Mechanical Engineering Qualifying Exam Guide

2009-2010 Edition

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TABLE OF CONTENTS

SECTION I – DESIGN

The examination covers the material taught in ME 561, ME 562, and ME 563. The subject matter on which the student will be examined consists of**:**

1) **Fundamentals of Machine Elements**

- ***a)*** Safety factor, critical section, static equilibrium, free body diagram
- ***b)*** Shear and moment diagrams, Mohr's circle, octahedral stresses, plain strain
- ***c)*** Torsion, bending, and transverse shear
- ***d)*** Singularity functions, method of superposition, Castigliano's theorem
- ***e)*** Stress concentration, fracture toughness, failure prediction
- ***f)*** Fatigue, modified endurance limit, cumulative damage
- ***g)*** Impact stresses and deformation
- ***h)*** Properties of solid materials, lubrication, friction, and wear principles

2) **Design of Mechanical Elements**

- ***a)*** Screws, fasteners and connections
- ***b)*** Welded joints
- ***c)*** Mechanical springs
- ***d)*** Rolling element bearings
- ***e)*** Gears (spurs, helical and bevel)
- ***f)*** Shafting and associated parts
- ***g)*** Clutches, brakes, couplings and flywheels
- ***h)*** Hydrodynamic bearings
- ***i)*** Flexible machine elements (belts, ropes, and chains)

The following texts are recommended as a guide for preparation:

Shigley, J.E. and Mischke C.R., Mechanical Engineering Design, McGraw-Hill, New York, 1989.
Collins, J.A., Mechanical Design of Machine Elements, First Edition, John Wiley and Sons, New York, 2003.

SECTION II – DYNAMICS AND KINEMATICS

The examination covers the material taught in ME 430 and ME 553. The subject matter on which the student will be examined consists of:

1) **Dynamics**
   - ***a.*** Rectilinear and plane curvilinear motion in different coordinate systems
   - ***b.*** Kinetics of particles
     - ***i.*** Newton's second law
     - ***ii.*** Work/energy
     - ***iii.*** Impulse/momentum
   - ***c.*** Kinetics of systems of particles
     - ***i.*** Newton's second law, work/energy and impulse/momentum
   - ***d.*** Rigid body kinematics
     - ***i.*** Absolute and relative motion
     - ***ii.*** Instantaneous center
     - ***iii.*** Motion relative to rotating axes
   - ***e.*** Rigid body kinetics
     - ***i.*** General equations of motion for translation, fixed axis rotation and general motion
     - ***ii.*** Angular momentum
     - ***iii.*** Work/energy relations
     - ***iv.*** Impulse/momentum equations

2) **Planar Linkages**
   - ***a.*** Degrees of freedom and mobility in linkages
   - ***b.*** Linkages with fixed and moving sliders
   - ***c.*** Graphical and analytical methods for velocities and accelerations
   - ***d.*** Instant centers

3) **Mechanism Force Analysis**
   - ***a.*** Analytical approaches to static and dynamic force analyses
   - ***b.*** Energy methods
   - ***c.*** Inertial forces and shaking forces

4) **Linkage Design**
   - ***a.*** Design for rigid body guidance
   - ***b.*** Design for function generation
   - ***c.*** Design of crank-rocker mechanisms
   - ***d.*** Design based on using the path of a coupler point

5) **Gear Kinematics**
   - ***a.*** Gear train analysis when rotation axes are fixed
   - ***b.*** Planetary gear train analyses"

The following texts are recommended as a guide for preparation:

Meriam, L.L. and Kraige L.G., Engineering Mechanics-Dynamics, any edition, John Wiley & Sons, New York.
Waldron, K.J. and Kinzel, G.L., Kinematics, Dynamics and Design of Machinery, John Wiley & Sons, New York, 2004.

SECTION III – FLUID MECHANICS

The examination will cover the topics covered in ME 503 and ME 504, and some introductory material in one-dimensional compressible flow. In the following outline, material in the first two sections is discussed ME 503, the next three sections in ME 504 (the last section is also in the first few weeks of ME 701).

1) **Integral Balances**
- ***a)*** Mass balance
- ***b)*** Momentum balance
- ***c)*** Moment of Momentum balance
- ***d)*** Energy balance

2) **Inviscid Flows**
- ***a)*** Bernoulli Equation
- ***b)*** Potential Flows

3) **Viscous Flows**
- ***a)*** Parallel flows, fundamentals of lubrication
- ***b)*** Boundary layer theory

4) **Turbulent Flows**
- ***a)*** Equations for the mean motion, Reynolds stresses
- ***b)*** Pipe flow
- ***c)*** Skin friction and form drag

5) **One-dimensional Compressible Flow**
- ***a)*** Isentropic flow with area change
- ***b)*** Effect of friction on a flow in a duct of constant area
- ***c)*** Effect of heat transfer on a flow in a duct of constant area
- ***d)*** Normal shocks

The following texts are recommended as a guide for preparation:

R. Fox and A. McDonald, Introduction to Fluid Mechanics, Fourth Edition, John Wiley & Sons, New York, 1992.
I. Shames, Fluid Mechanics, Second Edition, McGraw-Hill, New York, 1982.
F. White, Fluid Mechanics, Third Edition, McGraw-Hill, New York, 1994.
R. Sabersky, A. Acosta and E. Hauptmann, Fluid Flow, Third Edition, MacMillan, 1989.
Munson, Young, Okiishi, Fundamentals of Fluid Mechanics, Fifth Edition, John Wiley & Sons, New York, 2006.

SECTION IV – HEAT TRANSFER

The examination in heat transfer will cover the material taught in ME 510. The emphasis will be placed on student's ability to apply the fundamentals to the formulation of original heat transfer problems and to proceed with the solution. The subject matter on which the student will be examined will include:

1) **Conduction**
- ***a)*** Ability to apply balance of mass and energy to conduction
- ***b)*** Steady 1-D, 2-D, and 3-D conduction
- ***c)*** Heat transfer from extended surfaces
- ***d)*** Conduction in moving media
- ***e)*** Unsteady lumped systems
- ***f)*** Formulation of unsteady distributed systems (1-D, 2-D, and 3-D)

2) **Convection**
- ***a)*** Ability to apply balance of mass, momentum, and energy to convection
- ***b)*** Laminar and turbulent forced convection in internal and external flows
- ***c)*** Thermal and momentum boundary layers in forced convection
- ***d)*** Thermal and momentum boundary layers in natural convection
- ***e)*** Use of heat transfer correlations in forced and natural convection

3) **Radiation**
- ***a)*** Fundamental physics of thermal radiation
- ***b)*** View factors and their algebra
- ***c)*** Radiation exchange between gray-diffuse surfaces

4) **Multimode heat transfer**

The following texts are recommended as a guide for preparation:

F.P. Incropera and **D.P. DeWitt**, Introduction to Heat Transfer, Fifth Edition, J. Wiley, New York, 2006.
J.P. Holman, Heat Transfer, Ninth Edition, McGraw-Hill, New York, 2001.
V.S. Arpaci, A. Selamet, and **S.-H. Kao,** Introduction to Heat Transfer, Second Print, Prentice Hall, New Jersey, 2000.
F. Kreith and **MS Bohn**, Principles of Heat Transfer, Sixth Edition, Harper & Row, New York, 2000.

SECTION V – MEASUREMENTS AND CONTROLS

The examination in Measurements and Controls will cover material found in the courses ME 570 and 571. A table of Laplace Transforms will be provided. The subject matter covered includes:

1) **Measurements**
- ***a)*** Static and Dynamic Performance Characteristics of Measuring Devices
- ***b)*** Data and Error Analysis; Elementary Probability and Statistics
- ***c)*** Motion, Force, Pressure, Flow and Temperature Measurements

2) **Controls**
- ***a)*** Time and Frequency Domain Performance Specifications for Linear Continuous-Time Feedback Control Systems
- ***b)*** Stability Analysis Techniques-Routh-Hurwitz Criterion, Nyquist Criterion, Root-Locus Methods
- ***c)*** Basic Compensators: Proportional, Integral, and Derivative Controllers, and Lead and Lag Compensators

Relevant parts of the following texts or equivalents are recommended for study:

For Measurements (ME 570)
Primary:
Richard S. Figliola and Donald E. Beasley, Theory and Design for Mechanical Measurements, Fourth Edition, John Wiley & Sons, Inc., 2006 (ISBN: 0-471-44593-2)

Reference:
E.O. Doebelin, Measurement Systems, Application and Design, *Fifth Edition,* McGraw-Hill Book Company, 2004.

For Controls (ME 571)
Primary:
N.S. Nise, Control Systems, Fifth Edition, John Wiley (ISBN-13:978-0471-79475-2)

Reference:
G. Franklin, J.D. Powell, A. Emami-Naeini, Feedback Control of Dynamic Systems, Third Edition, Addison-Wesley, 1994.
R.C. Dorf, R.H. Bishop, Modern Control Systems, Seventh Ed. Addison-Wesley, 1995

SECTION VI – MECHANICS OF MATERIALS

The examination in mechanics will cover the material taught in ME 410 (formerly EM 400) and ME 420 (formerly EM 440). The subject matter on which the student will be examined will consist of:

1) **Statics**
- ***a)*** Particle equilibrium
- ***b)*** Rigid body equilibrium
- ***c)*** Structural analysis: trusses, frames, and machines
- ***d)*** Internal forces and moments
- ***e)*** Friction
- ***f)*** Centroids and moments of inertia

2) **Strength of Materials**
- ***a)*** Stress
- ***b)*** Strains
- ***c)*** Mechanical properties of materials
- ***d)*** Axial load
- ***e)*** Torsion
- ***f)*** Beam bending and transverse shear
- ***g)*** Combined loading
- ***h)*** Stress and strain transformations
- ***i)*** Deflection of beams and shafts
- ***j)*** Buckling of columns
- ***k)*** Energy methods

The following texts are recommended as a guide for preparation:

Hibbeler, R.C., Engineering Mechanics*, Statics*, any edition, Prentice Hall.
Hibbeler, R.C., Mechanics of Materials, any edition, Prentice Hall.
Beer, Johnston, Eisenberg, Vector Mechanics for Engineers, any Edition, McGraw Hill.

SECTION VII – SYSTEM DYNAMICS AND VIBRATIONS

The examination in System Dynamics and Vibrations will cover material found in the courses ME481, 482 and sections of 650. The subject matter covered includes:

1) **System Dynamics**
- ***a)*** Solution Methods for Ordinary Linear Differential Equations; Linearization Techniques
- ***b)*** System Elements - Mechanical, Electrical, Fluid and Thermal
- ***c)*** Fourier Analysis
- ***d)*** Frequency Response and Transfer Functions of First, Second and Higher Order Systems
- ***e)*** Lumped Parameter Models of Hydraulic Pumps and Motors, Motors, and Generators

2) **Mechanical Vibrations**
- ***a)*** Single degree of freedom systems:
  - ***i)*** Free and forced response to general excitations
  - ***ii)*** Frequency response
  - ***iii)*** Damping models
  - ***iv)*** Vibration isolation

- ***b)*** Multiple degree of freedom systems:
  - ***i)*** Natural frequencies and vibration modes of MDOF systems
  - ***ii)*** Free and forced response using modal analysis

Relevant parts of the following texts or equivalents are recommended for study:

Math
Primary:
W. E. Boyce and R. C. DiPrima, Elementary Differential Equations and Boundary Value Problems, 8th OSU custom edition, Wiley. (Or, find comparable books or course notes that cover the same topics in an undergraduate differential equations course.)

- Solution Methods for Ordinary Linear Differential Equations; Linearization Techniques
- Fourier Analysis

Students are encouraged to review undergraduate differential equations course (such as Math 415) topics and not just a summary of what is given in the system dynamics, vibrations or controls books.

Systems Dynamics
Primary:
W.J, Palm III, System Dynamics, McGraw-Hill, Second Edition, 2009
G. Rizzoni, Principles and Applications of Electrical Engineering, Part III: Electro Mechanical Systems (Chapters 15-17), McGraw-Hill, 2004.

Vibrations
Primary:
L. Meirovitch, Fundamentals of Vibrations, 2001, McGraw Hill.

Reference:
D.J. Inman, Engineering Vibration, Second edition, 2001, Prentice-Hall.
W. E. Boyce and R. C. Diprima, Elementary Differential Equations and Boundary Value Problems, Sixth (1997), Seventh (2001), or Eighth edition (2004), Wiley.

SECTION VIII – THERMODYNAMICS

The examination in thermodynamics will cover the material taught in ME 501 and ME 502. In the following outline, topics I and II are discussed in ME 501 and topics III-V are discussed in ME 502.

1) **Conservation and Balance Principles**
- ***a)*** Conservation of mass principle
- ***b)*** Energy balance for closed and open systems
- ***c)*** Entropy balance for closed and open systems
- ***d)*** Applications of balance principles to engineering devices

2) **Properties and Property Relations**
- ***a)*** Entropy, thermodynamic temperature scales
- ***b)*** Gibbs equations
- ***c)*** Use of "steam" tables and similar compilations
- ***d)*** Generalized compressibility charts
- ***e)*** Ideal gas model, ideal gas tables

3) **Application to Power and Refrigeration Systems**
- ***a)*** Rankine cycle with reheat and regeneration systems
- ***b)*** Brayton cycle
- ***c)*** Otto, Diesel and Dual cycles
- ***d)*** Vapor-compression refrigeration and heat pump systems

4) **Nonreactive Ideal Gas Mixtures**
- ***a)*** Dalton mixture model and its use in mixing processes
- ***b)*** Air water vapor mixtures, Psychrometric chart

5) **Combustion and Thermochemistry**
- ***a)*** Application of conversation of mass, the first law, and the second law to reacting systems; Stoichiometry
- ***b)*** Enthalpy of formation; Heating values; Adiabatic-combustion temperature
- ***c)*** Third law of thermodynamics; Absolute entropy; Entropy production in reacting mixtures

The following texts are recommended as a guide for preparation:

M. Moran and H. Shapiro, Fundamentals of Engineering Thermodynamics, Fifth Edition, J. Wiley, 2004.
M. Moran, Availability Analysis: A Guide to Efficient Energy Use, ASME Press, 1989.
R. Sonntag, C. Borgnakke, G.J. Van Wylen, Fundamentals of Thermodynamics, Fifth Edition, J. Wiley,