# ENGINEERING (CORE COURSES)

## *INTRODUCTION*

Engineering graduate programs require the study of some of the following general (core) graduate engineering courses.

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|---|---|---|
| 0600-503 | Statistical Concepts in Engineering | (3) |
| 0600-504 | Numerical Analysis and Computation | (3) |
| 0600-505 | Finite Element Methods | (3) |
| 0600-506 | Continuum Mechanics | (3) |
| 0600-507 | Mathematical Optimization | (3) |
| 0600-508 | Random Variables and Stochastic Processes | (3) |
| 0600-510 | Advanced Fluid Mechanics | (3) |
| 0600-511 | Computational Fluid Dynamics | (3) |
| 0600-512 | Advanced Engineering Mathematics I | (3) |
| 0600-513 | Advanced Engineering Mathematics II | (3) |

## *COURSE DESCRIPTION*

**0600-503: STATISTICAL CONCEPTS IN ENGINEERING**
**CR: 3**

Elements of probability theory, random variables, analytical models of random phenomena, reliability, factor of safety, safety margin, extreme value statistics, Monte-Carlo simulation, empirical determination of distribution models, confidence intervals, regression and correlation analysis, general applications to engineering design problems, stochastic processes.

**0600-504: NUMERICAL ANALYSIS AND COMPUTATION**
**CR: 3**

Norms, limits and condition numbers. Inverses of perturbed matrices. Integrative techniques for solving systems of equations. The LU, QR and singular value decompositions. Algorithms for the linear least squares and linear minimax problems. Computation of the eigenvalues of a matrix. the interpolation and polynomial approximation. Approximate methods for initial value problems and for boundary value problems.

**0600-505: FINITE ELEMENT METHODS**
**CR: 3**

Origin and basis of finite-element methods in continuum mechanics, stiffness method, assumed displacement field, potential energy and Rayleigh-Ritz method, types of elements, modeling, accuracy and convergence, solution techniques and computer application to structural and fluid mechanics.

**0600-506: CONTINUUM MECHANICS**
**CR: 3**

Cartesian tensors. Basic principles of continuum mechanics: deformation, displacement, strain, stress, conservation of mass, continuum thermodynamics and constitutive equations. Illustrative applications in elasticity, fluid dynamics, viscoelasticity ad plasticity.

**0600-507: MATHEMATICAL OPTIMIZATION**
**CR: 3**

Basic Concepts: The gradient vector and the Hessian Matrix, multidimensional Taylor's theorem, linear and quadratic approximation of a function. Unconstrained optimization, necessary

and sufficient conditions for optimality. Algorithms for single variable minimization, the Fibonacci search and the Golden section search, algorithms that use repeated polynomial interpolation. Algorithms for multi-dimensional minimization; The steepest descent, the Newton method and its variations, conjugate gradient algorithms such as the Flecter-Reeves, Polak and Ribieve, Quasi-Newton Methods such as the DEP-BFGS, Huang's family of algorithms. Constrained optimization: Necessary and sufficient conditions for constrained minima. Algorithms for constrained optimization: interior and exterior penalty function methods, augmented Lagrangian methods, Resen's gradient projection.

**0600-508: RANDOM VARIABLES AND STOCHASTIC PROCESSES**
**CR: 3**

Introduction to probability theory and engineering applications of probability. random variables and expected values. distribution of functions of random variables and applications of R.V. to system problems. Stochastic processes, correlation and power spectra, systems and random signals. Engineering decisions and estimation theories.

**0600-510: ADVANCE FLUID MECHANICS**
**CR: 3**

Motion of ideal, Newtonian, and non-Newtonian single-phase fluids. Continuity and Navier-Stokes equations for one and two dimensional flows. Turbulence and boundary layer theories. Flow through conduits, and porous medium. Homogenous and non-homogenous multiphase flow systems.

**600-511: COMPUTATIONAL FLUID DYNAMICS**
**CR: 3**

This course introduces students to the numerical and computational fluid dynamics. It will provide graduate students (Science and Engineering students) with techniques and approaches to solve numerical fluid mechanics problems encountered in real fluid flows. Methods for boundary layers, incompressible viscous flows, and inviscid compressible flows are studied. Finite differences and finite volume techniques are emphasized. The course utilizes using commercial CFD packages and MATLAB to solve fluid flow problems.

**0600-512: ADVANCED ENGINEERING MATHEMATICS I**
**CR:3**

Analytic function, residues, contour integration. Power series solutions of ordinary differential equations: Bessel's, Legendre's, Chebysheve's and Laguerre's functions. Matrix algebra eigenvalues, eigen-functions, and solutions of systems of differential equations. Software applications.

**0600-513: ADVANCED ENGINEERING MATHEMATICS II**
**CR:3 PR:0600-512**

Sturm-Liouville problem. Partial differential equations: Characteristic curves, separation of variables and integral transforms (Laplace and Fourier), method of characteristics. Wave, heat and diffusion-equations. Software applications.

# MASTER OF SCIENCE
# MECHANICAL ENGINEERING
# Program code: 0630

## *INTRODUCTION*

The Department of Mechanical Engineering offers a Master of Science Program in **Mechanical Engineering**. Research requirements include either thesis or non-thesis options. The program is a balanced combination of the theoretical and practical aspects of mechanical engineering with enough flexibility to allow for interaction with the ever developing sciences and technologies and with the changing needs of the region.

The program is designed to deepen and broaden the scientific and engineering skills in one of the following two lines:

- Mechanical Design and Manufacturing
- Thermo-Fluid Engineering

The general research interests in the department are focused in these two lines. They include works in mechanical vibration, dynamics and control, stress analysis, tribology, computer-aided design, robotics, computer-aided manufacturing, mechanical behavior of materials, composite materials, corrosion, thermodynamics, heat transfer, experimental and computational fluid mechanics, energy management, combustion and combustion engines, solar energy, heating and air-conditioning systems, desalination, aerodynamics, turbulence, and dual-purpose power plants.

***According to the University Council decision dated 4/2/2007, Thesis students admitted with effect from September 2007 are exempted from the comprehensive examination.***

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## *PROGRAM REQUIREMENTS*

**33(33) TOTAL COURSE CREDITS** (non-thesis option in parenthesis)

**6 (6) CORE ELECTIVE COURSES (3 credits each)**

0600-505 Finite Element Methods
0600-506 Continuum Mechanics
0600-507 Mathematical Optimization
0600-508 Random Variables and Stochastic Processes
0600-512 Advanced Engineering Mathematics I
0600-513 Advanced Engineering Mathematics II

**9 (9) SUBDISCIPLINE ELECTIVE COURSES(3 credits each)**

**I. MECHANICAL DESIGN AND MANUFACTURING**

0630-509 Analytical Mechanics
0630-511 Stress Analysis in Mechanical Design
0630-512 Mechanical Vibrations
0630-513 Dynamic Analysis and Design of Machines

0630-514 Computer-Aided Design
0630-515 Engineering Materials: Selection and Applications
0630-516 Reliability and Maintainability
0630-517 Optimal Design
0630-519 Stability of Structures and Systems
0630-534 Modeling Dynamic Systems
0630-542 Computer Integrated Manufacturing
0630-543 Fracture Mechanics
0630-554 Special Topics in Mechanical Design

**II. THERMO-FLUID ENGINEERING**

0630-520 Advanced Conduction Heat Transfer
0630-522 Radiation Heat Transfer
0630-523 Advanced Convection Heat Transfer
0630-524 Air-Conditioning
0630-525 Non-Conventional Energy Conversion Systems
0630-527 Power Plants
0630-528 Heat Exchangers Design
0630-529 Refrigeration Engineering
0630-531 Fluid Mechanics OR 0600-510 Advanced Fluid Mechanics
0630-532 Gas Dynamics
0630-533 Computational Fluid Mechanics OR 0600-511 Computational Fluid Dynamics
0630-535 Mechanical Aspects of Desalting Systems
0630-538 Special Topics in Thermo-Fluid Engineering
0630-539 Advanced Thermodynamics

**9(15) FREE ELECTIVE COURSES**

A maximum of 3 credit hours (thesis students) and 6 credits hours (project students) can be taken from **core engineering**, any other engineering, science, computing science, and engineering or joint graduate programs with the approval of the Graduate Program Director and Area Committee Chairman before registering the course. **Also, courses can be taken from the same graduate program courses.**

**9 (3) COMPULSORY**

0630-592 Seminar (0)
0630-593 Project (3) (non-thesis option only)
0630-597 Thesis (0)
0630-598 Thesis (0)
2000-599 Thesis (9)

## *COURSE DESCRIPTION*

**0630-509: ANALYTICAL MECHANICS**
**CR: 3**

Review of Newtonian mechanics. The principle of virtual work. D'Alemberts principle. Hamilton's principle. Lagrange's equations of motion. Case of impulsive forces. Conservation laws. Ralyleigh's dissipation function. Hamilton's equations. Motion relative to rotating frames. Rigid body dynamics. Gyroscopic effects. Canonical transformations. The Hamilton-Jacobi equation.

**0630-511: STRESS ANALYSIS IN MECHANICAL DESIGN**
**CR: 3**

Stress and strain in two and three dimensions. Plane theory of elasticity. Failure theories. Stress concentration. Residual Stresses. Thermal stresses. Contact stresses. Impact loading. Fracture mechanics and design. Fatigue and cumulative damage. Structural instability. Experimental stress analysis. Energy approach and numerical methods. Case Studies.

**0630-512: MECHANICAL VIBRATIONS**
**CR: 3**

Lagrange's equations. Response of multi-degree-of-freedom systems. Vibration of continuous systems. Approximate solutions. Introduction to nonlinear vibrations. Introduction to random vibrations. Spectral analysis.

**0630-513: DYNAMIC ANALYSIS AND DESIGN OF MACHINES**
**CR: 3**

General concepts in the dynamic analysis and design of machines, with reference to machine tools. Structure compliance, integrity, static and thermal deformations, structure design concepts. Drive systems, slides and bearings. Feed drives. Types of control systems; numerical, adaptive and computer control. Steady and dynamic cutting forces. Dynamics of machine tools. Receptance concept. Interaction between cutting and structural response. Machine tool stability. Vibration reduction of machine tools in the design stage and in the field. Design for fabrication by bonding.

**0630-514: COMPUTER-AIDED DESIGN**
**CR: 3**

Computer Graphics including solid modeling and image synthesis, curve and surface description, 3-D transformations. Use of prepackaged software. Review of optimization techniques: linear, non-linear and dynamic programming. Design applications in mechanical engineering systems.

**0630-515: ENGINEERING MATERIALS: SELECTION AND APPLICATIONS**
**CR: 3**

Mechanical behavior of materials: elastic and plastic behavior, yielding fracture, crack propagation, fatigue, creep. Behavior at low and high temperatures. Engineering properties of metallic and non-metallic materials. Functional requirements of engineering materials. Material selection process, criteria and techniques. Aspects of design for selection. Applications: material selection for springs, fasteners, gears, bearings etc. Material selection for abrasive-wear and corrosion-resistance applications. Case studies.

**0630-516: RELIABILITY AND MAINTAINABILITY**
**CR: 3**

Component factors in durability and reliability. Reliability concepts and assessments. The performance requirements. Static and dynamic reliability models. Random variables in design. Sampling estimation and confidence. Maintainability down-time and repair-time. Design factors determining down-time. Maintainability prediction. Maintainability and reliability in contracts. Maintenance handbook.

**0630-517: OPTIMAL DESIGN**
**CR: 3**

Survey of single-variable unconstrained optimization methods. Multi-variable unconstrained optimization. Single and multi-variable constrained optimization techniques. Applications from mechanical design, vibrations, solid mechanics, and thermal fluid systems.

**0630-519: STABILITY OF STRUCTURES AND SYSTEMS**
**CR: 3**

Concept of stability. Lejeune-Dirichlet criterion. Nyquist criterion. Routh and Hurwitz criterion. Liapunov second method. Examples from rigid body dynamics. Effects of damping. Gyroscopic effects. Elastic stability under static load: Beam-columns, bars and frames, torsional buckling, buckling of rings, curved bars and arches. Dynamic instability: Divergence and flutter. Instability under nonconservative forces. Examples.

**0630-520: ADVANCED CONDUCTION HEAT TRANSFER**
**CR: 3**

A generalized treatment of the solution of steady and transient heat conduction in finite and infinite regions. Approximate and exact methods of solution of problems involving phase change, variable thermal properties, heat generation, and non-linear boundary conditions. Heat conduction in composite media and in anisotropic solids.

**0630-522: RADIATION HEAT TRANSFER**
**CR: 3**

Exact and approximate methods of solution of radiative heat transfer. Heat radiation of black bodies and non black bodies. Radiation between surfaces and through participating and non-participating media. Experimental methods. Radiation heat processes. Radiative properties of surfaces and gases. Multimode heat transfer in thermal systems. Numerical modeling.

**0630-523: ADVANCED CONVECTION HEAT TRANSFER**
**CR: 3**

Differential forms of the balance laws of mass, linear momentum, and energy, Boundary layer theory, Scale Analysis, Similarity solutions, Forced and free convention in laminar and turbulent, internal and external flows. Analogy between momentum and heat transfer. Heat and mass transfer in compressible flow.

**0630-524: AIR-CONDITIONING**
**CR: 3**

Air-Conditioning systems and their physchrometric process, analysis and performance of direct contact heat and mass transfer exchanges: cooling towers, analysis of extended surface heat exchangers, analysis of cooling coils, air conditioning control.

**0630-525: NON-CONVENTIONAL ENERGY CONVERSION SYSTEMS**
**CR: 3**

Analysis and performance characteristics based on thermodynamics and fluid flow of non-conventional energy conversion systems.

**0630-527: POWER PLANTS**
**CR: 3**

Thermodynamics review, Availability, Irreversibility, Entropy creation efficiency and effectiveness. Rankine cycle: Ideal and real cycle, effects of superheating, reheating, feed water heat regeneration, condenser. Fossil-fuel steam generations: water tube boilers, design of natural and forced flow, furnace design with tube walls, evaporators, superheaters, economizers, fans, stacks. Rating of steam generators. Fuels and combustion. Steam turbines: Impulse and reaction turbines, analysis and sizing. Turbine rating methods, turbine losses, gas turbines cycles (simple open, regenerative and cooled), Combined cycle, rating of gas and gas/steam cycles. Condensate-feed water system: Condensers types and designs, feed water heaters types and designs, dearators, make up water. Circulating water systems.

**0630-528: HEAT EXCHANGERS DESIGN**
**CR: 3**

Double-pipe heat exchangers. Shell and tube heat exchanger. Flow arrangements for increased heat recovery in shell and tube exchangers. Gases cooling and heating. Extended surfaces. Condensation of vapors and condensers design. Evaporation and evaporators. Steam generator design: Furnaces, superheaters, economizers, evaporators, cooling towers.

**0630-529: REFRIGERATION ENGINEERING**
**CR: 3**

Machinery for vapor compression systems: Compressors (reciprocating, rotary positive displacement and turbo), condensing equipment, evaporators, expansion valves, cooling towers. Equipment design, characteristic and rating methods, equipment matching. Multistage vapor compression systems. Ammonia absorption refrigeration system design and characteristics.

Lithium bromide-water absorption system design and characteristics. Steam jet regeneration systems design. Cold storage. Defrosting methods.

**0630-531: FLUID MECHANICS**
**CR: 3**

Conservation laws and Navier-Stokes equations closed-form solutions of standard viscous flow problems. Boundary layer theory. Ideal-fluid flow equations, potential flow. Elementary flows.

**0630-532: GAS DYNAMICS**
**CR: 3**

Basic concepts of gas dynamics and gas properties. Subsonic flow. Supersonic flow. Hypersonic flow. Shock-wave phenomena. Dimensional analysis. Experimental techniques and other selected topics.

**0630-533: COMPUTATIONAL FLUID MECHANICS**
**CR: 3**

Characteristics of different types of partial differential equations. Scalar representations of Navier-Stokes equations. Covarient and contravarient base vectors and calculus. Transformation of Navier-Stokes equations from physical space to computational space; Grid generation methods. Numerical methods for inviscid flows. Numerical methods for incompressible viscous flows.

**0630-534: MODELING DYNSMIC SYSTEMS**
**CR: 3**

Unified approach to modeling, analysis and simulation of energetic dynamic system. Introduction to multi-domain system. System dynamic response in time and frequency domains. Introduction to model reduction. Application to Various dynamic system such as mechanical, thermal, fluid, electric, chemical, electormechanical system, emphasis on modeling and simulation of hybrid system using modern computer-aided tools.

**0630-535: MECHANICAL ASPECTS OF DESALTING SYSTEMS**
**CR: 3**

Design of submerged and falling film evaporators. Single and multi-effect desalting systems and component design. Multi-stage flash (MSF) desalting system design. MSF components design (pumps, stages, brine heater, evacuating system,..). Mechanical vapor compression desalting system. Reverse osmosis desalting systems.

**0630-538: SPECIAL TOPICS IN THERMO-FLUID ENGINEERING**
**CR: 3**

An upper division of graduate technical elective treating topics in mostly not covered in other courses, chosen at the discretion of the Graduate Program Committee.

**0630-539: ADVANCED THERMODYNAMICS**
**CR: 3**

Availability analysis. Irreversible Thermodynmics applied to engineering systems. Energy Analysis for power plants, refrigeration systems. Equilibrium and stability of thermodynamics system. General relations.

**0630-542: COMPUTER INTEGRATED MANUFACTURING**
**CR: 3**

Fundamentals of manufacturing and automation, production systems (types, analysis, automation, simulation), numerical control production systems (NC, DNC, CNC, ACO, ACC) - industrial robotics (technology-programming, and application in manufacturing systems). Materials handling systems - flexible classification, coding machine cells, workstations, computer control). Control systems (feedback, optimal, sequence control). Computer integrated manufacturing (fundamentals of CAD/CAM computer planning of material process, and capacity) shop floor control and automation-order release, scheduling, identification systems. Computer network.

**0630-543: FRACTURE MECHANICS**
**CR: 3**

Stationary crack under static loading. Energy balance fracture mechanisms: Crack initiation and growth. Fracture modes. Stress intensity factors. Fracture toughness. Brittle and ductile fractures. Dynamic crack growth. Fatigue. crack propagation and component's life prediction. Experimental methods. Case studies.

**0630-554: SPECIAL TOPICS IN MECHANICAL DESIGN**
**CR: 3**

An upper division of graduate technical elective treating topics in Engineering mostly not covered in other courses, chosen at the discretion of the Graduate Program Committee.

**0630-592: SEMINAR**
**CR: 0**

Following the directions of the graduate program committee related to thesis or project.

**0630-593: PROJECT**
**CR: 3**

**0630-597: THESIS**
**CR: 0**

**0630-598: THESIS**
**CR: 0**

**2000-599: THESIS**
**CR: 9**