Department of Mechanical Engineering
Ph.D. Qualifying Exam
Area Exam Information
(Rev. Dec 9, 2020)

This document provides details about the Area Exam portion of the Qualifying Exam. General information about the Exam is available in the ME Graduate Student Handbook.

Level of Testing: The area exams consist of questions that are consistent with the understanding gained in senior undergraduate and first year graduate mechanical engineering courses. In addition, specific exams may have additional information and/or requirements that are listed in the descriptions below.

Uniform rules:

- **Each exam has a 2-hour duration**
- **You must write the last 4 digits of your student ID number on the top of each page you want graded**
- **Communicative electronic devices, media players, laptops, tablets, e-readers, etc. must be turned off and stowed for each exam**
- **Non-programmable calculators, rulers, and pencils can be used on all exams**
- **Special or extra exam information is generally not available from the coordinators of the individual exams**

Controls (Zinn, Revised July 1, 2020):

- This is an open book examination. Only textbooks are allowed in the examination, and examinees will not be allowed to have any notes, study guides, or any other sheets during the examination. Books may be examined by the proctor to ensure that they do not contain added material that might give an unfair advantage to a student.
- The exam typically contains two or three questions.
- Topics covered are those in ME 446 (or ME 346) and ME 447 which include:
    - Modeling physical systems
    - Laplace transforms and transfer functions
    - Block diagrams for continuous and discrete time
    - Time domain system response (continuous and discrete time)
    - Classical continuous time controls design and compensation including root locus and frequency domain methods
    - Discrete time system modeling and analysis methods
    - Z-Transform methods
    - Discrete time controller design methods

Solid Mechanics (Rudraraju, Revised June 15, 2018):

- Topics covered include the syllabus of ME 306 (Mechanics of Materials) offered at UW-Madison, Applications of Energy methods and Elements of Theory of Elasticity. Broadly, the scope of the exam will be based on the following two books: 1) Mechanics of Materials, Beer, Johnston, DeWolf, Mazurek, 7th Ed., and 2) Advanced Mechanics of Materials, R.D. Cook and W. C. Young, 2nd Ed.
- Open book. Each student is permitted to bring no more than two text books to the exam. Books may be examined by the proctor to ensure that they do not contain added material that might give an unfair advantage to a student. None of them can be a solution manual, and they should not have any additional pages beyond the original published material.
- Greater emphasis is placed on conceptual clarity and solution methodology rather than the solution numbers.

Dynamic Systems/Vibrations (Eriten, Revised July 16, 2018):

- The exam is closed book. Any tables or charts that are necessary will be provided.
- Each of the four problems is worth 25 %.

- Write the exam on the paper provided. Begin the solution to each problem on a new sheet of paper. Write only on one side of a sheet and assemble each problem as a separate stapled packet with the problem statement sheet on the top.
- The scope of the exam is based on the syllabi of ME 340 (Mechanics of Materials) and partially ME 440 (Intermediate Vibrations) offered at the University of Wisconsin-Madison.
- The ME 340 part of the exam is based on chapters 1-4, and chapter 8 of Palm WJ, System Dynamics, 3rd Ed., McGraw-Hill, 2013.
- The ME 440 part is based on chapters 1-3, 5, and 6 of Rao SS, Mechanical Vibrations, 6th Ed., Pearson, 2017.

Kinematics/Dynamics (Negrut, Revised June 2020):

- You may bring one 8.5"x11" piece of paper with any formulas that you may want. This sheet must be turned in with the exam. Both sides of the paper can contain formulas.
- You may bring one textbook.
- Either analytic or graphic solutions are acceptable.
- Write the exam on the paper provided only.
- Resources to prepare for the exam:
    - For the ME240 component of the exam: Gray, Costanzo & Plesha, Engineering Mechanics, Dynamics, 2nd Edition. McGraw-Hill Education, 2012. ISBN: 9780073380308. Chapters: 1-8
    - For the ME451 component of the exam: Edward J. Haug: Computer Aided Kinematics and Dynamics of Mechanical Systems (Allyn and Bacon, 1989), Chapters 1 through 8. See material here: https://uwmadison.box.com/s/j7hj2nhiknnhx1b29l6woyqvoukbuzfv

Materials Processing (Turng, Revised November 30, 2015):

- Closed book, closed notes.
- The level of the exam is at that of students who have passed ME 313 Manufacturing Processes. The textbook for ME 313 would be useful to review for students from schools other than UW-Madison. Text: Kalpakjian, S. & Schmid, S.: Manufacturing Engineering & Technology, 4th ed., Prentice Hall, Polymer Processing Fundamentals, Hanser Publishers, (1997).
- Topics that could appear:
    1. Mechanical and thermal properties of materials
    2. Major material characterization methods
    3. Major material processing methods
        a. Metals: die casting, sand casting, investment casting,
        b. Machining: broaching, drilling, grinding, milling, planing, shaping, sawing, and turning,
        c. Plastics: injection molding, extrusion, compounding, thermoforming, film blowing, and blow molding
        d. Additive manufacturing
        e. Composites, alloys, and blends
    4. Dimensional analysis, dimensionless variables, and similarity and scaling
    5. Basic governing equations for fluid flow and heat transfer and their simplifications and analytical solutions
    6. Other relevant topics that fall into the basic scope of materials processing and manufacturing

Fluid Mechanics (Trujillo, Revised November 28, 2015):

- Closed book and closed notes.
- You should know the equations commonly needed to solve Fluid Mechanics problems. Uncommon equations or fluid property information / tables will be provided if they are needed.
- There are typically 4 problems on the exam
- Topics that could appear:

1. Fluid properties
2. Fluid statics
    a. Constant density fluid in rigid rotation and rectilinear acceleration
    b. Hydrostatic force
3. Fluid forces
    a. Body forces
    b. Surface forces: pressure and shear
    c. Stress tensor and surface force
4. Lagrangian/Eulerian flow description
    a. Lagrangian, temporal, and advective acceleration
    b. Streamlines
5. Control volume analysis
    a. Reynolds Transport Theorem
    b. Mass conservation
    c. Momentum conservation
    d. Energy conservation
6. Differential analysis
    a. Mass conservation
    b. Momentum conservation and the Navier-Stokes
    c. Analytical solutions concerning Couette and Poiseuille flows in both Cartesian and Cylindrical geometry
7. Bernoulli equation and its application
8. Dimensional analysis
9. Steady flow in pipes
    a. Friction factor, major head loss, and Moody chart
    b. Minor head loss: inlets, exits, and sudden area change
10. External flow
    a. Laminar boundary layer and Blasius' solution
    b. Turbulent boundary layer
    c. Drag and lift force over blunt bodies, cylinders and spheres

<u>Heat Transfer (Nellis, Revised June 11, 2018):</u>

- You may bring one book to use during the exam.
- Coverage will be consistent with an undergraduate heat transfer class and may include the following topics:
    - 1-D steady state heat transfer
    - Extended surfaces
    - Lumped capacitance problems
    - 1-D transient problems
    - Analytical and numerical solutions
    - External, internal, and natural convection concepts and correlations
    - Heat exchangers
    - Radiation – black and gray body radiation exchange

  Much greater emphasis is placed on the solution method versus the solution numbers! Attempt to present your solution in a clear, logical and readable fashion.

<u>Thermodynamics (Pfotenhauer, Revised November 30, 2015):</u>

- You may bring 1 (one) textbook primarily for the tables.
- You may bring 1 (one) 8.5" x 11" piece of paper with any formulas you may want. This sheet must be turned in with the exam. Both sides of the paper can contain formulas.
- Topics will include those covered in undergraduate thermodynamics courses, such as:
  1. Energy balance

a. Closed system
b. Open system
c. Discrete change

2. Property relations: ideal gas, polytropic, sub-cooled liquid
3. Second law statements
4. Temperature scales
5. Entropy balance
   a. Closed system
   b. Open system
   c. Discrete change
   d. Isentropic efficiency
6. Power cycles
   a. Rankine cycles with variations (reheat, open feedwater heater)
   b. Otto & Diesel cycles
   c. Brayton cycles with variations (reheat, recuperation, intercooling) for power generation
   d. Brayton cycles for propulsion
   e. Stirling cycle
7. Refrigeration cycles
   a. Vapor compression refrigeration
   b. Vapor compression heat pump
8. Psychrometrics
   a. Definitions and psychrometric chart
   b. Applications (humidifier, air-conditioner, cooling tower, etc.)
9. Combustion
   a. Stoichiometric and non-stoichiometric reactions, AF ratio, dew point
   b. Energy balance, enthalpy of formation, HHV, LHV, adiabatic flame temperature

Computer Aided Engineering (Qian, Revised December 2015):

- The scope of the exam is based on the following two books: 1) Principles of CAD/CAM/CAE Systems, Kunwoo Lee, Prentice Hall, 1999; 2) Scientific Computing, 2nd Edition, Michael T. Heath McGraw-Hill, New York, 2002.
- You may bring 1 (one) 8.5"x11" piece of paper with any formulas that you may want. This sheet must be turned in with the exam. Both sides of the paper can contain formulas.
- You may bring up to 3 (three) textbooks. None of them can be a solution manual, and they should not have any additional pages beyond the original published material.
- Write the exam on the paper provided.