Department of Mechanical Engineering  
M.S. Comprehensive Exam

This exam will be given during the first three weeks of each spring quarter. It consists of three subjects of the examinee's individual choice, among those listed at the end of this document. The exam will be at the entering M.S./first year Ph.D. level, focusing on the most fundamental topics of each area. All the examinees must submit their completed Intent to Register for the MS Comprehensive Examination Form to the Graduate Program Assistant during the winter quarter (typically deadline is in the 7-8th week).

The exam in each subject takes two hours. Details of exam formats, such as allowance of the use of a calculator and hand-written notes, vary depending on the subjects and will be announced a few weeks prior to the exam date.

Notes:
1. A student, who plans to take the M.S. comprehensive exam during the spring quarter, must submit a formal request to the Graduate Program Assistant during the winter quarter (deadline typically in the 7 – 8th week).
2. The Graduate Committee should review the exams and announce the decisions within two weeks following the exams.
3. Students are recommended to take the ME graduate courses offered during the fall and winter quarters for their preparation of the subject areas of the Exam.

The list of the exam areas (Note: More areas will be added as the Faculty grows in the future):

1. Control Systems:
   a. Laplace transform and solution of ODEs
   b. Transient and stationary response of 1st and 2nd order systems
   c. Linearization
   d. Poles/Zeros, Bode plots, Nyquist diagrams, root locus
   e. PID control
   f. State-space representation of dynamical systems
   g. Linear algebra

   Suggested reading: Katsuhiko Ogata, Modern Control Engineering.

2. Dynamics and Vibrations
   a. Motion Analysis of Particles and Rigid Bodies
   b. Newton’s Laws of Motion
   c. Work and Energy Method
   d. Linear Impulse and Momentum Method
   e. Angular Impulse and Momentum Method
   f. Vibrations with and without damping

   Suggested reading: W. F. Riley and L. D. Sturges: Engineering Mechanics:
3. **Engineering Analysis**  
   a. Linear Equations:  
      i. Matrix operations, determinants, elimination methods, eigenvalue problems.  
   b. Ordinary Differential Equations:  
      i. Separable equations, first and second order of ODEs, and system of ODEs.  
   c. Introductory PDEs  
      i. Laplace, Poisson and wave equations and their solutions, including Fourier series solutions.  
   d. Vector Analysis  
      i. Gradient and curl operations, Green’s and Stokes’s theorems.  
   e. Complex Analysis  
      i. Analytic functions, the residue theorem and contour integral.  
   f. Numerical Interpolation  
      i. Lagrange polynomials and cubic splines  
   g. Numerical Solutions  
      i. Non-linear algebraic equations and ODEs.  


4. **Fluid Mechanics**  
   a. Stresses in fluids, Hydrostatics, Newtonian fluids  
   b. Equations of motion  
   c. Inviscid flow, Bernoulli equation  
   d. Incompressible internal and external flows, boundary layers, lift and drag forces  
   e. Pipe flows, friction factors, loss coefficients, pump performance.  

*Suggested reading: Fox and McDonald: Introduction to Fluid Mechanics*  

5. **Heat Transfer**  
   a. Conduction: balance of mass and energy in conduction, steady 1-D, 2-D and 3-D conduction, heat transfer from extended surfaces, conduction in moving media, unsteady lumped systems, unsteady distributed systems (1-D, 2-D, and 3-D), and Heisler charts.  
   b. Convection: balance of mass, momentum, and energy in convection, laminar and turbulent forced convection in internal and external flows, thermal and momentum boundary layers as well as heat transfer correlations in both forced convection and in natural convection.  
   c. Radiation: Fundamental physics of thermal radiation, view factors and their algebra, and radiation exchange between gray-diffuse surfaces  
   d. Multimode heat transfer  


6. **Materials properties**  
   a. Mechanical behavior  
      i. Stress-strain relationships, plastic deformation  
   b. Failure mechanisms (fracture, creep, fatigue)  
   c. Composite material behavior  
   d. Electrical properties
i. Metallic conduction
ii. Semiconductors

*Suggested reading: Mechanical Behavior of Materials, TH Courtney*

7. Materials Structure
   a. Atomic bonding
   b. Crystalline structure (Bravais lattices, directions, planes, atomic packing factors)
   c. Defects (point, line and volume)
   d. Thermodynamic stability (phase diagrams)
   e. Diffusion (Fick's 1st and 2nd laws)

*Suggested reading: Materials Science & Engineering, WD Callister*

8. Solid Mechanics
   a. Elements of tensor analysis
   b. Strains and stresses in solids
   c. Equations of motion
   d. Constitutive relations for linear elastic solids
   e. Stress waves in linear elastic solids
   f. Degeneralized 2D theories for anti-plane shear, plane stress, and plane strain
   g. Degeneralized 1D theories for bars, shafts and beams


9. Thermodynamics
   a. Energy, work, heat, and the 1st law of thermodynamics
   b. Entropy, irreversibility, and the 2nd law of thermodynamics
   c. Concept of entropy and entropy balance for systems
   d. Open and closed systems. Control volume analysis. Enthalpy.
   f. Nozzles, pumps, turbines, heat exchangers, and other engineering hardware.
   g. Carnot cycle. Power and refrigeration cycles.

*Suggested reading: M. J. Moran and H. N. Shapiro, Fundamentals of Engineering Thermodynamics*