ME Ph.D. Qualifying Examination List of Topics Within Each Topic Area

Applied Mathematics

1. Basic Differentiation and Integration of Common Functions.
   - polynomials.
   - exponentials and logarithms.
   - sines, cosines, and tangents.
   - product and quotients of these functions.
   - total differentials and implicit differentiation.

2. Multiple Integration.
   - area of surfaces and volumes of solids.

3. Basic Statistics.
   - gaussian distribution.
   - average, standard deviation, and standard deviation of the mean.
   - accuracy, bias and precision.
   - histograms.

4. Ordinary Differential Equations.
   - solve 1st order problem and define/use time constants.
   - solve 2nd order linear, constant coefficient problem.
     -Runge-Kutta methods of solution (graphical interpretation of the method and reduction of order to system of 1st order problems).

5. Partial Differential Equations
   - method of separation of variables typical in transient heat transfer.
   - chain rule application.

6. Laplace Transforms.
   - definitions, and use in solving ordinary differential equations.
   - use in defining transfer functions.

7. Series Expansion of Functions.
   - Taylor Series expansion of non-linear functions.
   - Fourier Series expansion.

8. Linear Algebra.
   -solve systems of linear equations.
   - find determinants, eigenvalues, and eigenvectors.
   - change of basis.

9. Vector Operations.
   - gradient, divergence, and curl.
   - dot and cross products.
   - directional derivatives.

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Dynamics and Vibration (Includes Kinematics and System Dynamics)

I. Statics

1.) Analysis of forces, moments, and torques
2.) centroids
3.) trusses
4.) equilibrium of rigid bodies
5.) friction

II. Kinematics

1.) position, velocity, and accelerations
2.) derivative of a rotating vector
   a.) motion relative to a fix frame
   b.) motion within a rotating frame
3.) normal, tangential, coriolis accelerations
4.) gravity - motion of projectiles
5.) coordinate systems:
6.) radius of curvature
   a) rectangular, cylindrical, spherical
   b) normal-tangential (path dependent)

III. Kinetics

1.) Forces and Accelerations
   a) center of mass, mass moment of inertia
   b) linear and angular momentum
   c) equations of motion for a rigid body
   d) gyroscopic moments.
   e) interconnected rigid bodies
2.) Impulse-Momentum Methods
   a) definition of impulse
   b) definition of angular impulse
   c) conservation of momentum problems: central, oblique, and eccentric impact.
3.) Energy Methods
   a) Work, Kinetic, and Potential Energy.
   b) Principle of Work and Energy
      i) particles
      ii) planar rigid bodies

IV. Vibrations and System Dynamics

1. 1st Order System and Time Constants (definition, use, and meaning.)
2. One and Two degree of freedom systems:
   a) Natural frequencies, free and forced vibrations.
   b) Motion under Viscous and Coulomb friction.
   c) Damped vibrations: damping ratio, underdamped, critically damped, overdamped.
   d) Derivation of Analytical solutions.
   e) Transient and Steady State Response.
   f) Forced Harmonic Vibration
   g) Support Motion
   h) Transmissibility
3. Laplace Transforms and Transfer Functions
   a) Definition of Transfer Functions (TF).
   b) Obtaining TF from ODEs and vice-versa.
   c) Response to impulses, steps, ramps, and sinusoids..
   d) Partial Fraction Expansions.
   e) Initial & Final Value Theorems.

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Fluid Mechanics

1. Definition of a fluid, introductory concepts, fluid properties

2. Fluid Statics
   a) pressure
   b) hydrostatic forces
   c) equilibrium
   d) buoyancy and stability
   e) manometry

3. Basic Equations
   a) control volumes
   b) conservation of mass
   c) conservation of momentum
   d) Bernoulli's equation
   e) energy equation

4. Dimensional Analysis-what it is, how and why it is done

5. Internal Flow
   a) laminar and turbulent flow
   b) friction factor and minor losses
   c) series piping

6. External Flow
   a) boundary layers
   b) drag on 2-D and 3-D bodies
   c) lift

7. Measurements
   a) viscosity
   b) pressure
   c) velocity
   d) flow rate

8. Navier-Stokes Equations
   a) meaning of terms
   b) applications of ideas

9. Inviscid Flow
   a) equations
   b) stream function and potential
   c) irrotational flow

ME Ph.D. Qualifying Examination List of Topics Within Each Topic Area

Heat Transfer

1. General introduction of the principal modes of heat transfer and rate equations
   a) physical mechanisms of conduction, convection and radiation
   b) energy balances

2. Steady-state thermal conduction in one dimension
   a) 1-D S.S. conduction, Cartesian, cylindrical, spherical coordinates
   b) thermal resistance, composite series and parallel resistances

3. Heat transfer from extended surfaces
   a) fin efficiency b) overall conductance of a finned wall

4. Transient one-dimensional thermal conduction
   a) lumped capacitance b) exact solution & Heisler charts
   c) semi-infinite solid d) superposition of transient conduction solutions

5. Fundamentals of convection
   a) Newton's law of cooling, heat transfer coefficient, Nu=f(Re,Pr)
   b) concept of hydrodynamic and thermal boundary layers
   c) combination of rate equation and energy balance in problem solving

6. Forced convection: internal and external flow
   a) external convection results and correlations, laminar & turbulent
   b) internal flow--average velocity and temperature
   c) developing and fully developed flow
   d) internal convection results and correlations, laminar & turbulent

7. Free convection
   a) flow patterns, coupling of thermal and hydrodynamic components
   b) correlations of Gr, Ra
   c) instability, problems of free convection in enclosed spaces

8. Heat Exchangers
   a) simple heat exchangers (double pipe, shell and tube, cross-flow)
   b) LMTD and effectiveness-NTU methods

9. Fundamentals of radiative heat transfer
   a) radiation definitions and nomenclature
   b) blackbody radiation (Stefan-Boltzmann law, Wien's displacement law)
   c) radiation properties (diffuse, gray)

10. Radiative exchange between surfaces
    a) view factors b) blackbody radiation exchange
    c) radiation exchange in diffuse-gray enclosures

11. Multimode heat transfer

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Machine Design

Stress and Strain Analysis	Deflection and Stiffness Analysis
Material Behavior	Failure Theories
Analysis for Failure Under Static Loading	Fatigue Analysis (finite life and infinite life)
Bolted Joint Analysis	Welded Joint Analysis
Spring Design	Rolling Contact Bearing Life Relationship
Gear Forces, Gear Stresses	Clutch and Brake Analysis
Flywheels	

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Materials Science & Engineering

Textbook: any introduction to materials science book

Typical authors include:
W.F. Smith, D.R. Askeland, W.D. Callister, Jr.,
F. Trojan, J. F. Shackelford

Exam Format: Open book

Topics:

1. Material Classifications:
   - Atomic Bonds & Structure
2. Crystal Structure
   - unit cells, Bravais Lattice, Miller Indices
3. Physical and Mechanical Properties (Condon-Morse energy profiles)
4. Imperfections – Defects & Slip Systems
   - concentration on dislocations in FCC materials
5. Solid State Diffusion
6. Phase Diagrams
7. Strengthening Mechanisms in Crystalline Materials
   - Cold Work
   - Grain Size
   - Solid Solution
   - Eutectic
   - Precipitation
8. Classification of Metallic Materials
9. Aging Curves and TTT Diagrams
   - application to heat treatment processes
10. Ductile to Brittle Transitions
11. Surface Treatments
12. Properties of Polymers
13. Properties of Composites

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Solid Mechanics and Strength of Materials	
failure theories:	distortion energy theory maximum shear stress theory maximum normal stress theory
combined stresses:	bending, torsion, axial loading
elastic deformation	energy methods (Castiglianos' theorems)
torsion of circular and non-circular sections	nonsymmetrical bending
curved beams	elastic stability
fracture mechanics	fatigue
contact stresses	thermal stresses

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Thermodynamics

1. Basic Concepts

System/control volume, surroundings, universe;
Equilibrium, property, state
Process, path, and interactions (Work and Heat)
Units and dimensions

2. Properties of Pure Substances

Intensive and extensive properties
Definition of pure substances
Two-property rule and equations of state for pure substances
Systematic procedure for reading property tables.

3. Ideal and Real Gases

Ideal gas law (definition of an ideal gas)
Dependence of u, h, and specific heats on temperature only for ideal gas.
Empirical Real Gas equations.
Compressibility factor and the virial form of the pvT equation of state.

4. Processes, Heat and Work Interactions

Quasi-equilibrium processes and nonequilibrium processes.
Conceptual aspects of heat and work as boundary phenomena.
Displacement work in fully-resisted and partially-resisted system volume change.
Shear or shaft work.
Principal mechanisms for heat transfer and the corresponding rate equations.

5. The First law of Thermodynamics

Formal statements
The first law applied to non-flow processes (NFEE).
Application to flow processes (SFEE/FEE)

6. The Second law of Thermodynamics

Concepts (Reservoirs, Heat engines, Refrigerators)
Formal statements (Kelvin-Planck, Clausius)
Corollaries: Reversibility, thermodynamic temperature scale, the Inequality of Clausius
Entropy and the second law
Exergy Analysis and the second law

7. Applications

Power and Refrigeration cycles (Carnot, Rankine, Brayton, Otto, Deisel, Reversed Brayton, etc.)
Psychrometric processes including use of chart