DEPARTMENT OF MECHANICAL ENGINEERING QUALIFYING EXAMS

GUIDELINES AND FORMATS

Revised 09.25.2015

QUALIFYING EXAMINATION
IN
DYNAMICS

Topics

The Dynamics qualifying examination is at the level of our introductory dynamics subject 2.032. Highlights of this subject include:

- Kinematics
- Momentum principles
- Lagrangian mechanics
- Three-dimensional rigid body dynamics
- Vibration of discrete and continuous systems
- Gyroscopic effects

Format

The proposed exam will consist of two separate parts:

- A one (1) hour written exam (Closed Book)
- A separate oral exam consisting of 20 minutes to review the question followed by a 20 minute oral questioning period.

9/25/2015

ACOUSTICS

Course 2.066

Format:

The proposed exam will consist of two separate parts:

- A one (1) hour written exam (Closed Book)
- A separate oral exam consisting of 20 minutes to review the question followed by a 20 minute oral questioning period.

9/29/2015

QUALIFYING EXAMINATION
IN
SOLID MECHANICS

Topic

Course 2.071.

Format

The format will consist of a single oral examination.

- Students will be given 45 minutes to review, and to prepare responses to, two (2) submitted questions, which will be the same for all candidates.

- After preparation, students will be examined orally on their responses with a 45 minute questioning/examination time in which the candidates are expected to present solutions to both of the posed problems.

- Grading will consist of a single number in the range 0 – 20. The minimum passing mark will be 14.

9/28/2015

QUALIFYING EXAMINATION
IN
STRUCTURAL MECHANICS

Topics

Fundamental concepts of structural mechanics with applications to marine, civil, and mechanical structures. Residual stresses. Thermal effects. Analysis of beams, columns, tensioned beams, trusses, frames, arches, cables, and shafts of general shape and material, including composites. Exact and approximate methods, energy methods, principle of virtual work. Yield and failure criteria. Elastic buckling of columns, plates and sections.
RECOMMENDED SUBJECT 2.080J.

Format

The format will consist of a single oral examination.

- Students will be given 45 minutes to review, and to prepare responses to, a set of one or more submitted questions, which will be the same for all candidates.

- After preparation, students will be examined orally on their responses with a 40 minute questioning/examination time in which the candidates are expected to present solutions to both of the posed problems.

- Grading will consist of a single number in the range 0 – 20. The minimum passing mark will be 14.

9/28/2015

QUALIFYING EXAMINATION
IN
FLUID MECHANICS

Topics Covered

For the immediate future, the content will remain based on the subject matter covered in 2.25 Fluid Mechanics. Principal topics include conversation laws (mass, momentum, energy, angular momentum) for moving and deforming fluids, control volume techniques, dimensional analysis, viscous-dominated flows and lubrication theory, inviscid flows, potential flow theory and boundary layer analysis. As new subjects emerge we may introduce several options of fluid mechanics, enlisting additional examiners as needed.

Format

- There will be one oral examination. The applicant will have 30 minutes to review the question and then they will have 30 minutes for the oral part.

10/01/2015

QUALIFYING EXAMINATION
IN
HYDRODYNAMICS

Topics

Equations governing conservation of mass and momentum. Similitude and model testing. Ideal vortical and potential flows in two and three dimensions, including the concepts of lift and added mass. Lifting-surface theory for steady, unsteady, and cavitating hydrofoils. Real (viscous) laminar and turbulent flows, Reynolds stresses, laminar and turbulent boundary layers. Rudiments of linearized free-surface waves, including wave kinematics, superposition, dispersion, energy density and group velocity, and the effect of finite water depth. Water wave loads and motions of bodies in waves, ship wave resistance. Hydrodynamics of slender bodies. Application to floating and submerged vehicles.
RECOMMENDED SUBJECT 2.20.

Format

- There will be one examination. The applicant will have 30 minutes to review the question and then they will have 30 minutes for the oral part.

9/28/2015

QUALIFYING EXAMINATION
IN
GEOPHYSICAL FLUID DYNAMICS

Topics

Equations for mass, momentum, and energy and their application in fixed and rotating systems. Vorticity and potential vorticity. Geophysical boundary layers. Fluid-density effects, including density-driven flows. Scales and scaling of ocean flows. Oceanic circulation.
RECOMMENDED SUBJECT 12.800.

Format

- There will be one examination. The applicant will have 30 minutes to review the question and then they will have 30 minutes for the oral part.

9/28/2015

Subject & Research Qualifying Examination in Thermodynamics
MIT, Mechanical Engineering
Effective May 2012

Thermodynamics is one of the foundations of Mechanical Engineering. It is concerns with the rules governing energy conversion including mass and energy conservation, entropy balance and the properties of substances. It is applied extensively for the analysis and design of power and propulsion systems, refrigeration and energy conversion.

The qualifying exam focuses on single-component equilibrium thermodynamics.

Format of Research Exam
The thesis exam will continue to be the same as in most other areas, that is a total of 45 minutes for presentation and discussion.

Format of Subject Exam
Only an oral closed book exam will be offered. Students will be given a written problem statement and 30 minutes of preparation time. Then, students will demonstrate solving this problem to the faculty in a time period of 30 minutes including questions by the faculty. The problem typically contains calculations as well as conceptual questions.

Class Preparation
Students are expected to have a graduate level knowledge of undergraduate thermodynamics, in particular those thermodynamics focused topics covered in 2.005/6. To prepare for this exam, it is suggested that students take 2.42 - General Thermodynamics or an equivalent graduate-level class.

QUALIFYING EXAMINATION
IN
HEAT AND MASS TRANSFER

Objective and Scope

The purpose of this examination is to evaluate the candidate's depth in and understanding of the fundamental principles of heat and mass transfer. The student is expected to recognize, formulate, and solve problems and applications involving conduction, convection, radiation, mass diffusion, and phase change. He or she should be able to determine temperature distributions inside solid bodies, to predict heat transfer and mass transfer rates at solid-fluid interfaces for all types of flow conditions, to estimate radiation heat exchange between solid surfaces, and to evaluate the performance of heat and mass exchangers.

Preparation Guidelines

The examination will be based on material normally covered in the undergraduate core curriculum plus the elective 2.51 in Mechanical Engineering at M.I.T., but will presume the maturity and experience commensurate with a graduate student at the Master's level. The primary undergraduate subject to which the examination will relate is 2.51. Other related subjects are 2.005 and 2.006. A good graduate core course to prepare for the exam is either 2.52 (Modelling and Approximation of Thermal Processes) or 2.55 (Advanced Heat and Mass Transfer).

Recommended Textbooks

General Texts:

Mills, *Heat Transfer,* 2nd ed., Prentice Hall, 1997.

Lienhard and Lienhard, *A Heat Transfer Textbook,* 4th ed., Phlogiston Press, 2015. Also see http://web.mit.edu/lienhard/www/ahtt.html.

Convection:

Bejan. *Convection Heat Transfer,* 2nd ed., John Wiley & Sons, Inc. 1995.

Kays and Crawford, *Convective Heat and Mass Transfer,* 3rd ed., McGraw-Hill, Inc. 1993.

White, *Viscous Fluid Flow,* 2nd ed., McGraw-Hill, 1991.

Design and Applications:

Duffie and Beckman, *Solar Engineering of Thermal Processes,* 2nd ed., John Wiley & Sons, Inc., 1991.

Rohsenow, Harnett, Cho, *Handbook of Heat Transfer,* 3rd ed., McGraw-Hill, 1998.

Hewitt, *The Heat Exchanger Design Handbook 1998,* Begell House, N.Y., 1998

Kays and London, *Compact Heat Exchangers,* 3rd ed., McGraw-Hill, 1984.

Heat Conduction:

Arpaci, *Conduction Heat Transfer,* Ginn Press, 1991.

Carslaw and Jaeger, *Conduction of Heat in Solids,* 2nd ed., Oxford Univ. Press, 1959.

Radiation:

Brewster, *Thermal Radiative Transfer & Properties,* A. Wiley-Interscience Publication, 1991.

Edwards, *Radiation Heat Transfer Notes,* Hemisphere Publishing Corp. 1981.

Modest, *Radiative Heat Transfer,* McGraw-Hill, Inc. 1993.

Siegel and Howell, *Thermal Radiation Heat Transfer, 3rd ed.,* Hemisphere Publishing Corp., 1993

Mass Transfer:

Mills, A. F., *Mass Transfer,* Prentice-Hall, Inc., Upper Saddle River, 2001.

Format

- There will be one examination. The applicant will have 30 minutes to review the question and then they will have 30 minutes for the oral part.

QUALIFYING EXAMINATION
IN
SYSTEM DYNAMICS AND CONTROL

Basic Coverage

Exams are to cover material at the advanced undergraduate level, typically covering what is in corresponding MIT undergraduate subjects. They should not expect knowledge of material given in advanced graduate subjects, but may touch upon basic material in introductory or core graduate subjects.

Relevant classes

2.140 and 2.151

Format

- A one (1) hour written exam (Closed Book) and
- A separate oral exam consisting of 20 minutes to review the question followed by a 20 minute oral questioning period.

10/02/2015

QUALIFYING EXAMINATION
IN
SIGNALS AND SYSTEMS

Topics

Time domain concepts for linear, time-invariant systems, such as impulse response and convolution. Integral transform techniques for linear systems, including continuous and discrete Fourier, Laplace, and Hilbert transforms. Sampling theorem and reconstruction. Modulation and demodulation of signals. Analog and digital filtering. Transfer function for system with linear feedback, including concepts such as open- and closed-loop gain and phase response. RECOMMENDED SUBJECT 6.003.

Format

- A one (1) hour written exam (Closed Book) and
- A separate oral exam consisting of 20 minutes to review the question followed by a 20 minute oral questioning period.

9/30/2015

QUALIFYING EXAMINATION
IN
PROBABILITY AND RANDOM PROCESSES

Course 6.431 and 2.22

Format:

- A one (1) hour written exam (Closed Book) and
- A separate oral exam consisting of 20 minutes to review the question followed by a 20 minute oral questioning period.

9/30/2015

QUALIFYING EXAMINATION
IN
BIOLOGICAL ENGINEERING

Topics: This exam covers the mechanics of biological systems, from single molecules to whole tissues, as well as biologically-relevant topics in transport and fluid flow.

Preparation: Students wishing to take this exam would be recommended to be well-versed in those topics included in two graduate subjects: 2.795: *Fields, Forces and Flows in Biological Systems*, and 2.798: *Molecular, Cellular and Tissue Biomechanics*.

Purpose: The exam is based on the student's ability to read, comprehend, and analyze one or two publications from the relevant literature.

Logistics: Each student is given a copy of the paper at 9:00 am on the first day of the exam. They are then asked to submit a short written analysis of the paper by the morning of the second day. On the third day, a committee of three or more faculty examines each student on their written critique and related topics. The oral exam is between 20 and 50 minutes in length. The student should prepare a short presentation (no more than half of the length of the exam) to be used as a basis for questioning.

9/28/2015

QUALIFYING EXAMINATION
IN
OPTICS

Material Covered

Geometrical Optics

- Ray theory, thick/thin lenses, ray propagation matrices
- Optical systems: primate eye, telescope, microscope
- Aberrations, simple aberration correction methods

Physical Optics

- Wave equation, plane & spherical wave solutions
- Light propagation in matter, polarization
- Optical resonators, optical gain, lasers
- Fresnel & Fraunhoffer diffraction
- Interference/interferometers, diffraction gratings, holography
- Coherent/incoherent image formation

Two-dimensional non-causal signal processing

- Bandwidth, sampling, space-bandwidth product
- Spatial filtering, convolutions & correlations
- Inverse problems, resolution

Class preparation

Necessary – Optics
Basic (introductory, no background necessary; includes basic E&M) undergraduate/graduate optics. 2.71 (U), 2.710 (G), prereq. 2.003.

Optional – Optical Engineering
Advanced graduate class on optical sensing and imaging, emphasis on information and design. 2.717 (G)

Other Optics subjects around M.I.T.
6.161 (U), 6.631 (G), 6.634 (G), 6.637 (G), 8.421 (G), 8.422 (G)

Format

- Written exam *standard department format* (Closed Book) Duration 1 hour and

- Oral exam (*non-standard format)* Duration: 40 min/student
  Part 1: (~25 min)
    - Student is given a collection of two-three research papers focused on a research topic, one week before the exam
    - The topic and papers are decided by the exam committee in consultation with the student's research advisor and taking into consideration the student's research topic
    - The student presents a 15 min long summary of the papers and then answers questions by the committee.

  Part 2: (~ 15 min)
    - Free-form questions on the subject matter covered by 2.71/2.710 Optics as follow-up to previous questioning.

QUALIFYING EXAMINATION
IN
MANUFACTURING
(Final Version)
July 11, 2007

The doctoral qualifying exam in Manufacturing requires a graduate student understanding of the material contained in the undergraduate Subject 2.008. An important component of this includes how materials behave in manufacturing processing conditions. This includes elements of solid mechanics found in 2.001 and elements of fluid mechanics and heat transfer found in the undergraduate courses 2.005 and 2.006. All students are expected to have an understanding of basic manufacturing processes. This would include at least machining, casting, injection molding, and forming processes. This understanding of manufacturing processes should go beyond the physics and include the issues of cost, variation, quality, time and rate. It is also important that the candidate understands the relationship between design and manufacturability, and between design, manufacturability and system design. All students should have a basic familiarity with standard systems configurations such as transfer lines, flow lines, job shops, assembly systems and the Toyota Production System, including manufacturing cells.

The manufacturing exam requires familiarity with a few systems tools which can prove useful for characterizing system problems, these include SPC, reliability (MTTF, MTTR, Buzacott's result, zero buffers, infinite buffers), Little's Law, the M/M/1 Queue, and the treatment of random variables, in particular the Expectation and Variance operators. All of these elements will need to be integrated in order to analyze real problems and give insights into the fundamental mechanisms, as well as the potential trade offs between alternatives.

If you have not taken 2.008 or an equivalent, a recommended preparatory graduate subject is 2.810.

Format

- A one (1) hour written exam (Closed Book) and
  A separate oral exam consisting of 20 minutes to review the question followed by a 20 minute oral questioning period

QUALIFYING EXAMINATION
IN
PRODUCT DESIGN

Basic Coverage

Exams cover material at the advanced undergraduate level.

Relevant Undergraduate Classes

2.007, 2.72, 2.009

Graduate Classes in Design

2.739, 2.744, 2.76

Format

- A one (1) hour written exam
- An oral exam in which students are given 20 minutes to prepare answers to a short series of questions and then are asked to defend their answers to faculty members during a 20 minute oral questioning period.

Books Useful for Review

- Mechanical Engineering Design by Shigley and Mischke
- Product Design and Development by Ulrich and Eppinger

Exam Overview

For these exams, students are expected to have a deep and thorough understanding of material taught in the undergraduate design courses. Typical questions may focus on

- design of machine elements and the systems in which they are used
- questions about how a given system functions and about the strengths and weaknesses of the system.
- issues that must be understood when developing a product. Among these are, for example, product quality, product cost, product safety, manufacturability, product architectures, customer needs, product specification, concept generation, concept selection, concept testing, and prototyping.

9/28/2015

QUALIFYING EXAMINATION
IN
MECHANICAL ELEMENTS AND SYSTEMS DESIGN

For these exams, students are expected to have a deep and thorough understanding of material taught/incorporated and practiced in the undergraduate design course. All students are expected to have an understanding of the types of basic machine elements, how to model and optimize them, and how they are best used to create functional mechanical systems. All students should be familiar with standard elements, for example bolts, gears, bearings, shafts, structural elements/sub-systems, actuators, sensors, drives, linkages and springs/flexures. If you have not taken 2.72 or an equivalent, a recommended graduate preparatory subject is 2.75, 2.76. Typical questions focus on :

- Conceptual design of machine elements or systems
- Modeling, design and selection of machine elements
- Synthesis, modeling and design of machine systems
- Questions about how a given element or system functions
- Contrast/compare the strengths and weaknesses of elements and systems
- Practical issues in mechanical system design, for example, cost vs. performance, safety, design verification testing, fabrication and manufacturability

Basic Coverage
Exams cover material at the advanced undergraduate level.

Relevant Undergraduate Class
2.72

Graduate Classes in Mechanical System Design
2.75, 2.76

Format

- Students are given a selected technical paper to read, or other forms of documentation of a design. This reference material will be provided at least 3 days before the exam. This material may also include example questions for students to consider in preparing for the exam. Students may use publicly available resources as part of understanding the reference material and questions, but may not discuss the exam with any other people. Students must sign a certification to this effect.
- An oral exam in which students are given 40 minutes to present their understanding of the reference material and design issues, and are asked

to defend their answers to faculty members. The discussion will be initiated from design issues raised in the reference, and may extend into questions of how the designs work, fundamental physics and tradeoffs, as well as how to improve the designs for some performance metrics.

Books Useful for Review

- Mechanical Engineering Design by Shigley and Mischke
- Precision Machine Design by Slocum
- Fundamentals of Design available free on web.mit.edu/2.75

9/28/2015

QUALIFYING EXAMINATION
IN
MICRO/NANOENGINEERING
EFFECTIVE MAY 2015

Topic

Course 2.37: Fundamentals of Nano Engneering

Faculty Committee

Prof. Hadjiconstantinou, Prof. Fang, Prof. Karnik, Prof. Hart, Prof. Kolpak

Format
The format will consist of a single oral examination.

- Students will be given 30 minutes to review, and to prepare responses to the submitted question(s).

- After preparation, students will be examined orally on their responses with a 30 minute questioning/examination time in which the candidates are expected to present their solution(s).

- Grading will consist of a single number in the range 0 – 20. The minimum passing mark will be 14.

9/29/2015

Subject & Thesis Qualifying Examination in Computational Engineering
MIT, Mechanical Engineering

A significant number of graduate students in the Mechanical Engineering Department perform research with a strong focus on computational engineering, in particular including the development of numerical methods and tools. More specifically, the subtopics in computational engineering include i) computational fluid dynamics, ii) computational solid mechanics, iii) solution of partial differential algebraic equations, iv) molecular-level simulation and v) optimization/parameter estimation. The qualifier exam in Computational Engineering (oral subject exam and thesis exam) will address this type of research. It is offered since May 2011.

Format of Research Exam

The thesis exam will be the same as in any other area. Additional faculty will be invited if their expertise is needed for a particular thesis topic.

Format of Subject Exam

A written exam is not suitable for a computational engineering exam and therefore only an oral exam will be offered based on critical presentation of a journal article (or similar publication) from the literature. This will be in the general area of research interests/class preparation of the student but not closely related to their research work. Typically, each student will have a separate article to review. The articles will be given to the students a week in advance of the oral exam. At the exam date, the students will give a 15 minute presentation of the article followed by a 15 minute discussion with the faculty. The discussion covers computational engineering focusing on the article and the material covered in the class(es) taken by the student.

Class Preparation

Students are required to have taken one or more of the following classes. Student that have taken a similar subject at MIT or another institution, can petition a substitution

- 2.097J Numerical Methods for Partial Differential Equations
- 2.29 Numerical Fluid Mechanics
- 2.37 Molecular Mechanics

9/28/2015