Department of Mechanical Engineering

Pakistan Institute of Engineering and Applied Sciences

Curriculum

for

Master of Science

in

Mechanical Engineering

2017

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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) Mechanical Behaviour of Materials
  2) Applied Solid Mechanics
  3) Finite Element Method
  4) Introductory 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

- The curriculum was approved for implementation by Academic Committee in the meeting held on 3rd & 4th January 2018.

LIST OF COURSES IN MS ME CURRICULUM

Course Code	Course Title	Credit Hours
CORE COURSES		
ME-503	Finite Element Method	3 + 0
ME-505	Mechanical Behaviour of Materials	3 + 0
ME-516	Applied Solid Mechanics	3 + 0
ME-517	Introductory Multiphase Heat Transfer & Fluid Flow	3 + 0
INSTITUTIONAL REQUIREMENT		
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
ELECTIVE COURSES		
ME-507	Solar Devices and Renewable Energy	3 + 0
ME-509	Experimental Stress Analysis	3 + 0
ME-512	Computer-Aided Analysis	3 + 0
ME-513	Advanced Mechanical Vibrations	3 + 0
ME-514	Applied Mechatronics	3 + 0
ME-523	Theory of Machines and Mechanisms	3 + 0
ME-524	Mechanical Systems Design	3 + 0
ME-525	Advanced Thermodynamics	3 + 0
ME-526	Welding & Non-Destructive Testing	3 + 0
ME-601	Theory of Elasticity	3 + 0
ME-602	Fracture Mechanics	3 + 0
ME-603	Non-Linear Finite Element Method	3 + 0
ME-604	Theory of Plasticity	3 + 0
ME-605	MicroElectroMechanical Systems (MEMS)	3 + 0
ME-606	Boundary Element Method	3 + 0
ME-607	Finite Element Programming	3 + 0
ME-608	Theory of Plates and Shells	3 + 0
ME-609	Theory of Compressible Flows	3 + 0
ME-610	Turbo-machinery Theory	3 + 0
ME-611	Turbo-machinery Design	3 + 0
ME-612	Mechanical Design of Process Equipment	3 + 0
ME-69x	Special Topics in Mechanical Engineering I, II, III, IV	3 + 0
ME-697	MS Thesis Research	0 + 12
INTER-DISCIPLINARY ELECTIVE COURSES		
CHE-612	Multiphase Flow and Heat Transfer	3 + 0
CHE-613	Combustion Emission and Control	3 + 0
CHE-614	Computational Fluid Dynamics	3 + 0

CORE COURSES

ME-503 Finite Element Method

Course Objectives:

The course is intended to provide the fundamental concepts of the theory of finite element method and to expose aspects of the application of the method to realistic engineering problems in the fields of solid mechanics, heat transfer and fluid flow using any general-purpose finite element code.

Course Contents:

General concepts of FEM, Galerkin / weighted residual method, Rayleigh-Ritz / variational method, Shape functions, Isoparametric elements, 1D problems: trusses, beams and frames, 2D problems: plane stress, plane strain and axisymmetric problems, 3D stress analysis, Heat transfer, Fluid flow problems, Numerical integration: Gaussian quadrature, Reduced integration, The Patch test, Finite element error analysis, Error estimates, Convergence and accuracy of solutions, Infinite and singularity elements, Time Dependant problems, Semi-discrete FEM, Time approximations.

Recommended Texts:

1. F L Stasa, *Applied Finite Element Analysis for Engineers*, Int'l Thomson Pub, 1995
2. S S Rao. *Finite Element Method in Engineering*, 3rd ed., Pergamon Press, 1999
3. O C Zienkewicz, R L Taylor, *The Finite Element Method*, *Vol 1: Basics*, 5th ed., 2002

ME-505 Mechanical Behaviour of Materials

Course Objectives:

This course is designed to provide the student with knowledge of important aspects of material behavior, which a mechanical engineer as designer should clearly understand.

Course Contents:

Engineering stresses and strains, True stresses and strains, Methods of obtaining stress-strain curves, Procedures of performing tension, compression and hardness experiments, Types and design of test specimen used in tension and compression experiments, Stress concentration factor, Failure theories, Definition of homologous temperature and its importance in engineering, Creep and relaxation, Monotonic stress strain behavior of materials, 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 Fracture Mechanics, Modes of fracture, Stress intensity factor, Dislocation theory.

Recommended Texts:

1. K Chawla, M Meyers, *Mechanical Behavior of Materials*, Prentice Hall, 1st ed., 1998
2. J A Bannantine, J J C Former, J L Handrock, *Fundamentals of Metal Fatigue Analysis*, Prentice Hall publications. 1989
3. N E Dowling, *Mechanical Behavior of Materials: Engineering Methods for Deformation, Fracture, and Fatigue*, 2nd ed., Prentice Hall, 1998

ME-516 Applied Solid Mechanics

Course Objectives:

To enhance the knowledge gained from BS courses on mechanics of materials by including complete three-dimensional stress analysis and other advanced topics so that the students have a strong technical basis for the advanced design courses.

Course Contents:

Overview of tensor algebra & calculus, the Stress tensor, Stress transformations, Principal stresses and directions, Mohr's circles in 3D, Deformation gradients, Finite Strain tensors, Infinitesimal deformation theory, Stretch tensors, Constitutive equations, Linear elasticity, Generalized stress-strain relationship, Strain energy, Rate of work done by stress, Nominal & material stress tensors, Isotropic media, Elastic constants, Anisotropic media, Airy stress functions, Torsion,

Recommended Texts:

1. A F Bower, *Applied Mechanics of Solids*, CRC Press, 2010
2. G T Mase, GE Mase, *Continuum Mechanics for Engineers*, 3rd ed, CRC Press, 2015
3. R G Budynas, *Advanced Strength and Stress Analysis*, 2nd ed, McGraw Hill, 1999

ME-517 Introductory Multiphase Heat Transfer & Fluid Flow

Course Objectives:

To make the students able to assess the performance of systems meant to transfer heat; to analyze actual systems involving multiple modes of heat transfer; to determine the relative contributions of different modes of heat transfer and to select appropriate analysis methods based on the dominant physical characteristics; to be able to design and predict the performance of heat transfer systems based on boiling and two phase flow

Course Contents:

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*, 2nd ed, 1993
3. D Q Kern, Process Heat Transfer, McGraw Hill, 1960
4. E Ludwig, *Applied Process Design for Chemical & Petrochemical Plants* 3rd ed, Gulf Pub, 2001

INSTITUTIONAL REQUIREMENT

CMS-501 Communication Skills

Course Objectives:

Mastering communications skills is necessary for any professional and engineers are not considered as exception. The inclusion of this course is aimed at making PIEAS graduates more confident in the art of communication.

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

Course Objectives:

This course is designed for making any engineer, working in nuclear industry, familiar with the fundamental concepts of nuclear engineering.

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

Course Objectives:

This course is meant for making those working in nuclear industry conscious of radiation hazards.

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

Course Objectives:

Mechanical engineers form the core of personnel nuclear power plants. Therefore familiarization with various power plants systems is extremely important for a curriculum of mechanical engineering.

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-507 Solar Devices and Renewable Energy

Course Objectives:

Through this course fundamentals of solar energy have been introduced.

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*, 2nd ed, John Wiley & Sons, 1991

ME-509 Experimental Stress Analysis

Course Objectives:

The main purpose of experimental stress analysis (ESA) is to avert the failures of load bearing structures/machine components by providing information to aid the engineer in developing safe, reliable and durable products at economical costs.

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-512 Computer-Aided Analysis

Course Objectives:

To provide a firm understanding of computational engineering by introducing engineering analysis software through hands-on training sessions so that the students do not get misled while performing engineering analysis on computers and also use engineering judgment to correctly interpret the results.

Course Contents:

Introduction to available finite element analysis software (ANSYS). 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, introduction to dynamic (modal, harmonic, transient) analyses, parallel/ distributed computing

Recommended Texts:

1. *ANSYS Documentation*, Ansys Inc.
2. H H Lee, Finite Element Simulations using ANSYS Workbench.

ME-513 Advanced Mechanical Vibrations

Course Objectives:

This course is designed to provide basic and applied knowledge of vibration analysis.

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

Course Objectives:

The main theme of this course is to familiarize the students with the latest techniques involved in the implementation, realization and evaluation of mechatronic systems.

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-523 Theory of Machines and Mechanisms

Course Objectives:

To enhance the knowledge gained from BS courses on mechanics of machines by providing the students with a deeper theoretical basis including complete three-dimensional analysis & synthesis of kinematics & dynamics of machines & mechanisms.

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: Eulerian 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.

Recommended Texts:

1. R C Hibbeler, *Engineering Mechanics: Dynamics*, 14th ed, Prentice Hall, 2015.
2. J L Meriam, Kraige, *Engineering Mechanics: Dynamics*, 8th ed,
3. J J Uicker, G R Pennock, J E Shigley, *Theory of Machines & Mechanisms*, 3rd ed, Oxford Univ Press, 2003.

ME-524 Mechanical Systems Design

Course Objectives:

Machine design courses generally deals only with design of machine elements and not the machines. This course intends to understand design of machines as a complete system.

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.
4. G Pahl, W Beitz, *Engineering Design, a systematic approach*, 2nd ed, Springer, 1996

ME-525 Advanced Thermodynamics

Course Objectives:

It is hoped that this course will introduce the concept of the quality of energy and help engineers use the resources more efficiently. This course attempts to introduce basic concepts which should apply over the whole range of new technologies covered by engineering thermodynamics.

Course Contents:

Equilibrium of thermodynamics systems: spontaneous changes, criterion of stability, equilibrium of system. 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, steady state or irreversible thermodynamics, thermo-electricity.

Recommended Texts:

1. D E Winterbone, *Advanced thermodynamics for Engineers*, Arnold, 1997.
2. K Annamalai, I K Puri, *Advanced thermodynamics in engineering*, CRC Press, 2002.

ME-601 Theory of Elasticity

Course Objectives:

To introduce the student to the analysis of linear elastic solids under mechanical and thermal loads. The material presented in this course will provide the foundation for pursuing other solid mechanics courses such as plates and shells, fracture mechanics, theory of plasticity.

Course Contents:

Review of concepts of stress & strain, Index notation, Plane stress and plane strain, Two dimensional problems in rectangular coordinates and polar coordinates, Two dimensional problems in 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

Course Objectives:

This course will enable the student to apply knowledge of fracture in designing mechanical components with deeper understanding of material behavior under various types of loading and also in predicting the failure of mechanical components undergoing fatigue.

Course Contents:

Basic problems and concepts, Mechanisms of fracture and crack growth. The elastic crack-tip stress field, The crack tip plastic zone, The energy principle, Dynamics and crack arrest, Plane strain fracture toughness, Plane stress and transitional behavior, Elastic-plastic fracture, Fatigue crack propagation, Fracture resistance of maltreats, Fail-safety and damage tolerance, Determination of stress intensity factors, Practical problems, Fracture of structures, Stiffened-sheet structures, Prediction of fatigue crack growth.

Recommended Texts:

1. D Broek, *Elementary Engineering Fracture Mechanics*, 4th ed, Martinus Nijhoff Pub, 1982
2. C Brooks, A Choudhury, *Failure Analysis of Engineering Materials,* McGraw-Hill, 2001
3. V FrGechette, *Failure Analysis of Brittle Materials*, American Ceramic Society, 1990
4. T L Anderson, *Fracture Mechanics: Fundamentals & Applications*, 3rd ed, CRC Press, 2004

ME-603 Non-Linear Finite Element Method

Course Objectives:

The purpose of this course is to provide students with a critical survey of the state-of-the-art of finite element methods in solids, structures, and fluids, with an emphasis on methodologies and applications for nonlinear problems. The fundamental theoretical background, the computer implementations of various techniques and modeling strategies will be treated. Recent mathematical and algorithmic developments will be explained in terms comprehensible to students.

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 C^1 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, Vol-2: Solid Mechanics*, 5th ed., Butterworth and Heinemann, 2002

2. J Bonet, R D Wood, *Non-linear Continuum Mechanics for Finite Element Analysis*, Cambridge University Press, 1997
3. M Kleiber, A Borkowski, *Handbook of Computational Solid Mechanics: Survey and Comparison of Contemporary Methods*, Springer Verlag, 1998

ME-604 Theory of Plasticity

Course Objectives:

The main objective of this course is to enable students to understand, use and build constitutive models for plastic materials. The course is intended to emphasize the importance of theory of plasticity in engineering design to strengthen the theoretical background of practical problems.

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

Course Objectives:

This course introduces the recent trends in the field of MEMS and its applications.

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*, 2000.
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

Course Objectives:

This course will provide the students with the background necessary to implement the boundary element method to realistic engineering problems such as wave propagation, free vibration analysis, etc.

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

Course Objectives:

This course is intended to the students for developing their own computer programs which use the finite element method to solve specific problems. FEM has become the leading method in computer-oriented mechanics, so that many scientific branches have grown up over the last decades.

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*, 3rd ed, Wiley & Sons, Chichester, 1998.
2. R I Mackie, *Object Oriented Methods & Finite Element Analysis*, Saxe-Coburg Pub, 2001.
3. JF Thompson, B Soni, N Weathrill, *Handbook of Grid Generation*, CRC Press, 1999

ME-608 Theory of Plates and Shells

Course Objectives:

The objective of the course is to enhance knowledge in analysing the plates and shell structures and to familiarize students with various avenues of modelling structural engineering components and obtaining exact and/or approximate solutions.

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, 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

Course Objectives:

Exposure to gas dynamics is intended to show the application of mechanics and thermodynamics to a variety of compressible fluid problems. Emphasis is placed on understanding physical mechanisms of shockwaves, compressible flow in ducts with friction or heat transfer and flow with area change.

Course Contents:

General equations of compressible flow, Specialization to inviscid flows in 2D, Linearised solution in subsonic and supersonic flow, Characteristic equations for supersonic flow with applications in external and internal flow, 1D non-steady compressible flow, Introduction to Transonic flow.

Recommended Texts:

1. M Feistauer, I Straskraba, J Felcman, *Mathematical and Computational Methods for Compressible Flow*, Oxford University Press, 2003
2. Stephan, Schreier, *Compressible Flow*, John Wiley and Sons, 1982

ME-610 Turbo-Machinery Theory

Course Objectives:

The importance of turbo machinery cannot be overemphasized as it has a range of applications from Gas Power Plants to aero-engines and more. In order to attain expertise in designing systems involving turbo-machinery, it is very important that its underlying theory be completely understood. This course covers the theory of major components of turbo machinery.

Course Contents:

Introduction to turbo-machinery, elementary theory, propulsion, shaft power cycles, ideal cycles, methods of accounting for component losses, design of point performance calculations, comparative performance of practical cycles, combined cycles and cogeneration schemes, closed cycle gas turbine, turbojet, turbofan, turboprop and turboshaft engines, auxiliary power units, thrust augmentation, air breathing engines, simple compressible system, parametric cycle analysis of ideal engines, variation in gas properties, component performance, inlet and outlet pressure recovery, compressor and turbine efficiencies, burner efficiency and pressure loss, exit nozzle loss.

Recommended Texts:

1. Saravanamuttoo, Rogers & Cohen, *Gas Turbine Theory*, 5th ed, Pearson, 2001.
2. J D Mattingley, *Elements of Gas Turbine Propulsion*, Int'l ed., McGraw Hill, 2005
3. R S R Gorla, A A Khan, *Turbo-machinery design and theory*, Marcell Dekker, 2003.

ME-611 Turbo-Machinery Design

Course Objectives:

This course builds upon the earlier course on Turbomachinery Theory and deals with details of designing the various important components of turbomachinery systems.

Course Contents:

Principle of operation of gas turbines, work done and pressure rise, diffuser, compressibility effects, non-dimensional quantities for plotting compressor characteristics, computerized design procedures, factors affecting stage pressure ratio, degree of reaction, 3D flow, design process, blade design, calculation of stage performance, vortex theory, choice of blade profile, pitch and chord, blade cooling, radial flow turbine, off design performance of single shaft gas turbine, free turbine engine and jet engine, incorporation of variable pressure losses, prediction of performance of turbo-machinery.

Recommended Texts:

1. C A Norman, R H Zimmerman, *Introduction to Gas Turbine and Jet Propulsion Design*, Harper & Brothers, 1948.
2. D G Wilson, *Design of high efficiency turbo-machinery & gas turbines*, Prentice Hall, 1998
3. Boyce, *Gas Turbine Engineering Handbook*, 3rd ed., GPP. 2006.
4. J D Mattingley, *Aircraft engine design*, AIAA Education series. 2002

ME-612 Mechanical Design of Process Equipment

Course Objectives:

This course provides an understanding for the analysis and design of process equipment, with some introduction to the theory of plates and shells. The aim of the course is to have an understanding of designing in view of the ASME Boiler & Pressure Vessel Code, Section VIII.

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*, John Wiley, 1984
2. A C Ugural, *Stresses in Plates and Shells*, McGraw-Hill, 1999.

ME-697 MS Thesis Research

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-690 – ME-693) 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

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

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

CHE-614 Computational Fluid Dynamics

Course Contents:

Motivation for CFD; scope and limitations. Review of continuity and transport equationsfor momentum, heat & specie. Survey of numerical methods for convection-diffusion problems: Finite Difference, Finite Volume, Finite Element, Boundary Element Methods, etc. Finite difference method applied to potential flow and conduction problems. Finite Volume method: discretization of diffusion equation, various discretization techniques for convection-diffusion terms, various types of boundary conditions their applications and numerical implementations. Introduction to turbulence and its modeling. Review of solution techniques for system of linear equations, Tri-Diagonal Matrix Algorithm. Introduction to numerical instabilities and convergence; under and over relaxation techniques Case studies on a CFD code: Laminar flow case studies and their verification (Coute flow, convection heat transfer in a circular tube etc.), turbulent flow cases studies and their verifications (turbulent flow in a pipe, jet mixing etc.)

Recommended Texts:

1. S V Patankar, *Numerical heat transfer and fluid flow*, Hemisphere, 1980.
2. H K Versteeg, W Malalasekera, *An introduction to Computational Fluid Dynamics*, Addison Wesley Longman Limited, 1995
3. J D Anderson, *Computational Fluid Dynamics: The Basics with Applications*, McGraw Hill Book Co, 1995