed, McGraw Hill, 2011
2. AF Bower, *Applied Mechanics of Solids*, CRC Press, 2010
3. AP Boresi, RJ Schmidt, *Advanced Mechanics of Materials*, 6th ed, John Wiley & Sons, 2003
4. PP Benham, RJ Crawford, *Mechanics of Engineering Materials*, Prentice-Hall, 1996

ME-517 Multiphase Heat Transfer & Fluid Flow

Contact Hours:		**Credit Hours:**	
Theory	= **48**	Theory	= **3.0**
Practical	= **0**	Practical	= **0.0**
Total	= **48**	Total	= **3.0**

Prerequisite Course:

Course Learning Outcomes

Upon successful completion of the course, the student will be able to:

1	**APPLY** the concepts of multiphase flow and heat transfer.
2	**ANALYZE** various modes of heat transfer and analysis methods to their performances.
3	**EVALUATE** heat transfer systems performance based on boiling and two-phase flows.

Course Contents:

Steady-State Conduction One Dimension in Plane Walls, Cylinders and spheres; The Overall Heat-Transfer Coefficient; Conduction Heat transfer with heat generation; Nuclear Heat Source calculations; Radial temperature distribution in nuclear fuel elements; Heat generation and conduction in thermal shields and fins; Unsteady-State Conduction; Transient Heat Flow in Infinite, Semi-Infinite and finite body; Multidimensional Systems; Principles of Convection; Empirical correlations for Forced-Convection heat transfer and its application in Nuclear reactors; Heat transfer in single phase coolants; Introduction to two phase flow; Two phase flow models; Calculation of two phase pressure drop; critical flow phenomenon; Boiling heat transfer; Critical heat flux and core thermal design; Thermodynamics of nuclear power plant; Modeling of Pressurizer; Review of design of shell and tube heat exchangers and cooling towers.

Recommended Texts:

1. M M El Wakil, *Nuclear Heat Transport*, International Text Book, 1971
2. N E Todreas, M S Kazimi, Taylor & Francis, *Nuclear Systems 1 & 2*, 2^{nd} ed, 1993
3. D Q Kern, Process Heat Transfer, McGraw Hill, 1960
4. E Ludwig, Applied Process Design for Chemical & Petrochemical Plants 3^{rd} ed, Gulf Pub, 2001

INSTITUTIONAL REQUIREMENTS

CMS-501 Communication Skills

Contact Hours:		Credit Hours:	
Theory	**= 0**	Theory	**= 0.0**
Practical	**= 48**	Practical	**= 1.0**
Total	**= 0**	Total	**= 0.0**

Prerequisite Course:

Course Learning Outcomes

Upon successful completion of the course, the student will be able to:

1	**Compose v**arious types of formal/informal documents, used in an office
2	**Demonstrate** competence in various settings (e.g., interpersonal, group, organizational and public).
3	**COMPARE** effective strategies for recruiting and selecting qualified job applicants

Course Contents:

Writing Module; Preparation of a project proposal or technical report, Writing letters, mission statements, office memos etc. Speaking Module; Presentation of the project proposal or technical report. Listening Module; Simulations of interviews, lectures and question-answer sessions. Reading Module; Reading of a suitable fiction novel (approximately 30-50 pages a week) with the use of vocabulary support, completion of assigned tasks and discussions

Recommended Texts:

1. E H Glendinning, N Glendinning. *English for Electrical and Mechanical Engineering*, Oxford University Press, 1995
2. Huckin, Oslen. Technical Writing and Professional Communication for Non-native Speakers of English (Int'l Edition, 2nd Edition), McGraw Hill, 1991
3. J M Swales, C B Feak. Academic Writing for Graduate Students, A Course for Non-native Speakers of English, Uni. of Michigan Press, 2004

Fellowship Requirement

NE-501 Fundamentals of Nuclear Engineering

Contact Hours:		**Credit Hours:**	
Theory	**= 48**	Theory	**= 3.0**
Practical	**= 0**	Practical	**= 0.0**
Total	**= 48**	Total	**= 3.0**

Prerequisite Course:

Course Learning Outcomes:

Upon successful completion of this course, the student will be able to:

1	**Explain** the fundamental concepts of nuclear engineering
2	**Differentiate** between types of nuclear reactors
3	**Apply** the concepts of neutron cross-section and nuclear fuel cycle to **solve** relevant practical problems

Course Contents:

Role and importance of nuclear energy; Nuclear cross-sections, Reaction rates, Nuclear fission and chain reaction, criticality conditions, Conversion and breeding, Reactor components and their characteristics, Classification and design features of research, production and power reactors, Introduction to fast and fusion reactor systems. Different types of fuel cycles, Core and feed-material preparations, Uranium enrichment, Fabrication of fuel, Reprocessing of irradiated fuel, Process waste disposal, Reactor fuel requirements, Burnup studies of nuclear fuels, Fuel cycle performance of commercially available reactors, In-core fuel management and fuel management strategies.

Recommended Texts:

1. J R Lamarsh, *Introduction to Nuclear Engineering*, Addison-Wesley, 1983.
2. S Glasstone, A Sesonke, D Van Nostrand, *Nuclear Reactor Engineering*, 1981.
3. I U Rahman, P S Sheikh, *Introduction to Nuclear Engineering*, Krieger, 1981.
4. H W Graves Jr., *Nuclear Fuel Management*, John Wiley, 1979.

NE-507 Radiological Engineering

Contact Hours:		**Credit Hours:**	
Theory	= **48**	Theory	= **3.0**
Practical	= **0**	Practical	= **0.0**
Total	= **48**	Total	= **3.0**

Prerequisite Course:

Course Learning Outcomes:

Upon successful completion of this course, the student will be able to:

1	**EXPLAIN** the fundamental concepts of radiation interaction and detection
2	**SOLVE** problems related to radiation interaction and detection like calculation of dose, radiation shielding etc.
3	**APPLY** the concepts of plume dispersion on real-life problems

Course Contents:

Radiation sources, interaction of radiation with matter, basic principles of radiation detection, Radiation detectors & their applications, Nuclear Instrumentation, Radiation units, natural & man made radiation sources, Elementary biology & biological effects of radiation, Standards of radiation protection, Calculation of exposure & dose, Attenuation coefficient & buildup factors for gamma rays, Shielding of sources with different geometrical shapes, Shields with internal sources, Multi-layered shields, Concept of removal cross-section, Removal-attenuation & removal diffusion calculations, Dispersion of effluents from nuclear facilities, Radiation doses from nuclear plants.

Recommended Texts:

1. G F Knoll, Radiation detection and measurement, John Wiley 1989.
2. J R Lamarsh, *Introduction to nuclear engineering*, Addison Wesley, 1983.

NE-510 Nuclear Power Plant Systems

Contact Hours:		**Credit Hours:**	
Theory	**= 48**	Theory	**= 3.0**
Practical	**= 0**	Practical	**= 0.0**
Total	**= 48**	Total	**= 3.0**

Prerequisite Course:

Course Learning Outcomes:

Upon successful completion of this course, the student will be able to:

1	**UNDERSTAND** basic layout of a nuclear power plant and its important systems
2	**ANALYZE** different systems and components of a nuclear power plant
3	**EXPLAIN** design parameters of a nuclear power plant systems and buildings

Course Contents:

Layout of nuclear power plants, Containment buildings; Prirnary containment vessels; Structure of reactor core; and mechanical stress in various structures. Description and analysis of power plant systems and components including steam generator, steam dryer and separator, pressurizer, reheater, heat exchanger, condenser, demineralizer, pumps ,turbine, generator, cooling tower; Auxiliary cooling systems. Fuel handling mechanisms; Control and mechanisms; Radwaste systems; Electrical Systems; Reactor grid interface and load following. Basic considerations in nuclear plant design; Components of nuclear power cost; Economic comparison of nuclear and fossil fueled plants; Dual and multipurpose nuclear plants; Future trends in nuclear power cost.

Recommended Texts:

1. J H Rust, Nuclear Power Plant Engineering, Haralson, 1979.
2. M M El-Wakil, *Nuclear Energy Conversion*, International Text Book, 1982
3. E S Pedersen, *Nuclear Power*, Ann Arbor Science, 1978.
4. M M El-Wakil, *Power Plant Technology*, McGraw-Hill, 1984.
5. K C Lish, *Nuclear Power Plant Systems & Equipment*, Industrial Press Inc., 1972.

Elective Courses

ME-503 The Finite Element Method

Contact Hours:		Credit Hours:	
Theory	**= 48**	Theory	**= 3.0**
Practical	**= 0**	Practical	**= 0.0**
Total	**= 48**	Total	**= 3.0**

Prerequisite Course:

Course Learning Outcomes:

Upon successful completion of this course, the student will be able to:

1	**DESCRIBE** an engineering problem using the strong–weak formulations.
2	**CONSTRUCT** strong–weak formulation of engineering problems in elasticity and heat transfer.
3	**CONSTRUCT** strong–weak formulation of engineering problems in structural dynamics.
4	**ANALYZE** engineering problems using the finite element method and validate these by resolving convergence issues.

Course Contents:

Mathematical preliminaries, introduction to the strong and weak form, essential and natural boundary conditions, finite element formulation of 1D & 2D problems in elasticity and heat conduction, quadrature, divergence theorem, 2D scalar field multidimensional problems, 2D & 3D vector field multidimensional problems, autogenous strains, the patch test, convergence issues, structural dynamics and time-dependent scalar field problems and solution procedures, verification and validation, numerical solutions, parallel computing and FEM.

Recommended Texts:

1. I Koutromanos, Fundamentals of Finite Element Analysis, Wiley, 2018
2. KJ Bathe, *Finite Element Procedures*, 2nd ed, Prentice-Hall, 2014
3. JN Reddy, Introduction to the Finite Element Method, 4th ed, McGraw-Hill, 2018

ME-505 Mechanical Behavior of Materials

Contact Hours:		**Credit Hours:**	
Theory	= **48**	Theory	= **3.0**
Practical	= **0**	Practical	= **0.0**
Total	= **48**	Total	= **3.0**

Prerequisite Course:

Course Learning Outcomes:

Upon successful completion of this course, the student will be able to:

1	**DESCRIBE** the significance of the phenomenon of creep in engineering design applications.
2	**DESCRIBE** the cyclic stress-strain behavior of engineering materials.
3	**APPLY** the knowledge of fatigue in design and analysis.
4	**APPLY** the knowledge of linear elastic fracture mechanics to analyze behavior of cracked bodies.

Course Contents:

Engineering and true stress & strain, the stress-strain curve; the tension, compression & hardness experiments, types and design of test specimen; stress concentration factor; failure theories, definition of homologous temperature and its importance in engineering, creep and relaxation; Cyclic stress strain behavior of materials, methods of obtaining stress strain hysteresis loops, cyclic strain hardening and softening, Coffin-Manson law, fatigue and its importance in design and damage analysis, low cycle fatigue, high cycle fatigue, effect of different types of wave shapes, environment, temperature, etc. on fatigue; Introduction to linear elastic fracture mechanics, modes of fracture, the stress intensity factor.

Recommended Texts:

1. NE Dowling, Mechanical Behavior of Materials: Engineering Methods for Deformation, Fracture, and Fatigue, 4th ed., Prentice Hall, 2012
2. KK Chawla, MA Meyers, *Mechanical Behavior of Materials*, Cambridge University Press, 2nd ed., 2009
3. JA Bannantine, JJC Former, JL Handrock, *Fundamentals of Metal Fatigue Analysis*, Prentice Hall publications. 1989

ME-507 Solar Devices and Renewable Energy

Contact Hours:		**Credit Hours:**	
Theory	**= 48**	Theory	**= 3.0**
Practical	**= 0**	Practical	**= 0.0**
Total	**= 48**	Total	**= 3.0**

Prerequisite Course:

Course Learning Outcomes:

Upon successful completion of this course, the student will be able to:

1	**ANALYZE** Solar energy components used in the cooling/heating of building
2	**EVALUATE** and **COMPARE** different solar thermal energy storage system
3	**DESIGN** and **SELECT** appropriate Heating/cooling system for a building

Course Contents:

Solar irradiation, its nature and measurement, Insulation on tiled surfaces, Application of the principle of heat transfer and thermodynamics to the theoretical and experimental analysis of solar energy components used in the heating and cooling of buildings as well as hot water heating devices. Theoretical consideration of thermal storage devices, solar collectors and solar-augmented heat pumps, Approximate techniques and other research topics.

Recommended Texts:

1. J A Duffie, W A Beckman, *Solar Engineering of Thermal Processes*, 2^{nd} ed, John Wiley & Sons, 1991

ME-509 Experimental Stress Analysis

Contact Hours:		**Credit Hours:**	
Theory	**= 48**	Theory	**= 3.0**
Practical	**= 0**	Practical	**= 0.0**
Total	**= 48**	Total	**= 3.0**

Prerequisite Course:

Course Learning Outcomes:

Upon successful completion of this course, the student will be able to:

1	**SELECT** appropriate method for measuring strain & stress.
2	**ANALYZE** the results obtained from coating techniques and compare with theoretical results
3	**SELECT** Strain gage based on specified problem and ANALYZE the stress and strain.

Course Contents:

Scope of ESA, Revision of elasticity concepts which are essential for an experimental stress analysis, Theory of photoelasticity, Polariscope techniques, Two and three dimensional photoelastic stress analysis, Birefringent coatings, Photoelastic materials, Fundamental concepts of electrical resistance strain gages, Performance characteristics of strain gages, Strain gage circuits & indicators, Gage selecting criteria, Rosette analysis, Some special applications of strain gages, Introduction to brittle coating (ceramic as well resin-based) and Moiré method (Theory and some applications), Some Other Techniques of ESA.

Recommended Texts:

1. E J W Dally, W F Riley, *Experimental Stress Analysis*, McGraw Hill Inc, 1991.
2. A S Kobayashi (editor) *Handbook on Experimental Mechanics*, 2nd ed, VCH Pub., 1993
3. A Kuske, G Robertson, *Photoelastic Stress Analysis*, John Wiley & Sons, 1977
4. R B Heywood, *Photolasticity for Designers*, Pergamon Press, Oxford, 1969

ME-510 Reliability and quality Engineering

Contact Hours:		**Credit Hours:**	
Theory	= **48**	Theory	= **3.0**
Practical	= **0**	Practical	= **0.0**
Total	= **48**	Total	= **3.0**

Prerequisite Course:

Course Learning Outcomes:

Upon successful completion of this course, the student will be able to:

1	**DESCRIBE** The concept related to Reliability.
2	**APPLY** the reliability known ledge/concept to mechanical system/equipment.
3	**UNDERSTAND** the concepts related to quality ensuring.
4	**APPLY** different quality ensuring techniques/concepts to mechanical systems/ equipment.

Course Contents:

Reliability Measures: The reliability Function; Expected Life, Failure Rate and Hazard Function, Reliability and Hazard Function for distributions such as Exponential, Normal, Log Normal, Weibull, and Gamma Distributions, Hazard Models and Product Life, Constant Hazard Function, Linearly Increasing Hazard Function, Piecewise Linear Bathtub Hazard Function, Power Function Model, Exponential Model. Static Reliability Model: Series System, Parallel System, Series & Parallel Combinations, Complex System Analysis, Reliability Considerations in Design. Reliability Modelling and Design: Series Parallel System, Reliability Considerations in Design. Reliability Design Methodology, Strength and Stress Distributions, Safety Factors and Reliability, Reliability Bounds in Probabilistic Design, Error Analysis, Statistical Tolerancing. Reliability in Design and Testing: Dynamic Reliability Models, Reliability Estimation, Sequential Life Testing, Bayesian Reliability in Design and Testing, Reliability Optimization. Control Charts: Properties of the distribution of sample means, control charts for mean & range, control charts for mean & standard deviation, control charts for proportion defective & defects per assembly, Tests of significance to compute confidence limits. Acceptance Sampling: Introduction, OC curve, consumer & producer risks, AQL & LTPD, acceptance sampling for continuous production, acceptance by variables, single, double, & sequential sampling. Quality, Reliability, & Maintainability: Definitions, management of quality control, economic aspects of quality decisions, capability & variability analysis, various aspects of life testing, reliability, & maintainability, Introduction to ISO standards.

Recommended Books:

4. Reliability in Automotive and Mechanical Engineering-Determination of component and system Reliability Springer; 2008
5. BS Dhillon, Quality, and Safety for Engineers CRC Press, 2004.
6. John Bentley Introduction to Reliability and Quality Engineering Longman Pub Group,1993.

ME-513 Advanced Mechanical Vibrations

Contact Hours:		**Credit Hours:**	
Theory	= **48**	Theory	= **3.0**
Practical	= **0**	Practical	= **0.0**
Total	= **48**	Total	= **3.0**

Prerequisite Course:

Course Learning Outcomes:

Upon successful completion of the course, the student will be able to:

1	**ANALYZE** single/multi-degree-of-freedom (SDOF/MDOF) systems in free and forced vibration.
2	**CHARACTERIZE** the dynamic behavior of a structure in terms of its modal parameters (e.g. natural frequencies, damping, and mode shapes)
3	**APPLY** Vibration control via active methods
4	**ANALYZE** mechanical component foe vibration using available FEA software.

Course Contents:

Fundamentals of vibrations, Single and two Degree of Freedom Systems, Harmonically Excited Vibrations, Actual vibration systems and the analytical model. Multi-degree of freedom systems, Determination of natural frequencies and mode shapes, Transient Vibrations, Vibration under general Forcing Conditions, Random Vibrations, continuous systems, Vibration Control, Vibration measurement and Applications, Applications of finite element methods to analysis of mechanical vibrations.

Recommended Texts:

1. S S, Rao, Mechanical Vibrations, Mc-Graw
2. W T Thompson, Mechanical Vibrations: Theory & Applications,
3. C Lalanne, *Mechanical Shock*, Wiley
4. C Lalanne, Sinusoidal Vibrations, Wiley
5. M R Hatch, Vibration Simulation Using MATLAB and ANSYS, 2000.

ME-514 Applied Mechatronics

Contact Hours:	**Credit Hours:**
Theory = **48**	Theory = **3.0**
Practical = **0**	Practical = **0.0**
Total = **48**	Total = **3.0**

Prerequisite Course:

Course Learning Outcomes:

Upon successful completion of the course, the student will be able to:

1	**CREATE** interface between electronics and mechanical systems for given task.
2	**DESIGN** control systems using different Sensors and actuators
3	**INTERPRET** analogue and digital interfacing

Course Contents:

Review of analog and digital electronic domains; Microprocessors and the embedded systems: SoC and SoPC; FPGA realization of complex mathematical algorithms; Interfaces between electronics and mechanical systems; Sensors and actuators: Level shifting, isolation and signal conditioning; Data acquisition: A2D and D2A conversion; Real-Time techniques and artificial intelligence; Controller generations: From analog to micro-programmed to hardware based; Fail-safe systems; and the Star Wars technology; Modern trends in mechatronic technologies.

Recommended Texts:

1. Georg Pelz, (Translated by: Rachel Waddington), *Mechatronic Systems Modeling and Simulation with HDLs*, John Wiley & Sons Ltd, 2003.
2. A Preumont, Mechatronics: Dynamics of Electromechanical and Piezoelectric Systems, Springer, 2006.
3. H Martínez-Alfaro, *Advances in Mechatronics*, InTech, 2011.
4. A Milella, D Paola, G Cicirelli, *Mechatronic Systems, Applications*, InTech, 2010

ME-515 Modern Manufacturing Processes

Contact Hours:		**Credit Hours:**	
Theory	**= 48**	Theory	**= 3.0**
Practical	**= 0**	Practical	**= 0.0**
Total	**= 48**	Total	**= 3.0**

Prerequisite Course:

Course Learning Outcomes:

Upon successful completion of the course, the student will be able to:

1	**CORRELATE** how "the right information, in the right place, at the right time" should flow in manufacturing Process
2	**APPLY** solutions, only doable by additive manufacturing
3	**EVALUATE** manufacturing process data of a product for competitive advantage

Course Content:

Introduction to Industry 4.0 concept, Discrete and continues manufacturing, interpret Digital Manufacturing, Flexible Manufacturing and Lean Manufacturing, Digital Product life cycle management, Data collection, Data organization and Analysis using computational technique, in different manufacturing settings, methodologies and techniques comprising design for manufacture and assembly, failure mode effect analysis.

Recommended text:

1. K Kumar, D Zindani, J. P Davim, Digital manufacturing and assembly system in Industry 4.0, 1st ed, CRC Press, 2019
2. R Singh, J. P Davim, Additive Manufacturing Applications and Innovations, 1st Ed, CRC Press, 2018
3. Muammer Koç, Tugrul Özel, Modern Manufacturing Processes, Willey, 2019
4. R K Phanden, A Jain, J. P Davim, Integration of Process Planning and Scheduling: Approaches and Algorithms, 1st Ed, CRC press, 2019

ME-523 Theory of Machines & Mechanisms

Contact Hours:		**Credit Hours:**	
Theory	= **48**	Theory	= **3.0**
Practical	= **0**	Practical	= **0.0**
Total	= **48**	Total	= **3.0**

Prerequisite Course:

Course Learning Outcomes:

Upon successful completion of this course, the student will be able to:

1	**APPLY** knowledge of kinematics to calculate velocities and accelerations in three-dimensional mechanisms.
2	**PERFORM** three-dimensional kinetic analysis of mechanisms.
3	**SYNTHESIZE** mechanisms for required motion parameters by application of planar theory.

Course Contents:

Review of essential concepts in dynamics. 3D kinematics: rotation about a fixed point, time derivative of a vector in fixed & moving coordinate system, relative motion analysis using moving axes. Spatial mechanisms: Euler angles, analysis of position, displacement, velocity & acceleration, matrix methods of analysis, various methods for synthesis of linkages. 3D kinetics: moments & products of inertia, transformation of inertia axes, dynamic force analysis, angular impulse & momentum, kinetic energy, Euler's equations of motion, gyroscopes & torque-free motion. Synthesis of mechanisms: function generation, path generation, Chebyshev spacing, overlay method, coupler curve synthesis, cognate linkages.

Recommended Texts:

1. JJ Uicker Jr, GR Pennock, JE Shigley, *Theory of Machines & Mechanisms*, 5th ed, Oxford University Press, 2017
2. RC Hibbeler, *Engineering Dynamics*, 14th ed, Prentice Hall, 2015
3. JL Meriam, Kraige, *Engineering Mechanics: Dynamics*, 8th ed, 2009

ME-524 Mechanical Systems Design

Contact Hours:
Theory = **48**
Practical = **0**
Total = **48**
Prerequisite Course:

Credit Hours:
Theory = **3.0**
Practical = **0.0**
Total = **3.0**

Course Learning Outcomes

Upon successful completion of the course, the student will be able to:

1	**INTERPRET** Design methodology, design codes and failure theories
2	**DESIGN** a mechanical system for given constraints.
3	**DEVELOP** the model of mechanical system and its technical drawings using available CAD software.

Course Contents:

Design Methodology, Various design codes, Failure theories, Zero failure criteria, Philosophy of Mechanical System Design, Probability and uncertainty, Statistical factor of safety, individual project for a small Mechanical system design: from design calculations to manufacturing drawings.

Recommended Texts:

1. S P Patil, Jaico, *Mechanical System Design*, Publishing house, 2004.
2. K S Edwards Jr, R B Mckee, *Fundamentals of Mechanical Component Design*, McGraw-Hill, 1991
3. D G Ullman, *The Mechanical Design Process*, 3rd ed. McGraw-Hill, 2003.

ME 525 Advanced Thermodynamics

Contact Hours:		**Credit Hours:**	
Theory	**= 48**	Theory	**= 3.0**
Practical	**= 0**	Practical	**= 0.0**
Total	**= 48**	Total	**= 3.0**

Prerequisite Course:

Course Learning Outcomes

Upon successful completion of the course, the student will be able to:

1	**PERFORM** exergy and availability analyses for thermodynamic systems
2	**ANALYZE** systems of constant and variable chemical compositions
3	**DESIGN** of various special systems through application of thermodynamics concepts

Course Contents:

Equilibrium of thermodynamics systems, exergy and availability analyses, System of constant chemical composition: thermodynamic properties, equation of state, law of corresponding states, relations for pure substance, the third law of thermodynamics, Gibbs free energy equation, heats of reaction or calorific values, adiabatic combustion, heats of formation and Hess's law, entropy of ideal gas mixtures. Gas mixtures of variable composition: chemical potential, stoichiometery and dissociation, chemical equilibrium, equilibrium constant and heat of reaction, Van't Hoff's equation, temperature rise due to combustion reaction, Lighthill ideal dissociating gas, ionization of monatomic gases, non -equilibrium processes, equilibrium and frozen flows, Special systems: application of thermodynamics to elastic systems, systems with surface tension, reversible cell, fuel cell, magnetic systems, thermodynamics of irreversible processes, thermo-electricity.

Recommended Texts:

1. D.E.Wintterbone, Ali Turan, *Advanced Thermodynamics for Engineers*, 2^{nd} edition, Butterworth-Heinemann, 2015
2. K.Annamalai, I.K. Puri, *Advanced Thermodynamics in Engineering*, 2^{nd} edition, CRC Press, 2011.
3. Adrian Bejan, *Advanced Engineering Thermodynamics*, 4^{th} edition, Wiley, 2016

ME-526 Welding and Non-destructive Testing

Contact Hours:		**Credit Hours:**	
Theory	= **48**	Theory	= **3.0**
Practical	= **0**	Practical	= **0.0**
Total	= **48**	Total	= **3.0**

Prerequisite Course:

Course Learning Outcomes:

Upon successful completion of this course, the student will be able to:

1	**SELECT** a particular Non-Destructive Testing technique for a specific application.
2	**DESCRIBE** and **COMPARE** different Non-Destructive Testing techniques and design the non-destructive testing technique parameters for specific application
3	**DESCRIBE** and **COMPARE** different welding processes & principles for a particular application.
4	**DESCRIBE** the evolution of microstructure and principles of formation of metallurgical phases due to welding of a wide range of ferrous and non-ferrous alloys
5	**EXPLAIN** the causes of defects in welds and how they can be avoided

Course Contents:

Welding techniques, Manual Arc Welding, Gas Shielded Arc Welding, Submerged Arc Welding, laser beam welding, electron beam welding, solid state welding techniques, Microstructure of Weld and Heat-Affected Zones, Pre- and Post-Weld Heat Treatments, Weld Joint Design, Welding of aluminum alloys, Nondestructive testing techniques: Visual inspection (VT-1, VT-2, VT-3), dye penetrant inspection, Fluorescent dye-penetration inspection, Magnetic-particle inspection, Radiography, Principles and Applications of Ultrasonic Inspection, Eddy current inspection, Leak-rate inspection, Vibration analysis

Recommended Texts:

1. Linnert, G.E., "Welding Metallurgy", American Welding Society.
2. Easterling, K.: Introduction to the Physical Metallurgy of Welding, Butterworth-Heinemann, 1992.
3. Peter J. Shull, *Nondestructive Evaluation*, Theory, Techniques, and Applications, Marcel Dekker, Inc., 2001
4. Charles Hellier, Handbook of Nondestructive Evaluation, McGraw-Hill, 2003
5. R. Halmshaw, *Non-Destructive Testing*, 2nd Edition, Butterworth-Heinemann, 1991
6. Silk, M. G.: Ultrasonic Transducers for Nondestructive Testing, Adam Hilger Ltd., Bristol, 1984.
7. David H.Philips, "welding Engineering, An introduction", wiley

ME-527 Analytical Dynamics

Contact Hours:		**Credit Hours:**	
Theory	**= 48**	Theory	**= 3.0**
Practical	**= 0**	Practical	**= 0.0**
Total	**= 48**	Total	**= 3.0**

Prerequisite Course:

Course Learning Outcomes:

Upon successful completion of this course, the student will be able to:

1	**DESCRIBE** motion of particles in appropriate coordinates.
2	**ANALYZE** motion of systems of particles using Lagrange's equations of motion.
3	**DESCRIBE** motion of rigid bodies in appropriate coordinates.
4	**ANALYZE** motion of systems of rigid bodies using Lagrange's equations of motion.
5	**DEVELOP** computer models for analysis of mechanisms.

Course Contents:

Description of motion in different coordinate systems, time derivatives of vectors; Particle dynamics in unconstrained and constrained conditions, constraints and equations of motion, generalized coordinates, Lagrange's equations; Dynamics of system of particles; Kinematics and relative motion analysis, matrix formulation, Euler angles sets; Rigid body dynamics, work-energy approach, dynamics of systems of rigid bodies; General spatial dynamics; Introduction to dynamics of deformable bodies; Computational methods in engineering dynamics.

Recommended Texts:

1. LW Schmerr, Engineering Dynamics 2.0, fundamentals and numerical solutions, Springer, 2019
2. H Goldstein, C Poole, J Safko, *Classical Mechanics*, 3rd ed, Pearson, 2013
3. H Harrison, T Nettleton, *Advanced Engineering Dynamics*, John Wiley & Sons, 1997

ME-601 Theory of Elasticity

Contact Hours:
Theory = **48**
Practical = **0**
Total = **48**
Prerequisite Course:

Credit Hours:
Theory = **3.0**
Practical = **0.0**
Total = **3.0**

Course Learning Outcomes:

Upon successful completion of the course, the student will be able to:

1	**UTILIZE** Mathematical modeling of 2d problems of elasticity in different coordinate system
2	**ANALYZE** 3d problems of elasticity in different coordinate system based on mathematical model
3	**ANALYZE** of 2d and 3d models to solve practical problems

Course Contents:

Review of concepts of stress & strain, Index notation, Plane stress and plane strain, two dimensional problems, in rectangular coordinates, polar coordinates, curvilinear coordinates; Analysis of stress and strain in three dimensions, General theorems; Elementary problems of elasticity in three dimensions, Torsion, Bending of bar, Thermal stress, Application of finite difference equations

Recommended Texts:

1. S P Timoshenko, J N Goodier, Theory of Elasticity, 3rd ed., McGraw-Hill, 1987
2. S F Borg Stevens, Fundamentals of Engineering Elasticity, Inst. Tech., 1990
3. W S Slaughter, The Linearized Theory of Elasticity, Birkhäuser Boston, 2001

ME-602 Fracture Mechanics

Contact Hours:	**Credit Hours:**
Theory = **48**	Theory = **3.0**
Practical = **0**	Practical = **0.0**
Total = **48**	Total = **3.0**

Prerequisite Course:

Course Learning Outcomes:

Upon successful completion of this course, the student will be able to:

1	**DEMONSTRATE** the importance and application of fracture mechanics in engineering design.
2	**CALCULATE** stress intensity factors for common geometries.
3	**ANALYZE** elastic-plastic fracture using *J* integral and crack-tip opening displacement.
4	**APPLY** fracture mechanics to advanced structural design.

Course Contents:

Introduction and historical perspective; Importance in design; Linear elastic fracture mechanics, energy balance method, energy release rate, stress intensity factor, crack-tip plasticity, plain strain fracture toughness, mixed mode fracture, interaction of multiple cracks; Dislocation Theory, Elastic-plastic fracture mechanics, the *J*-integral, crack-tip opening displacement; Dynamics of crack growth, effects of creep and viscoelasticity; Fracture toughness testing of metals and non-metals; Fatigue crack propagation; Applications to structures; Computational fracture mechanics. Dislocation theory.

Recommended Texts:

1. TL Anderson, Fracture Mechanics, fundamentals and applications, 4th ed, CRC Press, 2017
2. EE Gdoutos, *Fracture Mechanics, an introduction*, 3rd ed, Springer, 2020
3. RJ Sanford, Principles of Fracture Mechanics, Pearson, 2002
4. D Broek, *Elementary Engineering Fracture Mechanics*, 4th ed, Martinus Nijhoff Pub, 1982

ME-603 Non-Linear Finite Element Method

Contact Hours:	**Credit Hours:**
Theory = **48**	Theory = **3.0**
Practical = **0**	Practical = **0.0**
Total = **48**	Total = **3.0**

Prerequisite Course:

Course Learning Outcomes:

Upon successful completion of this course, the student will be able to:

1	**ANALYZE** problem by application of appropriate solution methods and algorithms
2	**VALIDATE** results for problems involving systems design
3	**APPLY** a finite element Analysis software for non-linear problems

Course Contents:

General problems in solid mechanics and non-linearity, Solution of non-linear algebraic equations, Inelastic and non-linear materials, Plate bending approximation, Thin Kirchhoff plates and continuity requirements, Thick Reissner-Midlin plates, Irreducible and mixed formulations, Shells as an assembly of flat elements, Axisymmetric shells, Shells as a special case of three dimensional analysis, Reissner-Mindlin assumptions, Semi-analytical finite element processes, Use of orthogonal functions and finite strip methods, Geometrically non-linear problems, Finite deformation, Nonlinear structural problems, Large displacement and instability, Pseudo-rigid and rigid flexible bodies, Computer procedures for finite element analysis.

Recommended Texts:

1. O C Zienkiewcz, R L Taylor, *The Finite Element Method for Solid and Structural Mechanics*, 7th ed., Butterworth and Heinemann, 2014
2. J Bonet, R D Wood, Non-linear Continuum Mechanics for Finite Element Analysis, 2nd ed, Cambridge University Press, 2008
3. M Kleiber, A Borkowski, Handbook of Computational Solid Mechanics: Survey and Comparison of Contemporary Methods, Springer Verlag, 1998

ME-604 Theory of Plasticity

Contact Hours:		**Credit Hours:**	
Theory	= **48**	Theory	= **3.0**
Practical	= **0**	Practical	= **0.0**
Total	= **48**	Total	= **3.0**

Prerequisite Course:

Course Learning Outcomes

Upon successful completion of the course, the student will be able to:

1	**COMPARE** solution methodologies for Plastic-Elastic Problem
2	**EVALUATE** Solution methodologies for Plastic-strain problems
3	**ANALYZE** Nonlinear structures using plasticity model in finite element software

Course Contents:

Stress strain curve, General theorems, Solution of plastic-elastic problems, Plane plastic-strain and theory of the lip-line field, Two-dimensional problems of steady motion, Non-steady motion problems in two dimensions.

Recommended Texts:

1. R Hill, *The Mathematical Theory of Plasticity*, Oxford at the Clarendon press, 1985

ME-605 Micro-Electromechanical Systems

Contact Hours:		**Credit Hours:**	
Theory	**= 48**	Theory	**= 3.0**
Practical	**= 0**	Practical	**= 0.0**
Total	**= 48**	Total	**= 3.0**

Prerequisite Course:

Course Learning Outcomes:

Upon successful completion of this course, the student will be able to:

1	**INTERPRET** Engineering Mechanics of microsystem design
2	**ANALYZE** effect of different types of loading on MEMS
3	**DEVELOP** mathematical model (Kinematics and kinetics) of MEMS
4	**ANALYZE** a design of MEMS using available FEA/MEMS software

Course Contents:

Introduction to MEMS: Fundamentals of MEMS design, analysis and fabrication. Materials and manufacturing of MEMS: Basic IC-processing. Engineering mechanics of microsystem design: Residual stresses, Static bending of thin plates, Mechanical vibration, Thermomechanics, Fracture mechanics, Thin-film mechanics, General material considerations. Scaling laws in MEMS. Sensors: Force and pressure sensors, resonant sensors, Thermofluid sensors. Actuators: Fundamentals of microactuation. Parallel plate electrostatic actuation. Electrostatic pressure, Comb drive actuator. Mathematical modeling: Kinematics and kinetics of MEMS. Determination of force components, Analysis of dynamic effects and frictional effects in MEMS. Design of MEMS: CAD and FEM for MEMS. Hands on practice using available MEMS software. MEMS Packaging. Introduction to Nanotechnology. Future trends in MEMS/NEMS.

Recommended Texts:

1. N Maluf, Introduction to Microelectromechanical Systems Engineering, 2nd Edition, 2004.
2. T-R Hsu, MEMS & Microsystems: Design and Manufacture, McGraw Hill, 2002
3. M Elwenspoek, R Wiegerink, *Mechanical Microsensors*, Springer-Verlag, 2001
4. S D Senturia, *Microsystem Design*, Kluwer, 2001
5. M Gad-El-Hak, *The MEMS Handbook*, CRC Press, 2001

ME-606 Boundary Element Method

Contact Hours:		**Credit Hours:**	
Theory	**= 48**	Theory	**= 3.0**
Practical	**= 0**	Practical	**= 0.0**
Total	**= 48**	Total	**= 3.0**

Prerequisite Course:

Course Learning Outcomes:

Upon successful completion of this course, the student will be able to:

1	**COMPARISON** and **ASSESSMENT** of whether the Boundary Element or Finite Element method would be appropriate for a particular modeling situation
2	**ANALYZE** given problem using different methodologies of BEM
3	**UTILIZE** open source computer software for developing routine of different methodologies of BEM.

Course Contents:

Introduction to boundary solutions, Fundamental solutions, Weighted residual methods, Potential problems, Solution to Laplace, Poisson’s and Helmoltz equations, Non-homogeneous solids, Linear elasticity problems, Anisotrpoic elasticity, Coupling of Finite and Boundary elements, Singular elements for fracture mechanics.

Recommended Texts:

1. CA Brebbia, The Boundary Element Method for Engineers, Pentech, 1984.
2. CA Brebbia, J Dominguez, *Boundary Elements, An introductory course*, McGraw-Hill, 1989

ME-607 Finite Element Programming

Contact Hours:		**Credit Hours:**	
Theory	= **48**	Theory	= **3.0**
Practical	= **0**	Practical	= **0.0**
Total	= **48**	Total	= **3.0**

Prerequisite Course:

Course Learning Outcomes:

Upon successful completion of this course, the student will be able to:

1	**DEMONSTRATE** the ability to write own FEM computer programs, for mathematically simple but physically challenging problems in open source software
2	**SYNTHESIZE** Program for Automatic mesh generation and its refinement for specified physical problem
3	**MODIFY** an existing finite element program to implement alternative finite elements and/or finite element techniques

Course Contents:

Implementation of FEM, Development of general geometry-based code, Higher order adaptive techniques, Effective construction of element matrices, Ordering of the unknowns, Automatic mesh generation and refinement, adaptive mesh refinement, Program and database structures, Object oriented FEM.

Recommended Texts:

1. I M Smith, D V J Griffith, *Programming the Finite Element Method*, 5th ed, Wiley & Sons, Chichester, 2015.
2. Dan Lo, *Finite element mesh generation,* Boca Raton : CRC Press, Taylor & Francis Group, [2015]
3. R I Mackie, Object Oriented Methods & Finite Element Analysis, Saxe-Coburg Pub, 2002.
4. JF Thompson, B Soni, N Weathrill, *Handbook of Grid Generation*, CRC Press, 1999

ME-608 Theory of Plates and Shells

Contact Hours:
Theory = **48**
Practical = **0**
Total = **48**

Credit Hours:
Theory = **3.0**
Practical = **0.0**
Total = **3.0**

Prerequisite Course:

Course Learning Outcomes:

Upon successful completion of this course, the student will be able to:

1	**ANALYZE** the effect of discontinuity on the stress distribution in plates and shells
2	**ANALYZE** and **DESIGN** plates and shell for given loading condition
3	**FORMULATE** Finite Element Equations for solution of the structural response of plate bending problems and obtain solutions to shell structures

Course Contents:

Preliminaries of linear, three-dimensional elasticity theory, Reduction of the elasticity theory to theories of plates and shells, Anisotropy, Nonlinear theories, Effects of discontinuities on the stress distribution in plates and shells, Energy methods and thermal stresses in plates, application of finite element method for plate bending Design construction features of plates and shells, Applications.

Recommended Texts:

1. J F Harvey, Van Nostrand, *Theory and Design of Modern Pressure Vessels*, 3rd ed, Reinhold Co., New York, 1974
2. S Timoshenko, W Krieger, *Theory of Plates & Shells*, 2nd ed, McGraw-Hill, 1959
3. E Ventsel, Thin Plates & Shells, Theory, Analysis and Application, CRC Press, 2001

ME 609 Theory of Compressible Flows

Contact Hours:		**Credit Hours:**	
Theory	**= 48**	Theory	**= 3.0**
Practical	**= 0**	Practical	**= 0.0**
Total	**= 48**	Total	**= 3.0**

Prerequisite Course:

Course Learning Outcomes

Upon successful completion of the course, the student will be able to:

1	**COMPREHEND** basic characteristics of compressible flows
2	**ANALYZE** and **PERFORM** calculations for 1D compressible flows with heat addition/friction
3	**ANALYZE 2D** compressible flows having shock waves/expansion waves/moving normal shock waves
4	**ASSES** various practical systems having compressible flow through the use of software

Course Contents:

General equations of compressible flow, Specialization to inviscid flows in 2D, Characteristic equations for supersonic flow with applications in external and internal flow, 1D non-steady compressible flow, Introduction to Transonic/Hypersonic flows, numerical approaches used to solve practical compressible flows problems.

Recommended Texts:

1. John Anderson, *Fundamentals of Aerodynamics*, 6th edition, McGraw Hill, 2017
2. John Anderson, Modern Compressible Flows: With Historical Perspective, 3rd edition, McGraw Hill, 2002.

ME-612 Mechanical Design of Process Equipment

Contact Hours:		**Credit Hours:**	
Theory	**= 48**	Theory	**= 3.0**
Practical	**= 0**	Practical	**= 0.0**
Total	**= 48**	Total	**= 3.0**

Prerequisite Course:

Course Learning Outcomes:

Upon successful completion of the course, the student will be able to:

1	**INTERPRET** the ASME code section-VIII for design of pressure vessels
2	**ANALYZE** the different components of pressure vessels
3	**ANALYZE** pressure vessel design using FEA software
4	**COMPARE** pressure vessel design (used in different industries), based on mechanics Theory, FEA and ASME code

Course Contents:

Pressure Vessel codes; Analysis and design of cylindrical shells, formed heads and transition sections; flanges; cover plates; openings; nozzles; external loadings; vessel supports; individual project for a process equipment design.

Recommended Texts:

1. A H Jawad, J R Farr, Structural Analysis & Design of Process Equipment, Third Edition John Wiley, 2019
2. A C Ugural, Stresses in Plates and Shells, McGraw-Hill, Third Edition 2010

ME-613 Hypersonic Aerodynamics

Contact Hours:		**Credit Hours:**	
Theory	**= 48**	Theory	**= 3.0**
Practical	**= 0**	Practical	**= 0.0**
Total	**= 48**	Total	**= 3.0**

Prerequisite Course:

Course Learning Outcomes

Upon successful completion of the course, the student will be able to:

1	**DEMONSTRATE** the critical physical phenomena in hypersonic and planetary re-entry flows
2	**CALCULATE** hypersonic inviscid flows using approximate and exact methods
3	**ANALYZE** problems involving shock-wave/boundary layer interactions and high temperature gas dynamics
4	**COMPARE** hypersonic flows around various geometries under various flow conditions using open source code

Course Contents:

Hypersonic environment; governing equations and hypersonic relations; approximation in hypersonic inviscid flow; approximate and exact method in hypersonic inviscid flows; hypersonic boundary layer theory; hypersonic viscous interaction; hypersonic vehicle design considerations; high temperature gas dynamics; inviscid high temperature equilibrium and non-equilibrium flows; viscous high temperature flows and solution strategies;

Recommended Texts:

1. John D Anderson Jr, Hypersonic and High Temperature Gas Dynamics, 3rd edition, 2019
2. J. Bertin, *Hypersonic Aerothermodynamics*, AIAA series, 1991

ME-614 Advanced Computational Fluid Dynamics

Contact Hours:		**Credit Hours:**	
Theory	= **48**	Theory	= **3.0**
Practical	= **0**	Practical	= **0.0**
Total	= **48**	Total	= **3.0**

Prerequisite course:

Course Learning Outcomes

Upon successful completion of the course, the student will be able to:

1	**EXPLAIN** major theories and methods used in CFD to solve engineering problems.
2	**SOLVE** the CFD related problems using learned techniques.
3	**DEVELOP** a CFD model for practical engineering problems.
4	**EVALUATE** a practical fluid system problem and **SELECT** the right software, CFD methodology, flow and numerical models for its analysis.

Course Contents:

Motivation, scope and limitations of CFD; review of Navier-Stokes equations and Finite Volume Method; grid generation on complex geometries; mesh adaptation and dynamic mesh; numerical modelling of compressible and incompressible flows; turbulence modelling; multiphase modelling; introduction to fluid-structure interaction and its applications; user defined functions for CFD a commercial software.

Recommended Texts

1. J. Tu, G. H. Yeoh, C. Liu, Computational Fluid Dynamics: A Practical Approach, 3rd Ed, Butterworth-Heinemann, 2018
2. H. K. Versteeg, W. Malalsekera, *An Introduction to Computational Fluid Dynamics*, 2nd Ed, Pearson, 2010.
3. J. H. Ferziger, M. Peric, *Computational Methods for Fluid Dynamics*, 3rd Ed, Springer 2001.
4. J. D. Anderson, Computational Fluid Dynamics: The Basics with Applications, McGraw Hill Education, 1995.
5. S. V. Patankar, *Numerical Heat Transfer and Fluid Flow*, McGraw Hill Education, 1980.

ME-615 Hybrid Energy Systems

Contact Hours:	**Credit Hours:**
Theory = **48**	Theory **= 3.0**
Practical = **0**	Practical **= 0.0**
Total = **48**	Total **= 3.0**

Prerequisite Course:

Course Learning Outcomes

Upon successful completion of the course, the student will be able to:

1	**DEMONSTRATE** pathways of the components of hybrid energy systems
2	**ANALYZE** and **PERFORM** design calculations of wind and solar energy systems
3	**ANALYZE** various aspects of nuclear-renewable hybrid energy systems for given conditions.
4	**EVALUATE** and **MODEL** hybrid energy systems using available simulation software

Course Contents:

Overview of power system structure and operation; introduction to hybrid energy systems; advantages and challenges of hybrid energy systems. Wind energy system (aerodynamic model, wind turbine generators and their analysis, modeling of wind energy system). Photovoltaic power system (photovoltaic power conversion, PV characteristics, modeling of PV energy system). Hybrid energy systems based on wind and solar power with some case studies, design and analysis of renewable energy system or hybrid energy systems using available software. SMRs and their types; Design characteristics of various SMRs and their challenges. Issues for the deployment of nuclear-renewable hybrid systems. Economic aspects of nuclear-renewable hybrid energy systems with some case studies from the literature. Energy storage systems. Grid integration impact of hybrid energy sources; options of electricity grids (Micro grid, Smart grid and Super grid systems). Dynamic energy switching.

Recommended Texts:

1. John Twidell, Tony Weir, *Renewable Energy Resources*, 3rd Edition, Routledge, 2015
2. Henrik Lund, *Renewable Energy Systems*, 2nd Edition, Elsevier, 2014
3. Mohamed Abdelaziz Mohamed, Modeling and Simulation of Smart Grid Integrated with Hybrid Renewable Energy Systems, Springer, 2018
4. Mario D. Carelli, Daniel T. Ingersoll, *Handbook of Small Modular Reactors*, WP, 2015
5. IAEA TECDOC-1885, Nuclear Renewable Hybrid Energy Systems for Decarbonized Energy Production and Cogeneration, 2018
6. IAEA's database on Advanced Reactor Information Systems (ARIS)

ME-616 Advanced Turbomachinery

Contact Hours:		**Credit Hours:**	
Theory	= **48**	Theory	= **3.0**
Practical	= **0**	Practical	= **0.0**
Total	= **48**	Total	= **3.0**

Prerequisite Course:

Course Learning Outcomes:

Upon successful completion of the course, the student will be able to:

1	**APPLY** elementary theory of turbomachines
2	**ANALYZE** performance of various turbomachines and characteristic curves.
3	**ASSESS** design features of turbomachines
4	**SELECT** turbomachine according to the given working condition

Course Contents:

Introduction to turbo-machinery, elementary theory , methods of accounting for component losses, principle of operation of gas turbines, radial and axial flow gas turbines, work done and pressure rise,diffuser, compressibility effects, scaling and similitude for turbomachinery performance, hydraulic turbines, cavitation in hydraulic turbine, pump section and their characteristics, cavitation in pumps, radial and axial compressors, steam turbines and performance parameters, incorporation of variable pressure losses.

Recommended Texts:

1. V. Dakshina Murty, Turbomachinery Concepts, Applications and Design, CRC, 2018
2. Seppo A. Korpela, *Principles of turbomachinery*, John Wiley & Sons, 2011
3. Erik Dick, Fundamentals of turbomachines, Springer, 2015
4. S.L.Dixon, Fluid Mechanics and Thermodynamics of Turbomachinery, 6ed, Butterworth-Heinemann, 2010
5. R S R Gorla, A A Khan, Turbo-machinery design and theory, Marcell Dekker, 2003.

ME-697[a & b] MS Thesis Research

Contact Hours:		**Credit Hours:**	
Theory	= **0**	Theory	= **0**
Practical	= **288+288**	Practical	= **6+6**
Total	= **576**	Total	= **12**

Prerequisite Course:

Course Learning Outcomes

Upon successful completion of the course, the student will be able to:

1	**INVESTIGATE** Research topic in through detail
2	**FORMULATE** the solution(s) of Research Topic in through detail
3	**PLAN** and **MANGE** research to achieve the targets in specified time line.
4	**CONCLUDE** effectively, Research details through a technical report and oral presentations.
5	**JUDGE** consciousness of the ethical aspects of research and development work.

The student will undertake an in-depth study of some mechanical engineering related problem. This will be done either by joining an on-going research program, or by initiating a new program under the guidance of a PIEAS faculty member / a visiting faculty member from another R&D organization / scientists, engineers of the establishments where the graduates are likely to be employed. The nature of the thesis may be research, development or design and may involve experimental, theoretical, or computational work or a combination of these. Each student will be assigned a 'Thesis supervisor' from the PIEAS faculty. 'Co-supervisors' may also be assigned, depending on the nature of the work. The supervisor and co-supervisors will guide, instruct and supervise the student in their thesis work. They will also be responsible for reporting the grade of the student based on their evaluation. In this evaluation they may be aided by committee of experts to be appointed by the Department Head. The student shall write a comprehensive report and shall deliver at least one presentation before the end of each semester. The report and the presentation shall also be used in the overall evaluation of the student.

Recommended Texts:

- As advised by the Project Supervisor

Special Topics in Mechanical Engineering I, II, III, IV

All of these Special courses (ME-59x and ME-69x) will be designed to accommodate such special topics in the field of mechanical engineering that are not presently covered under other titles described here. The course will be designed and updated to keep pace with the emerging technologies in the field of mechanical engineering. The course will include lectures by visiting faculty on such advanced topics that may not be taught under other titles described here. Courses offered under the title of Special Topics will be approved by either the Board of Studies or three senior faculty members of the department. A course may be offered for two years, meanwhile it will be approved through the approved channel as a regular course.

INTER-DISCIPLINARY ELECTIVE COURSES

CHE-612 Multiphase Flow and Heat Transfer

Contact Hours:
Theory = **48**
Practical = **0**
Total = **48**

Credit Hours:
Theory = **3.0**
Practical = **0.0**
Total = **3.0**

Prerequisite Course:

Course Learning Outcomes

Upon successful completion of the course, the student will be able to:

1	**SELECT** Multi-fluid model for solution of given problem
2	**APPLY** multi-phase flows model for solution of given problem
3	**ANALYZE** multi-phase flows in Nuclear power plant
4	**ANALYZE** Multi fluid problem using available computer software

Course Contents:

The nature of multiphase flows; Basic models for two-phase flows, Pressure drop and void fraction, Phenomenological models for two-phase flows, Phase change heat transfer, Multifield models, Thermal non-equilibrium flows, Instabilities in two-phase flow, Applications of single-phase CFD to two-phase systems, Application of multifluid models, Interface-tracking methods, Description of various approaches for multiphase fluid models, Volume of Fluid, Level Sets, embedded interface methods etc, Turbulence modelling in two-phase flows, Multiphase phenomena in Nuclear Systems, Computational Multi-fluid Dynamics (CMFD)

Recommended Texts:

1. C Crowe, M Sommerfield, Y Tsuji, *Multiphase Flows with Droplets and Particles*, CRC Press, 1998
2. P B Whally, Two-Phase Flow and Heat Transfer, (1996)
3. L S Tong, Y S Tang, *Boiling Heat Transfer and Two-Phase Flow*, Taylor & Francis, 2nd ed, 1997

CHE-613 Combustion Emission and Control

Contact Hours:		**Credit Hours:**	
Theory	**= 48**	Theory	**= 3.0**
Practical	**= 0**	Practical	**= 0.0**
Total	**= 48**	Total	**= 3.0**

Prerequisite Course:

Course Learning Outcomes

Upon successful completion of the course, the student will be able to:

1	**JUDGE** design trade-offs between increasing performance and maintaining low emission characteristics of combustion systems
2	**ANALYZE** Pollutants formation in different combustion systems
3	**FORMULATE** mechanisms and reduction strategies of pollutant species in a combustion system
4	**ANALYZE** combustion system using available computer software

Course Contents:

Fundamental Concepts in Combustion, Primary and Secondary Fuels and Fuel Testing, Energy Conversion with Combustion, Combustion technology of gas, oil and coal, Operation of combustion plant, Pollutants formation in combustion systems, Production and emission of nitrogen oxide and sulphur oxide gases from combustion engines, Emission from coal fired power plants, Combustion calculations, staged combustion, Recent Development in control technologies, Chemical kinetics of reactions; multi-component reacting systems and their equations; coupling of chemical and thermal analysis of reacting systems; Constant pressure fixed mass reactor model; Constant volume fixed mass reactor model; perfectly stirred reactor model; Plug flow reactor model; Application to combustion system modelling; Combustion and chemical kinetic modellingsoftwares; Introduction to chemical kinetic codes for plug flow reactors, perfectly stirred reactors, shock tubes and premixed flames.

Recommended Texts:

1. Glassman, *Combustion*, Academic Press, 1994
2. E N Goodger, *Combustion Calculation*, MacMillan, 1977
3. R A Strehlow, *Combustion Fundamentals*, McGraw Hill, 1988
4. S Brame, J G King, Fuels, *Solid, Liquid and Gaseous*, St Martin's Press, NewYork. 1973
5. M L Smith, K W Stinson, *Fuels and Combustion*, McGrawHill Book Company, 1959
6. J M Smith, *Chemical Engineering Kinetics*, McGraw Hill, 1985