MS Mechanical Engineering Curriculum

(Revision November 2011)

The Program Objectives:

Through its MS ME program PIEAS aims at enhancing technical competence of the mechanical engineers in the major disciplines of mechanical engineering along with reasonable exposure to advanced mathematics, use of computers in engineering, communication skills and research methodologies. The curriculum is designed for providing knowledge based confidence to mechanical engineers, not only for undertaking a variety of industrial assignments but also for pursuing R&D activities.

Basis and the Outcomes of the Revision.

1. The revision is based on the teaching experience of 04 batches of MS ME, feedback provided by the students of earlier batches and the job market requirements.
2. Some new courses have been introduced and some of the existing courses have been improved while others remain unchanged.
3. Efforts are made for keeping the course contents in line with their stated objective(s) which are in turn consistent with objectives of the degree program (stated above).

Table 1 A Summary of Courses of Revised MS ME Curriculum (Sorted Knowledge Area Wise)

Knowledge Area	Course Title	Course Code	Credit Hours	Status	Remarks
Mathematics	Applied Mathematics	PAM-501	3	C	This is a unified course for most of the MS programs of PIEAS
Solid Mechanics	Applied Solid Mechanics	ME-516	3	C	Course contents are improved
	Mechanics of Composites	MME-522	3	O	Course contents of these courses remain unchanged
	Theory of Elasticity	ME-601	3	O	
	Fracture Mechanics	ME-602	3	O	
	Theory of Plasticity	ME-604	3	O	
	Theory of Plates & Shells	ME-608	3	O	
Computational Engineering	Finite Element Method	ME-503	3	O	Course contents of these courses remain unchanged
	Numerical Methods in Engineering	EE-503	3	O	
	Non-linear Finite Element Method	ME-603	3	O	
	Boundary Element Method	ME-606	3	O	
	Finite Element Programming	ME-607	3	O	
	Computational Gas Dynamics	CHE-633	3	O	
	Computer-Aided Analysis	ME-512	2+1	C	Course contents of these courses are updated
	Computational Fluid Dynamics	CHE-614	3	O	
Thermo-fluids	Thermal Engineering Principles	NE-403	3	C	Course contents of these courses are updated
	Process Heat Transfer	CHE-512	3	C	
	Transport Phenomenon	CHE-513	3	O	
	Advanced Thermodynamics	ME-525	3	O	A new optional course
	Theory of External Flows	CHE-536	3	O	Course contents of these courses remain unchanged
	Theory of Compressible Flows	ME-609	3	O	
Design & Manufacturing	Mechanical Behavior of Materials	ME-505	3	O	Course contents of these courses remain unchanged
	Design of Machine Elements-I	ME-518	3	O	
	Design of Machine Elements-II	ME-519	3	O	
	Welding & Nondestructive Testing	MME-543	3	O	
	Turbo-machinery Theory	ME-610	3	O	
	Turbo-machinery Design	ME-611	3	O	
	Theory of Machines & Mechanisms	ME-523	3	C	Kinematics and Dynamics (KD) is upgraded to Theory of Machines & Mechanisms (TMM).
	Mechanical Systems Design	ME-524	1+2	O	A special topic course is made a regular course
	Mechanical Design of Process Equipment	ME-612	3	O	A new design course is added.
	Experimental Stress Analysis	ME-509	3	O	Only minor changes are introduced
Power Plants	Power Plant Systems	ME-510	3	O	Contents remain unchanged
	Nuclear Power Plant Systems	NE-510	3	O	Compulsory for PAEC fellows, contents remain unchanged

Nuclear	Fundamentals of Nuclear Engineering	NE-501	3	O	Compulsory for PAEC fellows, contents remain unchanged
	Fundamentals of Radiation Protection	CHE-413	3+1	O	
	Nuclear Reactor Analysis	NE-505	3	O	Contents remain unchanged
Miscellaneous	Vibrations Analysis	ME-513	3	O	Course contents are updated
	Mathematical Modeling of Physical Systems	CHE-511	3	O	Included as a pre-requisite of CME-518 in addition to its own merit.
	Process Dynamics & Control	CHE-518	3+1	O	Included in curriculum as per demand of some PAEC establishments.
	Communication Skills	CMS-501	1	IR	Course Contents of these courses remain unchanged.
	Project Management	CMS-505	3	O	
	Mechanical Engineering Laboratory	ME-502	0+3	O	
	Solar Devices and Renewable Energy	ME-507	3	O	
	Application of Computer Graphics in Engineering	ME-514	3	O	
	Measurements and Instrumentation	ME-515	2+1	O	
	Micro Electromechanical Systems	ME-605	3	O	
	Turbulence Modeling and Grid Generation	CHE-618	3	O	
	Special Topics in Mechanical Engineering-I	ME-690	3	O	Courses designed to address the emerging issues of the industry and to meet the employers need for specialized jobs.
	Special Topics in Mechanical Engineering-II	ME-691	3	O	
	Special Topics in Mechanical Engineering-III	ME-692	3	O	
	Special Topics in Mechanical Engineering-IV	ME-693	3	O	
Thesis Research		ME-697	15	C	Thesis research is normally distributed over more than one semesters

Table 2: MS ME Courses (Tentative Semester-wise Distribution) for session 2011-13 and onwards

Code	Title	Abbr	Status	Credit	Pre-req	Semester
ME-516	Applied Solid Mechanics	ASM	C	3		Spring1
ME-523	Theory of Machines & Mechanisms	TMM	C	3		Spring1
NE-403	Thermal Engineering Principles	TEP	C	3		Spring1
PAM-501	Applied Mathematics	AM	C	3		Spring1
ME-518	Design of Machine Elements-I	DME-I	O	3		Spring1
NE-501	Fundamentals of Nuclear Engineering	FNE	O	3		Summer Session
CHE-413	Fundamentals of Radiation Protection	FRP	O	3+1		Summer Session
CMS-501	Communication Skills	CS	IR	1		Summer Session
ME-504	Advanced Thermodynamics	AT	O	3	TEP	Summer Session
ME-609	Theory of Compressible Flows	TCF	O	3	TEP	Summer Session
CHE-511	Mathematical Modeling of Physical Systems	MMPS	O	3	AM	Summer Session
ME-519	Design of Machine Elements-II	DME-II	O	3		Summer Session
MME-522	Mechanics of Composites	MC	O	3		Summer Session
ME-690	Special Topics in Mechanical Engineering – I	STME1	O	3		Summer Session
CHE-512	Process Heat Transfer	PHT	C	3		Fall
ME-503	Finite Element Method	FEM	O	3		Fall
ME-505	Mechanical Behavior of Materials	MBM	O	3		Fall
ME-524	Mechanical Systems Design	MSD	O	1+2		Fall
ME-510	Power Plants Systems	PPS	O	3		Fall
NE-510	Nuclear Power Plant Systems	NPPS	O	3		Fall
CHE-518	Process Dynamics and Control	PDC	O	3+1	AM, MMPS	Fall
ME-601	Theory of Elasticity	TE	O	3		Fall
CHE-513	Transport Phenomena	TP	O	3		Fall
CHE-536	Theory of External Flows	TEF	O	3		Fall
EE-503	Numerical Methods in Engineering	NME	O	3		Fall
NE-505	Nuclear Reactor Analysis	NRA	O	3		Fall
ME-691	Special Topics in Mechanical Engineering – II	STME2	O	3		Fall
ME-515	Measurements & Instrumentation	MI	O	2+1		Fall
ME-509	Experimental Stress Analysis	ESA	O	3		Fall
ME-612	Mechanical Design of Process Equipments	MDPE	O	3		Spring2
ME-512	Computer-Aided Analysis	CAA	O	2+1	FEM	Spring2
MME543	Welding & Nondestructive Testing	WNDT	O	3		Spring2
ME-602	Fracture Mechanics	FM	O	3	MBM	Spring2
ME-603	Nonlinear Finite Element Method	NFEM	O	3	FEM	Spring2
ME-604	Theory of Plasticity	ThP	O	3	TE	Spring2
ME-606	Boundary Element Method	BEM	O	3	FEM	Spring2
ME-607	Finite Element Programming	FEP	O	3	FEM	Spring2

ME-608	Theory of Plates & Shells	TPS	O	3	TE	Spring2
ME-610	Turbo Machinery Theory	TMT	O	3	TEP	Spring2
ME-513	Vibrations Analysis	VA	O	3		Spring2
ME-514	Applications of Computer Graphics in Engineering	ACGE	O	3		Spring2
CHE-614	Computational Fluid Dynamics	CFD	O	3	TP	Spring2
CHE-633	Computational Gas Dynamics	CGD	O	3	TCF	Spring2
ME-692	Special Topics in Mechanical Engineering– III	STME3	O	3		Spring2
ME-697	Thesis Research	TR	C	6		Spring2
CMS-505	Project Management	PM	O	3		Summer Semester
ME-507	Solar Devices and Renewable Energy	SDRE	O	3		Summer Semester
ME-605	Microelectromechanical Systems	MEMS	O	3		Summer Semester
ME-611	Turbo Machinery Design	TMD	O	3	TMT	Summer Semester
CHE-618	Turbulence Modeling and Grid Generation	TMGG	O	3	TP	Summer Semester
ME-693	Special Topics in Mechanical Engineering– IV	STME4	O	3		Summer Semester
ME-697	Thesis Research	TR	C	9		Summer Semester

	Semester-wise Structure of MS ME (2011 – 13 & Onwards)				
	(Only frequently offered optional courses have been shown)				
Code	**Title**	**Abbr**	**Status**	**Pre Req**	**Credit Hours**
	Spring 1				
PAM-501	Applied Mathematics - I	AM1	Comp.	Nil	3+0
ME-516	Applied Solid Mechanics	ASM	Comp.	Nil	3+0
NE-403	Thermal Engineering Principles	TEP	Comp.	Nil	3+0
ME-523	Theory of Machines & Mechanisms	TMM	Comp.	Nil	3+0
			Total Credit Hours =		***12***
	Summer Session				
NE-501	Fundamentals of Nuclear Engineering	FNE	Compulsory for PAEC fellows	Nil	3+0
CHE-413 / NE-507	Fundamentals of Radiation Protection / Radiological Engineering	FRP / RE	Compulsory for PAEC fellows	Nil	3+0
CMS-501	Communication Skills	CS	Comp.	Nil	1+0
			Total Credit Hours =		***7***
	Fall Semester				
ME-503	Finite Element Method	FEM	Opt.	Nil	3+0
NE-510/ ME-510	Nuclear Power Plant Systems/ Power Plant Systems	NPPS/ PPS	Opt.	Nil	3+0
ME-505	Mechanical Behavior of Materials	MBM	Opt.	Nil	3+0
CME-512	Process Heat Transfer	PHT	Comp.	Nil	3+0
ME-524	Mechanical Systems Design	MSD	Opt.	Nil	1+2
			Total Credit Hours =		***15***
	Spring 2				
ME-512	Computer-Aided Analysis	CAA	Opt.	FEM	2+1
ME-612	Mechanical Design of Process Equip	MDPE	Opt.	Nil	3+0
CMS-505	Project Management	PM	Opt.	Nil	3+0
CME543	Welding & Nondestructive Testing	WNDT	Opt.	Nil	3+0
ME-697	Thesis Research	TR	Comp.	Nil	0+6
			Total Credit Hours =		***15***
	Summer Semester				
ME-697	Thesis Research	TR	Comp.	Nil	0+9
			Total Credit Hours =		***9***
		Grand Total of Credit Hours =			***58***

Mathematics

PAM-501 ***Applied Mathematics***

Compulsory	Yes
Credits	3
Prerequisite	Nil

Course Objectives: The very basic difference of MS level engineering courses from BS level courses is that the MS level courses are mathematically intensive. This necessitates strengthening of the mathematical knowledge of the students, through inclusion of a compulsory Math course, in the very beginning of an MS engineering program.

Course Contents: Partial derivatives of explicit and implicit functions; Maxima and minima of function of several variables; Multiple integrals and their applications; Bessel functions; Legendre functions; Gamma functions; error function; Series solution of differential equations; Fourier transforms; Types and methods of solution of partial differential equations; Vector and Tensor Calculus; Coordinate Transformation system including Curvilinear coordinates.

Recommended Texts:
1. Kreyszig, E. *"Advanced Engineering Mathematics"*, 9th edition, John Wiley and Sons, 2005.
2. Berret, C.R. "*Advance Engineering Mathematics*," 5th edition, John Wiley & Sons, USA, 1994.
3. Munem, M.A. and Foulis, D.J. "*Calculas and Analytical Geometry*," Worth Publishing Co., USA, 1995.

Solid Mechanics

ME-516 ***Applied Solid Mechanics***

Compulsory	Yes
Credits	3
Prerequisite	Nil

Course Objective: 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: Review of mechanics of materials, Stress transformations, general 3D stress stat, Mohr's circles in 3D, strain transformations, generalized stress-strain relationship, equilibrium and compatibility, introductory topics from theory of elasticity, Airy stress functions, Prandtl's stress functions for torsion, shear flow, torsion of thin-walled tubes, bending of unsymmetrical beams: stress & deflection, transverse shear, composite beams in bending, curved beams, bending of thin flat plates, axisymmetric circular plates in bending, thick-walled cylinders & rotating disks, contact stresses, distributed contact surfaces, contact between curved surfaces. Energy techniques.

Recommended Texts:
1. F P Beer, E R Johnston, J T Dewolf, D E Mazurek, *Mechanics of Materials*, 5th ed, McGraw-Hill, 2009
2. P P Benham, R J Crawford, C G Armstrong, *Mechanics of Engineering Materials*, 2nd ed, NBF, 1995
3. R G Budynas, *Advanced Strength and Stress Analysis*, 2nd ed, McGraw Hill, 1999

MME-522 Mechanics of Composites

Compulsory	No
Credits	3
Prerequisite	MME-504 / Instructor’s Consent

Course Objectives: Design and manufacturing with composite materials demands a prior knowledge of the mechanics of composites, for which this course is made part of the curriculum of MS ME.

Course Contents: Definition and classification, natural composites, property enhancement by reinforcement and orientation, matrix interface, Constitutive relations for anisotropic materials; Stiffness and compliance matrices of lamina; Effective moduli of lamina; Macro-mechanical behavior of cross-ply and angle-ply laminates; Interlaminar strength; Symmetric and anti-symmetric laminates; Failure theories for lamina and laminate; Micromechanics of single-fiber-composite; Statistical aspects of fiber strength; Viscous and dynamic behavior.

Recommended Texts:

1. R. E. Shalin., *Polymer Matrix Composites*, Chapman& Hall, 1995.
2. Matthews & Rawlings, *Composite Materials: Engineering and Science*, Chapman& Hall, 1995.
3. Ramesh Talreja and Jan-Anders E. Manson; *Polymer Matrix Composites*, Elsevier 2001.
4. Sperling, L. H.: *Polymeric Multi-component Materials*, John Wiley, 1997.
5. Hull, D. and Clyne, T.W., *An Introduction to Composite Materials*, 2nd Ed. Cambridge University Press, 1996.
6. Ochiai, S. *Mechanical Properties of Metallic Composites*, Marcel Dekker, 1994.
7. Vigo, TL & Kinzig BJ, *Composite Applications: The Role of Matrix, Fiber, and Interface*, VCH Publishers, 1992
8. Surace, G., Carpinteri, A. and Sih. G.C., *Advanced Technology for Design and Fabrication of Composite Materials and Structures* Kluwer Academic Publications, 1995.
9. Matthews, F. L. and Rawlings, R. D., *Composite Materials: Engineering & Science*, Chapman & Hall, 1994.

ME-601 Theory of Elasticity

Compulsory	No
Credits	3
Prerequisite	Nil

Course Objectives: The objective of this course is 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 equation in elasticity

Recommended Texts:

1. S. P. Timoshenko and J. N. Goodier, *Theory of Elasticity*, 3rd ed., McGraw-Hill Book Company, 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

Compulsory	No
Credits	3
Prerequisite	ME-505

Course Objective: 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. David Broek, *Elementary Engineering Fracture Mechanics*, 4th ed, Martinus Nijhoff Pub, 1982
2. C. R. Brooks, A. Choudhury *Failure Analysis of Engineering Materials* The McGraw-Hill Companies 2001
3. Van Dereck FrGechette, *Failure Analysis of Brittle Materials*, The American Ceramic Society, 1990.
4. T. L. Anderson, *Fracture Mechanics: Fundamentals and Applications,* 3rd ed, CRC Press, 2004

ME-604 Theory of Plasticity

Compulsory	No
Credits	3
Prerequisite	ME-601

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 Text:

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

ME-608 Theory of Plates and Shells

Compulsory	No
Credits	3
Prerequisite	ME-601

Course Objectives: The objective of the course is to enhance knowledge in analyzing the plates and shell structures and to familiarize students with various avenues of modeling 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. Timoshenko, S. Woinowsky-Krieger, *Theory of Plates & Shells*, 2nd ed, McGraw-Hill, 1959
3. E. Ventsel, *Thin Plates and Shells, Theory, Analysis and Application*, CRC Press, 2001

Computational Engineering

ME-503 Finite Element Method

Compulsory	Yes
Credits	3
Prerequisite	Nil

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, Computer implementation.

Recommended Texts:

1. O. C. Zienkewicz, R. L. Taylor. *The Finite Element Method*, Vol. 1: Basics, 5th ed., 2002.
2. F. L. Stasa, *Applied Finite Element Analysis for Engineers*, Int'l Thomson Pub, 1995.
3. S. S. Rao. *Finite Element Method in Engineering*, 3rd ed., Pergamon Press, 1999.
4. I. M. Smith, *Programming the Finite Element Method*, 3rd ed. John Wiley & Sons, 1997.

ME-512 Computer-Aided Analysis

Compulsory	Yes
Credits	2+1
Prerequisite	ME-503

Course Objective: 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, post-processing, presentation of results, the scripting language for batch processing, parallel/distributed computing.

Recommended Text:
ANSYS 13.0 Documentation

EE-503 Numerical Methods in Engineering

Compulsory	No
Credits	3
Prerequisite	Nil

Course Objective: The course is meant for providing a solid base for a variety of engineering courses in which the numerical methods are extensively used.

Course Contents: System of non-linear algebraic equations; Eigenvalues and eigenvectors; Higher order differential equations and system of first order differential equations; Numerical algorithms for the determinations of the state-transition matrix of the system of differential equations; Partial differential equations. Finite element techniques; Recent developments in Approximate Methods.

Recommended Texts:
1. Faires, J.D. and RLBurden, Numerical Methods, Prindle, Weber and Schmidt, 1993.
2. Burden, R.L., et al, Numerical Analysis, Prindle, Weber and Schmidt, 1993.
3. Brebbia, C.A. and AJ. Ferrante, Computational Methods for Solution of Engineering Problems, Pentech, 1986.

ME-603 Non-Linear Finite Element Method

Compulsory	No
Credits	3
Prerequisite	ME-503

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. Micha Kleiber, Michal Kleiber, Adam Borkowski, *Handbook of Computational Solid Mechanics: Survey and Comparison of Contemporary Methods*, Springer Verlag, Oct. 1998

ME-606 Boundary Element Method

Compulsory	No
Credits	3
Prerequisite	ME-503

Course Objectives: The Boundary Element Method has in recent years become an established method of solution in several important areas of engineering such as fracture mechanics, solid mechanics among others. 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. Brebbia, C.A, *The Boundary Element Method for Engineers*, Pentech, 1984.
2. Brebbia, C.A. and J. Dominguez, *Boundary Elements, An Introductory Course*, McGraw-Hill, 1989.

ME-607 Finite Element Programming

Compulsory	No
Credits	3
Prerequisite	ME-503

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. Smith, I.M., Griffith, D.V., J. *Programming the Finite Element Method*, 3rd ed., Wiley & Sons, Chichester, 1998.
2. Mackie, R.I., *Object Oriented Methods and Finite Element Analysis*, Saxe-Coburg Publications, 2001.
3. J.F. Thompson, B.K. Soni, N.P. Weathrill, *Handbook of Grid Generation*, ed. CRC Press, 1999.

CHE-614 Computational Fluid Dynamics

Compulsory	No
Credits	3
Prerequisite	CHE-513

Course Objectives: Objective of this course is to make the student familiar with the underlying science of three major methods employed in CFD i.e. Finite Difference Method, Finite Volume Method ad Finite Element Method. Due to its extensive application, Finite Volume Method is covered in more detail. An overall picture of boundary conditions and their implementation is also given to familiarize the student with practical applications. An introduction to turbulence modeling and use of CFD codes is also included to enable student use the available tools.

Course Contents: Governing Differential Equations: continuity, momentum, turbulence and energy balance equations; The generic form of governing equations.; Basic steps for numerical solution: geometry definition, grid, boundary conditions, solutions, post-processing; Finite Difference Method in CFD: Forward, Backward, Central Difference and Upwind Schemes for advection-diffusion and wave equations, discussion of round-off and numerical errors and stability of various schemes; Finite Volume Method in CFD: General guidelines and various interpolation schemes, derivation of discretization equations for diffusion, advection-diffusion and full Navier-

Stokes Equations; pressure-velocity coupling algorithms, SIMPLE, SIMPLER, SIMPLEC etc, Implementation of boundary conditions, discussion of methods of solution, convergence and tools for accelerating convergence. Introduction to Finite Element Method for CFD: element shapes and shape functions, derivation of finite element equations for potential flow using weighted residual approach. An introduction to modern commercial and open-source CFD codes and practical case studies using these codes.

Recommended Texts:
1. Tu, J., Yeoh, G. H., and Liu, C., *Computational Fluid Dynamics, A Practical Approach*, Butterworth & Heiemann, 2008
2. Patankar. S. V. *Numerical heat transfer and fluid flow,* Hemisphere, 1980.
3. Malalasekra, W. and Versteeg, H., *An Introduction to Computational Fluid Dynamics: The Finite Volume Method* 2nd ed, Prentice Hall, 2007.
4. Anderson, J., *Computational Fluid Dynamics*, McGraw Hill Book Co., 1995.

CHE-633 Computational Gas Dynamics

Compulsory	No
Credits	3
Prerequisite	ME-609

Course Objectives: The objective of the course is to learn and implement various numerical techniques applied to hyperbolic conservation laws. The course is intended to develop the understanding of Riemann solvers, monotonicity and Godunov theorem; first- and higher-order upwind schemes and total-variation-diminishing schemes.

Course Contents: Governing equations of gas dynamics, Riemann problem, Riemann solvers, conservation and other basic principles, Properties of Euler Equation, CFL condition, Linear Stability, Nonlinear Stability, Basic numerical methods for scalar conservation laws, Basic numerical methods for nonlinear systems, Flux vector splitting methods, High order and TVD methods for scalar equations, High order and TVD methods for nonlinear.

Recommended Texts:
1. C. B. Laney, *Computational Gas Dynamics* Cambridge University Press, 1998
2. E. F. Toro, *Riemann Solvers and Numerical Methods for Fluid Dynamics* Springer, 1999
3. K. A. Hoffmann and S. T. Chiang, *Computational Fluid Dynamics* Vol-I and II, EES, 2000

Thermo – Fluids

NE-403 Thermal Engineering Principles

Compulsory	Yes
Credits	3
Perquisite	Nil

Course Objectives:
- In this course, the student will develop and/or refine the Fundamental understanding of how basic laws of thermodynamics and properties of matter describe states of systems and processes involving heat and work.
- Ability to use tabulated charts, state equations and steam tables
- Ability to perform energy and mass balances for the design and/or analysis of cycles for steam power plants
- Physical descriptions of fluid systems, and how to simplify generalized conservation equations for a fluid in an appropriate manner to apply to specific problems
- Physical descriptions of thermal systems, and how to use fundamental laws of conduction convection and radiation in an appropriate manner to apply to specific problems

Course Contents: Review of basic concepts in Thermodynamics; First law of thermodynamics; Equations of state; Properties of pure substances; Phase diagrams and use of steam tables; Thermodynamic processes; Steady flow energy equation and its applications; Second law of thermodynamics, Thermodynamic cycles, efficiencies, and their applications; Idealized P-V and T-S diagrams of cycles; Rankine cycle and its application to nuclear power cycles. The Concept of a Fluid; Dimensions and Units; Flow Patterns; Pressure and Pressure Gradient; Manometry and its Application; Basic Physical Laws of Fluid Mechanics; Conservation of Linear and Angular-Momentum; Bernoulli Equation and energy equation and its application in fluid mechanics; Dimensional Analysis; Pipe sizing; Flow metering; Pump sizing. Introduction to Heat Transfer; Conduction, Convection and Radiation

Recommended Texts:

1. Y.A. Cengel, M.A. Boles, *Thermodynamics, An Engineering Approach*, McGraw Hill, 2007
2. Moran Michael, *Fundamentals of Thermodynamics*, John Wiley, 2008
3. F.M. White, *Fluid Mechanics*, 6th ed McGraw Hill, 2006
4. C T Crowe, D F Elger, *Engineering Fluid Mechanics*, 9th ed, Wiley, 2008
5. Munson, Young, Okiishi, Huebsch, *Fundamentals of Fluid Mechanics*, 6th ed, John Wiley & Sons, 2009

CHE-512 Process Heat Transfer

Compulsory	Yes
Credits	3
Prerequisite	Nil

Course Objectives: 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
The thermal hydraulics examples as applied to the nuclear power plants and other chemical industry will be used as detailed case studies.

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

CHE-513 Transport Phenomena

Compulsory	No
Credits	3
Prerequisite	Nil

Course Objectives: To develop detailed understanding of the physics behind transport phenomena in various engineering systems by understanding the fundamental connections between the conservation laws in heat, mass, and momentum in terms of vector and tensor fluxes. How to formulate conservation statements in heat, mass, and momentum at multi-scales from microscopic to macroscopic in both steady and unsteady modes.To learn the solution techniques to solve the above formulated transport phenomena problems

Course Contents: Momentum Transport: Derivation of equation of continuity and motion; Application to laminar flow problems. Energy Transport: Derivation of energy equation; Application to heat Transfer Problems involving conduction, forced and free convection. Mass Transport: Derivation of species conservation equations for binary and multi-component mixtures; Application to mass transfer problems with and without chemical reactions.

Recommended Texts:
1. Bird, R. B, Stewart, W. E, and Lightfoot, E. N, *Transport Phenomenon*, 2nd Ed., John Wiley, 2002
2. Welty, J. R., et al., *Fundamentals of Momentum, Heat, and Mass Transfer*, 5th Ed., John Wiley , 2001

ME-525 Advanced Thermodynamics

Compulsory	No
Credits	3
Prerequisite	NE-403

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. DE Winterbone, *Advanced thermodynamics for Engineers*, Arnold, 1997.
2. Kalyan Annamalai, Ishwar K. Puri, *Advanced thermodynamics engineering*, CRC Press, 2002.

CHE-536 Theory of External Flows

Compulsory	No
Credits	3
Prerequisite	Nil

Course Objectives: The objective of this course is to teach the students the fundamentals of viscous and inviscid external flows (Low speed, subsonic). Course is intended to teach basics of potential flow, wing theory in both 2D and 3D, and boundary layer theory for incompressible flows. The course also aims at teaching the understanding and utilization of experimental data of drag and lift coefficients.

Course Contents: Introduction, Fundamental principles and equations, Circulation, Stream function, Velocity Potential, Dynamics of incompressible inviscid flow-field, Characteristic parameters for airfoil and wing aerodynamics, Airfoil nomenclature, Incompressible flow around airfoils, Incompressible flow about wings, Boundary layer flows, Boundary layer equations for incompressible flows, 2D incompressible laminar flows, 2D incompressible turbulent flows, Boundary layer Separation phenomena in laminar flows, Interactive boundary layer theory, Experimental external flows

Recommended Texts:

1. Anderson, J.D., Fundamentals of Aerodynamics", 3rd edition, McGraw Hill International, 2001
2. Bertin, J. J., Aerodynamics for Engineers, Prentice Hall Edition, 2002
3. White, F. M., *Fluid Mechanics*, 5th edition, McGraw Hill International, 2005
4. White, F. M., *Viscous Fluid Flow*, McGraw Hill International, 1991
5. Schlichting, H., Boundary Layer Theory, 8th edition, McGraw Hill International, 2000
6. Young, A. D., Boundary Layers, AIAA, 1989

ME-609 Theory of Compressible Flow

Compulsory	No
Credits	3
Prerequisite	NE-403

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, Linearized 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. Miloslay Feistauer, Irvan Straskraba, Jiri Felcman, *Mathematical and Computational Methods for Compressible Flow*, Oxford University Press, 2003
2. Stephan, Schreier, *Compressible Flow*, John Wiley and Sons,1982

Design & Manufacturing

ME-505 Mechanical Behavior of Materials

Compulsory	Yes
Credits	3
Prerequisite	Nil

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

ME-509 Experimental Stress Analysis

Compulsory	No
Credits	3
Prerequisite	Nil

Course Objective: 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, and W. F. Riley, *"Experimental Stress Analysis"*, McGraw Hill Inc, 1991.
2. A.S. Kobayashi (editor) "*Handbook on Experimental Mechanics*", 2nd ed, VCH Publishers, 1993.
3. Kuske, A. and Robertson, G., "*Photoelastic Stress Analysis*", John Wiley & Sons, 1977.
4. Heywood, R.B., "*Photolasticity for Designers*", Pergarmon Press, Oxford, 1969.

ME-518 Design of Machine Elements – I

Compulsory	No
Credits	3
Prerequisite	Nil

Course Objectives: This is first of the two courses meant for reviewing some design fundamentals before moving towards the advanced courses of mechanical design.

Course Contents: Engineering design fundamentals, CAD/CAM, Equilibrium of forces and moments, factor of safety, measurement of material properties, static failure, fatigue failure, fracture, design of tension members, design of compression members, design of members in twisting, design for combined loads, beam applications.

Recommended Texts:
1. K.S. Edwards Jr, Fundamentals of Mechanical Component Design, McGraw Hill, 1991.
2. R.L. Norton, Machine Design an Integrated Approach, 3rd ed., Prentice Hall, 2005.
3. M.F. Ashby, Material Selection in Mechanical Design, 3rd ed, Butterworth-Heinemann, 2005.

ME-519 Design of Machine Elements – II

Compulsory	No
Credits	3
Prerequisite	Nil

Course Objectives: This is second of the two courses meant for reviewing some design fundamentals before moving towards the advanced courses of mechanical design.

Course Contents: Design with composites, bolts nuts and joints, spring design, stresses in springs, compression springs, extension springs, spring washers, design of welded components, bearing selection, sliding-contact bearing, rolling-contact bearings, bearing mountings and lubrication, belt drives; Tribology.

Recommended Texts:
1. K.S. Edwards Jr, Fundamentals of Mechanical Component Design, McGraw Hill, 1991.
2. R.L. Norton, Machine Design an Integrated Approach, 3rd ed, Prentice Hall, 2005.
3. M.F. Ashby, Material Selection in Mechanical Design, 3rd ed, Butterworth-Heinemann, 2005.

ME-523 Theory of Machines & Mechanisms

Compulsory	Yes
Credits	3
Prerequisite	Nil

Course Objective: 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. Computer methods.

Recommended Texts:
1. R C Hibbeler, *Engineering Mechanics: Dynamics*, 7th ed, Prentice Hall, 1995.
2. J J Uicker, G R Pennock, J E Shigley, *Theory of Machines & Mechanisms*, 3rd ed, Oxford Univ Press, 2003.

ME- 524 Mechanical System Design

Compulsory	Yes
Credits	1+2
Prerequisite	Nil

Course Objectives: Machine design courses generally deals only with design of machine elements and not the machines. This course intends to understand the 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. Kenneth S. Edwards Jr. Robert B. Mckee, *Fundamentals of Mechanical Component Design*, McGraw-Hill, 1991.
3. David 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

MME-543 Welding and Non-destructive Testing

Compulsory	No
Credits	3
Prerequisite	Nil

Course Objective: The importance of welding and NDT in the industry, especially process and Nuclear is paramount. Keeping in view the importance of this field the course is designed to give a good know how of these areas to the Mechanical Engineers who especially focus to work as Manufacturing Engineers.

Course Contents: Welding techniques, Manual Arc Welding, Gas Shielded Arc Welding, Submerged Arc Welding, Microstructure of Weld and Heat-Affected Zones, Pre- and Post-Weld Heat Treatments, Weld Joint Design, Welding of aluminum alloys, Nondestructive testing: Radiography, Magnetic-particle inspection, Fluorescent die-penetration inspection, Principles and Applications of Ultrasonic Inspection, Eddy current inspection.

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. Hull, J.B. and V.B.John, *Non-Destructive Testing*, Macmillan Education, Ltd., 1988.
4. Silk, M. G., *Ultrasonic Transducers for Nondestructive Testing*, Adam Hilger Ltd., Bristol, 1984.

ME-610 Turbo-Machinery Theory

Compulsory	No
Credits	3
Prerequisite	NE-403

Course Objective: 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*, International edition, McGraw Hill, 2005
3. R.S.R. Gorla, A.A. Khan, *Turbo-machinery design and theory*, Marcell Dekker, 2003.

ME-611 Turbo-Machinery Design

Compulsory	No
Credits	3
Prerequisite	ME-610 or Instructor's consent

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, *the Design of high efficiency turbo-machinery and 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

Compulsory	Yes
Credits	3+0
Prerequisite	Nil

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 and Pressure Vessel Code, Section VIII.

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. Maan H. Jawad, James R. Farr, *Structural Analysis and Design of Process Equipment*, John Wiley & Sons, 1984.
2. Ansel C. Ugural. *Stresses in Plates and Shells*, McGraw-Hill, 1999.

POWER PLANTS

ME-510 Power Plant Systems

Compulsory	No
Credits	3
Prerequisite	Nil
Equivalent Course	NE-510: Nuclear Power Plant Systems

Course Objectives: Mechanical engineers form the core of personnel in any power plant. Therefore familiarization with various power plants systems is extremely important for a curriculum of mechanical engineering.

Course Contents: Layout of thermal power plants; Containment buildings; Primary 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 power plants; Future trends in nuclear power cost.

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

NE-510 Nuclear Power Plant Systems

Compulsory	No
Credits	3
Perquisite	Nil

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

NUCLEAR

NE-501 Fundamentals of Nuclear Engineering

Compulsory	No
Credits	3
Prerequisite	Nil

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-505 Nuclear Reactor Analysis

Compulsory	No
Credits	3
Perquisite	Nil

Course Objective : The course is designed to provide some familiarity with core neutronics.
Course Contents: Neutron slowing-down; Thermal neutron spectra; Neutron diffusion in non-multiplying media; The one-speed diffusion model of a nuclear reactor, Criticality calculations for bare and reflected homogeneous systems; Effects of heterogeneity reactor parameters; The multigroup diffusion method. The point reactor kinetics model; Temperature and void coefficient of reactivity, Fuel depletion; Fission product poisoning, Control rods.

Recommended Texts:
1. Duderstadt, J.J. and L.J. Hamilton, *Nuclear Reactor Analysis*, John Wiley, 1976.
2. Lamarsh, J.R*, Introduction to Nuclear Reactor Theory*, Addison-Wesley, 1966.

3. Ott, K.O. and W.A. Bazella, *Introductory Nuclear Reactor Statics*, American Nuclear Society, 1983.
4. Lamarsh, J.R, *Introduction to Nuclear Engineering*, Addison-Wesley, 1983.

CHE-413 Fundamentals of Radiation Protection

Compulsory	No
Credits	3+1
Prerequisite	Nil

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

MISCELLANEOUS

CMS-501 Communication Skills

Compulsory	Yes
Credits	1
Prerequisite	Nil

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

CMS-505 Project Management

Compulsory	No
Credits	3
Prerequisite	Nil

Course Objectives: Through MS ME it is also aimed to enhance managerial capabilities of the engineers and with this purpose in mind this course is included in the curriculum of MS ME.

Course Contents: Introduction to project management, Strategic relevance of project management, Project Management in the organizational context, How projects come into being?, Project selection techniques and project portfolios, Project initiation, Project planning, Project implementation, Project monitoring and control, Project leadership, communication and teamwork, Performance Monitoring and Evaluation, Cultural issues in project management, Case studies of project management, Application of Microsoft Project/ Primavera

Recommended Texts:

1. Gray, Clifford F., Larson, Erik, W., *Project Management: The Managerial Process*, McGraw Hill., 3rd ed, 2006
2. Cleland, David I. and Ireland, Lewis R., *Project Management: Strategic Design and Implementation*, McGraw-Hill Professional Book Group, 4th ed, 2002
3. *A Guide to Project Management Body of Knowledge (PMBOK)*, 3rd ed, Project Management Institute, 2003
4. Wysocki, Robert K., Beck, Robert Jr. and Crane, David B., *Project Management: How to Plan, Manage, and Deliver Projects on Time and within Budge*t, John Wiley & Sons Inc., 1995
5. Meredith, Jack R. and Muntel, Samuel J. Jr., *Project Management: A Managerial Approach*, John Wiley & Sons Inc., 4th ed, 2001
6. Ghattas, R. G. and McKee, Sandra L., *Practical Project Management*, Pearson Education Inc., 2001

ME-502 Mechanical Engineering Laboratory

Compulsory	No
Credits	3
Prerequisite	Nil
Course Format	Nine hrs of laboratory per week

A number of experiments will be offered from the list of experiments given below and students will be required to carry out a minimum of eight experiments.

- Use of electrical resistance strain gauges in mechanics
- Fluid circuit friction study
- Fundamental properties of fluid flow
- Power plant study
- Process control
- Study of characteristics of pumps
- Study of electrochemical behavior of metals and alloy
- Study of proportional, derivative and integral response in feedback control loop
- Study of thermal conduction
- Tensile, hardness and impact testing
- Study of creep behavior of materials
- Study of fatigue behavior of materials
- Use of transmission photo elasticity
- Application of electrical resistance strain gauges and its testing
- Use of reflection polariscope
- Study of characteristics of turbine
- Study of feedback control using hydraulic system
- Study of feedback control using pneumatic system
- Double pipe heat exchanger
- Mechanical measurement and use of coordination measurement machine

ME-507 Solar Devices and Renewable Energy

Compulsory	No
Credits	3
Prerequisite	Nil

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 Text:

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

ME-513 Vibrations Analysis

Compulsory	No
Credits	3
Prerequisite	Nil

Course Objectives: Rotating machinery is the most common type found in all types of industry. This course is designed to provide basic and applied knowledge of vibration analysis necessary for condition monitoring and safe operation of rotating machinery.

Course Contents: Introduction to vibration technology, Vibration, causes and its effects on machine life, Maintenance philosophies, condition monitoring technologies, Vibration as a predictive maintenance tool, Components of Vibration Analysis (VA) Program and its additional applications, components of a mechanical system, free(without and with damping) and forced (without and with damping) single, two and multiple degree of freedom system, characteristic of Vibration including amplitude, frequency and phase analysis with their significance in VA, Vibration Severity Standards and guidelines, setting of machine alarms, bearing and gears fault diagnosis techniques like spike energy and PeakVue, vibration transducers including displacement probes, velocity pickups and accelerometers, their construction, selection and mounting techniques, Vibration frequency analyzers, FFT spectrum analysis, spectral parameters of FFT, directional and non-directional vibrations, identification of most common machinery problems using FFT spectrum like unbalance, misalignment, looseness, resonance, aerodynamic/hydraulic problems of pumps and fans, bearing and gear problems, drive belt problems, rotor and stator problems in electric motor, eccentricity and bent shaft problems, general consideration and pitfalls, implementation of a successful predictive maintenance program.

Recommended Text:
1. James E. Berry, *Introduction to Vibration Technology*, EntekIRD International, USA, 1993
2. M. L. Adams Jr., *Rotating machinery problem from analysis to Troubleshooting*, Marcel Dekker Inc., 2000.
3. James Taylor*, The Vibration Analysis* Handbook , 2nd ed, VCI Pub, 2003

ME-514 Application of Computer Graphics in Engineering

Compulsory	No
Credits	3
Prerequisite	Nil

Course Objectives: This course provides the theory of graphics as applicable to engineering.

Course Contents: Graphics Input / Output devices, Graphic primitives: lines, circles, etc; Transformations (translation, rotation, scaling, etc), windowing and clipping; 2D and 3D object representation, 3D transformations, 3D viewing; parallel and perspective projections; Hidden lines and hidden surface removal; Mathematical representations of lines, curves and surfaces; Wire-frame and solid modeling.

Recommended Texts:
1. D. Hearn, M.P. Baker, *Computer Graphics*, Prentice Hall,1986
2. V.B. Anand, *Application of Computer Graphics for Engineers*, John Wiley & Sons, Inc., 1993

ME-515 Measurements and Instrumentation

Compulsory	No
Credits	2+1
Prerequisite	Nil

Course Objectives: This course is meant for familiarizing the students with measurement systems.

Course Contents: General measurement system, Static and dynamic characteristics of measurements systems, Error analysis, Loading effects and two port network modeling, Signal and noise in measurement systems, Reliability analysis, Transducer elements, Motion measurement and seismic analysis, Force measurement, Pressure measurement, Temperature measurement, Flow measurement, Torque and shaft power measurement, Transducer interfacing.

Recommended Texts:
1. J. P. Bentley, *Principles of Measurement Systems*, Longmann Scientific & Technical Publishing. 1995
2. Ernest O. Doeblin, *Measurement System, Application and Design*, McGraw-Hill Publishing International 1990

ME-605 Microelectromechanical Systems (MEMS)

Compulsory	No
Credits	3
Prerequisite	Nil

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

CHE-511 Mathematical Modeling of Physical Systems

Compulsory	No
Credits	3
Prerequisite	PAM-501

Course Objectives: The course is beneficial for any engineer interested in mathematical modeling. Additionally it is a pre-requisite for another course CME-518.

Course Contents: Use of models in process engineering: Model as a working description of a system; Level of detail; types and functions of models: Mechanistic, empirical, stochastic, procedural and qualitative. Strategy for model building: relationship between engineering and mathematical approximations; Example of dynamic delay of air heater; conceptual models; formulation of functional mechanistic models based on the conservation equations; coordinate free methods based on vector / matrix rotation; models for complex and irregular geometries; Case study examples for heat exchanger and tubular reactor. Definition of system parameters consistent with the model; averaging and model reduction techniques; numerical procedures based on weighted residuals.

Recommended Texts:
1. Murthy, D. N. P, *Mathematical Modeling*, Pergamon Press, 1990
2. Thomas, P., *Simulation of Industrial Processes for Control Engineers*, Butterworth Heinemann Pub, 1999

CHE-518 Process Dynamics and Control

Compulsory	No
Credits	3+1
Prerequisite	PAM-501, CHE-511

Course Objectives: As per advice of PAEC officers, the course is beneficial for MS ME graduates to be absorbed in nuclear power programs.

Course Contents: Introduction to Process Control; Process Dynamics and Laplace Transform; First Order Systems; Second Order Systems; Inverse Response and Time Delay; Frequency Domain; Linearization and Nonlinear Systems; Stability; Process Identification; Feedback Control Systems; Conventional Design; Inverse Response and Time Delay; Feed forward, Inverse Response, and Time Delay; Model-based Control; Digital Control - Sampling; Z Transforms and Digital Block Diagrams; Digital Controller Design; Model Predictive Control; Multivariable Control; RGA and Modal Analysis; SVD and Decoupling; Multivariable Examples.

Recommended Texts:

1. Smith, C. A, Corripio, A. B, *Principles and Practice of Automatic Process Control*, John Wiley, 1985.
2. Marlin, T.E., *Process Control*, 2nd Ed., McGraw Hill Book Co., 2000.
3. Ogunnaike, B. A., et al., *Process Dynamics, Modeling, and Control*, Oxford University Press, 1997.

CHE-618 Turbulence Modeling & Grid Generation

Compulsory	No
Credits	3
Prerequisite	CHE-513

Course Objectives: This course consists of two independent modules, turbulence modeling and grid generation. This is a post graduate level course and its purpose is to teach turbulence models already being used by CFD community. On similar lines, the 2nd module is to enable the student learn various grid (or mesh) generation techniques used for domain discretization.

Course Contents: Turbulence Modeling: Turbulent flows; laminar/turbulent transition, turbulent boundary layers, separated flows, Nature of turbulence, Statistical description, Length scales, turbulent transport, Reynolds-averaged Navier-Stokes equations, turbulent closure, Reynolds stress, Kinetic energy balances, turbulence models; Application in CFD; Large eddy simulation. Measurement and model evaluation. Grid Generation: Introduction; geometry modeling and surface grids; algebraic mesh generation; structured meshes from partial differential equations; automatic generation of unstructured meshes; multiblock mesh generation; unstructured grids by the default triangulation; mesh adaptation on unstructured grids; unstructured grids for viscous flows.

Recommended Texts:

1. Bradshaw, P, Cebeci, T, Whitelaw, J. H, *Engineering calculation methods for turbulent flows*, Academic Press, 1981.
2. Thompson, M., *Grid Generation*, John Wiley, 1988.

ME-690,691,692,693 Special Topics in Mechanical Engineering – I, II, III, IV

Compulsory	No
Credits	3
Prerequisite	Instructor's consent

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 same course can be offered at most for two years only, meanwhile it will be approved through the approved channel as a regular course.

ME-697 MS Thesis Research

Compulsory	Yes
Credits	15
Prerequisite	Nil

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.