ENGINEERING DESIGN

LEVEL: EG 209, ME 202, ME 306, ME 401, ME 402, ME 454/654

This study guide was written to assist you in preparing for the Ph.D. qualifying examination in Engineering Design. To be successful on the exam, you must demonstrate that you know:

- How to formulate a problem
- How to sketch and understand engineering drawings (projections),
- How to obtain order of magnitude results (approximately analysis),
- What next steps you would take to get to a more in-depth solution,
- How to identify failure criteria and assess failure,
- How and when to perform optimization,
- Component design, (we will use the design of shafts to examine your <u>fundamental</u> knowledge.)

You should show analytical insight through design solutions that exhibit the level of maturity and understanding expected of Master's level students.
CLOSED BOOK. Equation Sheet and tabulated information will be provided.

TOPICS:

1. Shaft design. Forces and torque exerted on shafts, stresses and deformations, stress concentrations, static and fatigue failure.
2. Design process.
3. Engineering drawing.
4. Decision-making.
5. Modeling and simulation.
6. Material selection.
7. Optimization methods – problem formulation, solution by differential calculus, search methods and LaGrange multipliers.

RERENCES:

Primary:
1. <u>Machine Elements in Mechanical Design</u>, Mott, 3rd ed. (Chapter 12)
2. <u>The Engineering Design Process</u>, Ertas and Jones, (Chapter 1-4, 6)
3. <u>EG 209 notes</u>

Secondary:
1. <u>Engineering Design and Design for Manufacturing</u>, Dixon and Poli
2. <u>Fundamentals of Machine Component Design</u>, Juvinall and Marshek, 3rd edition

Approval by: ______________________________________ Revised: _______________.

FLUID MECHANICS

LEVEL: ME 203, EM 320 with subject mastery

TOPICS:

1. Basic laws for finite control volumes
   a. Conservation of mass
   b. Linear momentum
   c. First Law of Thermodynamics
2. Differential Forms of the Basic Laws
   a. Conservation of mass
   b. Euler's equations
   c. Havier-Stokes Equations
3. Dimensional Analysis and Similitude
4. Kinematics
   a. Stream Function and velocity potential
   b. Circulation, rotation, vorticity
   c. Eulerian and Lagrangian descriptions
5. Differential Analysis, including exact solutions for classical viscous flows (i.e. pipeflow, Couette flow, etc.)
6. Boundary layer concept and approximations, including Law of the Wall
7. External flow over bodies

1. Fundamentals of Fluid Mechanics, Munson, Chapters 1-9, 11
2. Foundations of Fluid Mechanics, Currie

Approved by:____ Revised: _______________.

MANUFACTURING PROCESS

LEVEL: ME 404, ME 440

TOPICS:

1. Manufacturing Properties of Engineering Materials

Emphasis: Suitability of engineering materials for various processing operations.

i) Fluidity, castablilty, formability, forgeability, weldablilty, etc.

2. Tribological and Dimensional Characteristics of Surfaces

Emphasis: Implication of tribological and dimensional characteristics of tool and part surfaces in manufacturing.

i) Friction, wear, and lubrication
ii) Metrology, dimensional tolerances and surface finish

3. Manufacturing Processes for Engineering Materials

Emphasis: Analysis of manufacturing processes for engineering materials.

i) Processing of metallic materials
- Casting, bulk deformation, sheet-metal forming, powder metallurgy, cutting, abrasive, chemical electrical and high-energy beam material removal processes

ii) Processing of polymers and reinforced plastics
- Extrusion, injection, rotational flow, compression and transfer molding, and theromforming

iii) Processing of ceramics, glasses and composites
- Slip casting, extrusion, dry, wet and hot pressing, jiggering and injection, molding for ceramics; blowing and centrifugal casting for glasses, processing of metal and ceramic matrix composites

iv) Joining Processes
- Welding, brazing and soldering

4. Selection of Manufacturing Processes

Emphasis: Methodologies for process selection.

i) Process attributes
ii) Process selection charts

REMARKS:

Questions will typically deal with qualitative aspects of the working principles associated with various manufacturing processes, fundamental relationships between materials properties and process attributes and with methodologies for process selection. The questions may include the use of quantitative relationships discussed in the reference books listed below to carry out a short supporting calculation (such as determination of the solidification shrinkage, calculation of the minimum forging pressure or total specific work of deformation, computation of the economic batch size of a process, etc.)

REFERENCES:

1. Manufacturing Processes for Engineering Materials, 4th Ed., Kalpakjian and S.R. Schmid, Prentice, Hall, 2002

2. Materials Selection in Mechanical Design, 2nd Edition, Michael F. Ashby, Chapters 11-12, Butterworth-Heinemann, Oxford 1999

3. Introduction to Manufacturing Processes, 2nd Edition, John A. Schey, Chapters 1-9 and Chapter 12, McGraw Hill, New York, N.Y., 1987.

Approved by:______________________________________ Revised:______________________.

THERMODYNAMICS

LEVEL: ME 203, ME 303, and ME 810

TOPICS: Students are responsible for any and all material in Primary references #1 and #2 (see below). A focus on the following eight topics can be expected.

1. First and Second Law Topics
2. Property Models
    - Equations of State
    - "Real" Substance Behavior
    - Theory of Corresponding States
    - Thermodynamic Tables of Properties
3. Thermodynamic Relations
4. Phase and Chemical Equilibrium
5. Mixtures
6. Entropy
7. Chemical Reactions/Combustion

REFERNCES:

Primary:

1. <u>Fundamentals of Classical Thermodynamics,</u> Van Wylen and Sonntag, --Entire text
2. <u>Fundamentals of Engineering Thermodynamics</u>, Moran and Shaprio—Entire text

Secondary:

1. <u>A Course in Thermodynamics</u>, Kestin
2. <u>Advanced Thermodynamics for Engineers</u>, K. Wark
3. <u>Advanced Engineering Thermodynamics</u>, A Bejan

Approved by:____Revised:________________.

MATERIALS

LEVEL: CME 210, ME 440

TOPICS

1. Materials Properties and Their Measurement

   Emphasis: Definition and experimental measurement of main properties of the engineering materials which influence their selection in engineering design. The following classes of properties are covered:

   i) Mechanical Properties
      Strength, hardness, ductility, fracture toughness, creep resistance, fatigue strength.

   ii) Physical properties
      Electrical, magnetic, thermal and optical properties.

   iii) Environmental Properties
      Wear, corrosion and oxidation resistances.

2. Engineering Materials Classes and Their Applications
   Emphasis: Taxonomy of engineering materials and the analysis of the defining properties of each material class and main subclasses. The following classes of materials are covered:
   i) Metallic Materials
      Ferrous, nonferrous, light, noble and refractory metals and alloys
   ii) Ceramic Materials
      Glasses, traditional ceramics and technical ceramics.
   iii) Polymeric Materials
      Thermoplastics, thermosets and elastomers.
   iv) Composite Materials
      Dispersion-strengthened, fiber-reinforced and laminar composites

3. Effect of Microstructure on Materials Properties

Emphasis: Interrelationships among materials microstructure, properties and performance. Specific concepts to be covered include:

i) Cold working and annealing of metals

Strain hardening, stress relieving, recovery, recrystallization and, grain growth.

ii) Heat treating and surface modifications of metals

Quenching and tempering, precipitation hardening, carburizing and nitriding.

iii) Texture and anisotropic behavior

Normal and planar anisotropy, deformation and annealing textures.

iii) Phase and microstructural transformation in polymers

Cross-linking, crystallization, glass transition, etc.

4. Materials Selection in Mechanical Design

Emphasis: Methodology of materials selection in mechanical design. The following aspects of material selection will be covered:

i) Materials Selection Charts

ii) Materials Performance Indices

iii) Selection of materials in mechanical and thermo-mechanical designs.

REMARKS:

Questions will typically deal with qualitative aspects of the fundamental relationships between materials microstructure, materials properties and materials selection. The questions may include the use of quantitative relationships discussed in the reference books listed below to carry out a short supporting calculation (such as determination of the minimum creep rate, optimum recrystallization temperature, materials performance index for s strength/stiffness driven mechanical design, etc.) A calculator is not needed nor allowed.

REFERENCES:

1. The Science and Engineering of Materials, 4th Edition, Donald R. Askeland and Pradeep P. Phuli,, Chapters 1-22, Thomson Learning, 2003.

2. Materials Selection in Mechanical Design, Michael F. Ashby, Butterworth – Heinemann, 3rd Edition, Oxford 2005.

Approved by: E. M Austin, M. Grujicic, D. A. Zumbrunnen

Revised: January 26, 2007

MATHEMATICS
LEVEL: Undergraduate and First-Year Graduate

TOPICS:

Vectors	Basic vector operations. Derivatives of vectors
Calculus	Geometric relations involving derivatives and integrals. Two variable relations. Improper integrals. Taylors series.
Differential Equations	Classification and definitions of Differential Equations. Recognition of appropriate methods of solution. Application of existence theorems. Series solutions, integral transforms and separation of variables.
Matrix Algebra	Solution of linear systems of equations. Matrix manipulations and definitions. Eigenvalues and eigenvectors.
Numerical Methods	Solution of Equations by iteration, Interpolation, Numerical Integration and Differentiation.
Complex Variables	Complex Numbers, Complex Analytic Functions. Conformal mapping

REFERENCES: A textbook on Advanced Engineering Mathematics, for example:

1. Kreyszig Advanced Engineering Mathematics.
2. Zill and Cullen, Advanced Engineering Mathematics

Revised:

HEAT TRANSFER

LEVEL: ME 304

TOPICS:

Students should have proficiency with each heat transfer mode (conduction, convection, and radiation) and also be able to combine them to develop thermal models for applications. Familiarity with fundamental boiling concepts is also required.

The list below provides an overview of topics.

1. Conduction
   - Heat diffusion equation
   - Solutions of the heat diffusion equation for steady-state and one spatial dimension in Cartesian, spherical and cylindrical coordinate systems
   - One-dimensional heat conduction with heat sources
   - Extended surfaces such as fins
   - Thermal resistances
   - Finite difference methods
   - Transient conduction (lumped capacitance and similarity techniques)

2. Convection
   - Boundary layer analysis
   - Conservation of momentum and energy in differential and integral forms
   - Similarity methods and solutions
   - Reynolds analogy
   - Convection heat transfer correlations for internal and external flows (both forced and natural convection)
   - Free (natural) convection

3. Boiling Fundamentals
   - Modes of boiling
   - Pool boiling

4. Radiation
   - Radiation fundamentals
   - Radiative properties of surfaces
   - Modeling methods for black and gray surfaces
   - Radiation exchange between surfaces

5. Heat Exchangers
    - Heat exchanger configurations
    - Log-mean temperature
    - Overall heat transfer coefficient
    - Effectiveness-NTU methods

REFERENCE:

Primary:

1. Fundamentals of Heat and Mass Transfer, 6th Ed., F.P. Incropera, D.W. Dewitt, T. L. Bergman, A. S. Lavine, John Wiley & Sons, New York (Chapters 1-13), 2007.

Approved by: ________________________ Revised: January 25, 2007

SOLID MECHANICS

LEVEL: ME 302, ME 425/625

The examination will focus on advanced undergraduate and Master's level material in solid mechanics. The emphasis will be on problem formulation and solution approaches to demonstrate maturity of understanding and knowledge in this subject area. The exam will be closed book. The attached sheet will be provided exam.

TOPICS:

1. Stress and deformation analysis of rods, shafts, beams, trusses, frames, and machines due to mechanical and thermal loads. Both statically determinate and indeterminate structures.
2. Bending of curved beams.
3. Unsymmetric beam bending.
4. Torsion of noncircular members.
5. Beams on elastic foundations.
6. Combined stresses, stress and strain transformations in 2-D and 3-D.
7. Generalized Hooke's law.
8. Plane stress and plane strain
9. Static failure theories

REFERENCES:

Primary:

1. Mechanics of Materials, Hibbler (Chapters 1-13)
2. Advanced Mechanics of Materials, Cook and Young, (First Edition: Chapters 1-3, 5, 8-10), (Second Edition:1-3, 5-10)

Secondary:

1. Mechanics of Materials, Gere and Timoshenko
2. Engineering Mechanics of Solids, Popov
3. Mechanics of Solids, Lardner and Archer

Approved by:______________________________________ Revised: ________________.

Dynamics and Vibrations

Level: Undergraduate dynamics (EM202/ME201) and vibrations (ME450)

TOPICS:

Kinematics (2D) and Kinetics of Rigid Bodies
Energy Concepts of Rigid Bodies from "sophomore" Dynamics
Principles of Linear and Angular Impulse-Momentum of Rigid Bodies
Modeling and Free Vibrations of Multi-Degree-of-Freedom Systems

SCOPE OF UNDERSTANDING:

Successful candidates demonstrate a thorough understanding of the basic principles of dynamics and vibrations listed above. Questions requiring the candidate to explain the dynamics of simple physical systems in terms of the underlying principles are often the most challenging and treacherous.

REFERENCES:

Examples of books covering "Sophomore Dynamics" are
Engineering Mechanics: Dynamics, Hibbeler
Vector Mechanics for Engineers: Dynamics, Beer/ Johnson
Engineering Mechanics: Statics and Dynamics, Meriam/Kraige,

Examples of books covering beginning vibration theory are
Theory of Vibration with Applications, Thompson and Dahleh
Fundamentals of Vibrations, Meirovitch
Engineering Vibrations, Inman

Written by E. M. Austin, 25 January 2007

Approved by ________________________ Revised ___________________

Clemson University
Department of Mechanical Engineering
Ph.D. Qualifying Exam Information
System Modeling and Control

Updated: May 2007

Test Material:

The exam will test the undergraduate system modeling, analysis and classical control material. At Clemson these topics are covered in the two courses: ME305 and ME416/616. Graduate understanding of the material is expected.

Topics: I) Modeling and Analysis of Dynamic Systems:

1. Modeling principles of lumped parameter systems
   - Mechanical, Electrical, Electromechanical, Fluid, Thermal

2. Recognition of applicable physical laws such as
   - Newton Laws, Kirchhoff Laws, Continuity, Energy

3. Transfer function models
   - Laplace transform and properties, notion of pole and zero, canonical form of the transfer functions, Block diagrams

4. Stability of Dynamic Systems:
   - Stability versus location of poles, Routh-Hurwitz stability criterion

5. State-space models

6. Linearization of nonlinear systems

7. Time Domain Response of Dynamic Systems:
   - Solution of linear ODE's using transfer function or state-space approach
   - Transient Response, time domain specifications, influence of pole and zero locations on the response, damped and undamped vibrations
   - Steady-State Response, DC gain, steady-state errors, system type

8. Frequency Domain Response of Dynamic Systems:
   - Steady-state response to sinusoidal inputs, gain and phase concepts
   - Bode plots

II) Classical Control of Dynamic Systems:

9. Feedback Control Design
   - Closed-loop transfer functions
   - PID control
   - Lead and Lag compensation

10. Root Locus Method for Control Analysis and Design

11. Frequency Domain Methods in Control Analysis and Design
    - Control Design Using Bode plots
    - Nyquist Method, Nyquist Stability Criterion
    - Relative Stability, Phase and gain margins

References: Modeling and Analysis of Dynamic Systems (ME305)

- **Primary text**: C.M. Close, D.H. Frederick and G.C. Newell, *Modeling and Analysis of Dynamic Systems*, John Wiley, Third Edition, 2002.
- K. Ogata, *System Dynamics*, Fourth Edition, Prentice Hall, 2004.
- W. Palm, *System Dynamics*, First Edition, McGraw Hill, 2004. (or W. Palm, *Modeling, Analysis and Control of Dynamic Systems*, Second Edition, Wiley, 1999.)
- R.H. Cannon, *Dynamics of Physical Systems*, Dover, 2003.

Control of Mechanical Systems (ME416/616):

- **Primary text**: K. Ogata, *Modern Control Engineering*, Fourth Edition, Prentice Hall, 2002.
- N.S. Nise, *Control Systems Engineering*, Fourth Edition, John Wiley & Sons, 2005.
- G. F. Franklin, J.D. Powell, and A. Emami-Naeini, *Feedback Control of Dynamic Systems*, Fifth Edition, Prentice Hall, 2006.
- R.C. Dorf and R.H. Bishop, *Modern Control Systems*, Tenth Edition, Prentice Hall, 2005.