VILLANOVA UNIVERSITY

College of Engineering

Qualifying Examinations Guidelines

Ph.D. Program

Villanova, Pennsylvania

1.0 Introduction

This booklet was prepared for the benefit of the Ph.D. candidate and should be read in conjunction with the College of Engineering Ph.D. Program Handbook. The purpose of this booklet is to help the student to prepare for the Villanova University College of Engineering Ph.D. Program Qualifying Examinations.

2.0 General Requirements

In order to continue their doctoral studies, all Ph.D. students are required to pass the Qualifying Examination. The Qualifying Examination will be given annually during the second week of school in the Fall and Spring semesters.

Full-time students who being their Ph.D. coursework in Fall semester are required to take the Qualifying Examination in Fall of the following year, that is at the conclusion of their second semester. Full-time students who begin their Ph.D. coursework in Spring semester are required to take the Qualifying Examination in the Spring semester of the following year, that is at the conclusion of their second semester.

Part-time students will be required to take all of the Qualifying Examination by the conclusion of their fourth semester of Ph.D. coursework.

Any request for postponing the Qualifying Examination must be submitted to the College of Engineering Ph.D. Committee Chair, in writing, at least 30 days before the examination is to be taken. Extensions will only be granted if there are extremely extenuating and documented circumstances.

Failure to pass the Qualifying Examination will result in the termination of candidacy.

3.0 Content and Conduct of the Examination

The Qualifying Examination will consist of either a written and/or oral examination in the following areas:

- Mathematics (depending on your department requirement)
- Discipline Specific

The examinations will be administered two times a year: once in the Fall Semester and once in the Spring Semester. Exam dates will be the second Wednesday (Mathematics) and second Friday (Discipline) of each semester. For full-time students, both examinations must be taken in the same period, except in the case where an examination that was previously failed is being re-taken. The requirement of taking both examinations in the same period will be waived for part-time students. The examinations are intended to demonstrate the candidate's mastery of the subject material at the Master of Science level prior to embarking on a Ph.D. program.

3.1 Mathematics Qualifying Examination

A detailed description of the department requirements of the examination procedures, coverage, and designated preparatory courses and references is given in a following section.

3.2 Discipline Specific Qualifying Examination

Every candidate must take a qualifying examination in a disciplinary track area which is pertinent to the candidate's emphasis of study. The disciplinary examination committee will consist of at least two full-time Villanova College of Engineering faculty members who are approved by the College Ph.D. committee. In a subsequent section, this booklet presents a listing of disciplinary track areas that have been defined by the faculty of the College of Engineering Departments, and a detailed description of the examination procedures, coverage, and designated preparatory courses and references for each disciplinary specific examination.

In some instances, it may be preferable to create a customized disciplinary examination to better reflect the interdisciplinary nature of a candidate's probable research ear. In that case, the student's advisor and the Ph.D. Committee will discuss and agree on the content of the examination and a suitable examining committee.

The intent of the qualifying examination is both (1) to evaluate the student's knowledge and understanding of the materials covered in the examination, and (2) to evaluate the candidate's potential to successfully complete a Ph.D. research program. Thus, while knowledge of the material and mathematical techniques covered in the individual examinations is important, the examiners look for much more that the ability to just memorize material. It is important that the candidate also have a good overall integrated understanding of the underlying fundamental theory so that he/she can: properly relate the mathematical techniques and physical principles and apply these to engineering problems; apply the material to a wide range of situations including situations the student may not have previously seen; and be able to demonstrate the ability to think about problems in a logical and appropriate manner.

4.0 Outcome of Qualifying Examination

The outcome of the Examination will be communicated to the student as a Pass, Partial Pass, or Failure. In the event of a Partial Pass or Fail, the student will also be informed if a second attempt at the failed examination(s) has been granted. The examination scores will not be communicated to the student.

If a second attempt is granted, the failed examination(s) must be re-taken in the next available opportunity. **No more than two attempts to pass any examination are permitted within the College of Engineering, regardless of whether the student changes departments**.

5.0 Appeals

Formal appeals to the examination results must be submitted in writing to the college Ph.D. Committee within 30 days of receiving the results of the examination. A candidate may request to look at their graded examination and discuss it with the appropriate members of the examining committee who graded the examination. The candidate however will not be allowed to remove the examination from the office, nor make a photocopy of the graded examination. The chair of the Ph.D. committee, in consultation with the appropriate Ph.D. examination committee members and the student' advisor, will be the final arbiter of all disputes concerning grading of the examinations and the determination of pass or failure status.

6.0 Detailed Examination Descriptions

The following sections contain a detailed description of the examinations, including:

a) Procedures to be followed for the examination (written and/or oral)
b) Topics to be covered in each examination area
c) Recommended reference books covering the topics to be examined
d) Designated preparatory courses for each Qualifying Examination

It is highly recommended, but not mandatory, that the designated preparatory courses for each exam be taken prior to taking the examination. The subcommittee responsible for each exam are prepared this detailed information. Membership of each subcommittee appears under the subject heading. Students who have further questions should consult with the members of the subcommittees. A summary of the Disciplinary Specific examination tracks is given in Table 1.

The format and content of the examination may change. The candidate is advised to check with the chair of the subcommittee for each of the examinations well in advance of the examinations for an updated version of these examination guidelines.

Table 1
Listing of Discipline Specific Qualifying Examination Tracks

Department	Discipline
Bioengineering	Math Requirement Bioengineering
Chemical Engineering	Math Requirement Chemical Engineering
Civil Engineering	Math Requirement Environmental Engineering Geotechnical Engineering Structural Engineering Transportation Systems Water Resources Engineering
Computer Engineering	Mathematics Computer Engineering Computing Systems/Network Fundamentals Cybersecurity
Electrical Engineering	Mathematics Antennas, Microwaves and RF Circuit Design Communications and Signal Processing Energy Systems
Mechanical Engineering	Mathematics Dynamic Systems and Control Solid Mechanics and Materials Thermal Fluid Science
Sustainable Engineering	Math Requirement Sustainable Engineering

Bioengineering Area
Ph.D. Mathematics Qualifying Examination Guidelines

September 2013

Ph.D. candidates who take the qualifying exam in the Bioengineering disciplinary track shall have the option of satisfying the Mathematics Ph.D. Qualifying Examination requirements of any one of the Villanova University engineering programs (CEE, ChE, CpE, EE, or ME), independent of the affiliation of their faculty advisor. At least 60 days before the date of the examination, the candidate, in consultation with the Ph.D. advisor, will select the option that is best aligned with the student's background and planned Ph.D. research area. The Ph.D. advisor will be responsible for coordinating the logistics of administration of the mathematics qualifying examination with the selected department/program.

If the selected engineering program requires the successful completion of specified coursework in mathematics, then the program's guidelines for whether the course grade(s) constitute passing of the Ph.D. mathematics qualifying examination shall be followed. If the selected program's mathematics requirements include one or more qualifying examinations, then the student's performance will be jointly reviewed by the qualifying examination committees of both the administering department/program and of the Bioengineering Area; both committees shall be allowed to submit their own recommendation to the Ph.D. Committee regarding the student's performance.

BIOENGINEERING
QUALIFYING EXAMINATION

Noelle Comolli (ChE), Jens Karlsson (ME), William Kelly (ChE), Qianhong Wu (ME)

January 2015 *(Subject to change)*

PROCEDURE AND FORMAT

The Bioengineering qualifying examination will be a combination of a written and oral examination lasting for a period not to exceed four hours in duration (three hours for the written portion and one hour for the oral portion). It will have the following format.

- The student will select three of the topic areas listed below (two from Group A and one from Group B); the selected topics must be submitted in writing at least 60 days before the date of the examination.
- The student will be given six written questions, two from each selected topic area.
- The student must answer a total of three questions, one question from each topic area.
- The level of the written examination questions will be at the M.S. level.
- The oral portion will comprise a student presentation on one or more journal articles from the bioengineering literature, followed by an open period of questions related to the article(s). The journal articles (selected by the examining committee) will focus on experimental studies, and will exclude literature from the student's intended research area, to avoid overlap with the Dissertation Proposal examination. The presentation will be approximately 20 minutes in length, and should summarize the significance, experimental design, methods, and results of the study, and also include a critique of the paper. Questioning will probe the student's understanding of the paper, focusing on experimental design, techniques, as well as data analysis and interpretation of results.
- Examination will be open book and open notes.
- The passing grade is 70%.

TOPICS

Group A (Select Two)

Biotransport I: Modeling and interpretation of transport in living tissue, including momentum- and mass-transfer fundamentals and applications to biofluid and mass transport phenomena in the circulatory system, kidneys, bone, and cartilage.
Preparatory Course: ME 7700 Transport Phenomena in Biological Systems (or equivalent)
Suggested Textbooks: Deen, *Analysis of Transport Phenomena*, 2nd Ed., 2012, Oxford University Press; Fournier, *Basic Transport Phenomena in Biomedical Engineering*, 3rd Ed., 2012, Taylor & Francis.

Biotransport II: Analysis of biothermal and biomolecular processes in cells, tissues, and bioreactors. High- and low-temperature biothermal processes, including heat transfer, phase change, and biological injury mechanisms. Biological mass transfer processes involving chemical reactions coupled with diffusive or advective transport.
Preparatory Course: ME 9010 Bioheat and -Mass Transfer (or equivalent)
Suggested Textbooks: Truskey et al., *Transport Phenomena in Biological Systems*, 2nd Ed., 2009, Pearson.

Biomaterials: Materials for use in medicine and in/on the body, material bulk and surface properties, biological responses to materials, applications, manufacturing processes, cost, sterilization, packaging and regulatory issues.
Preparatory Course: CHE 8586 Biomaterials & Drug Delivery (or equivalent)
Suggested Textbook: Ratner et al., *Biomaterials Science*, 2nd Ed., 2004, Academic Press.

Group B (Select One)

Upstream Bioprocess Engineering: Basics of biochemistry, microbiology, cell biology and molecular biology, as applied to bioproduct formation; enzyme kinetics, immobilized enzymes, diffusion limitations, immobilized enzyme reactors; cell growth kinetics, batch and continuous fermentor operation, bioreactor operation; sterilization, oxygen transfer and scale-up.
Preparatory Course: CHE 8588 Biochemical Engineering I (or equivalent)
Suggested Textbook: Shuler & Kargi, *Bioprocess Engineering: Basic Concepts*, 2nd Ed., 2001, Prentice Hall.

Downstream Bioprocess Engineering: Fed-batch, continuous, immobilized-cell and other advanced bioreactors; bioreactor monitoring and control; design and operation of downstream processes, including cell disruption, filtration, extraction, chromatography; facility design; validation and regulatory issues.
Preparatory Course: CHE 8589 Biochemical Engineering II (or equivalent)
Suggested Textbook: Belter et al., *Bioseparations: Downstream Processing for Biotechnology*, 1st Ed., 1988, Wiley.

CHEMICAL ENGINEERING

MATH QUALIFYING EXAMINATION
June 2015

a) Take ME 7000 and earn a grade of B or higher; OR

b) Take ME 7000 and either
   - ChE 8579 Advanced Process Modeling or
   - ChE 8663 Systems Biology or
   - ChE 8564 Fluid Dyamics

   and earn an average grade of B or higher.

Any PhD candidate who fails to meet these requirements within the equivalent of two years of full-time study is subject to dismissal, but may appeal the decision to the College PhD Committee.

CHEMICAL ENGINEERING

QUALIFYING EXAMINATION
June 2015

****For general information only. Subject to change****

A. PROCEDURE AND FORMAT

- This examination is to last no more than four (4) hours.
- Questions will be at the senior/first year MS level.
- The exam contains 10 questions equally divided amount five subject areas:
    - A. Mass Transport Phenomena
    - B. Momentum & Heat Transport Phenomena
    - C. Thermodynamics
    - D. Reaction Engineering
    - E. Special topic: Systems Biology
- Answer any five of the 10 questions from 4 of the 5 areas in this examination.
- Each problem has the same weight.
- The examination is entirely OPEN book and OPEN notes.

B. TOPICS

1) Mass Transport Phenomena:

- Subtopics:
    - Diffusion and Mass Transfer:
    - Continuous Contacting for Absorption and Stripping
    - Equilibrium Stage Methods for Absorption and Stripping
    - Binary Distillation
    - Multicomponent Distillation
    - Liquid Extraction (as staged contacting)
    - Distillations: Batch, Azeotropic, Extractive, Reactive
- References:
    - Geankopolis, C., *Transport Processes and Unit Operations*, Prentice Hall
    - Wankat, P.C., *Separation Process Engineering*, Prentice Hall
- Preparatory course:
    - CHE 3032: Chemical Engineering Mass Transfer
    - CHE 8571: Separation Process I

2) Momentum & Heat Transport Phenomena:

- Subtopics:
  - FLUIDS
    - Viscosity, Rheological models, Newtonian and non-Newtonian fluids
    - Navier-Stokes Equations
    - Applications of N-S equations – axial flows
    - Applications of N-S equations – curvilinear flows
    - Applications to viscometry – Newtonian and non-Newtonian fluids
    - Laminar flow applications – wire coating die
    - Power Law fluids – turbulent flow in pipes
    - Complex piping systems
  - HEAT TRANSFER
    - Conduction – Fourier's Law
    - Unsteady conduction
    - Forced Convection
    - Natural Convection
    - Condensation and Boiling
    - Thermal design of heat exchangers
    - Effectiveness method for heat exchangers
    - Heat Transfer to non-Newtonian fluids
    - Fins, enhancement
    - Radiation
- References:
    - FLUIDS –
      - J.O. Wilkes, J.O., *Fluid Mechanics for Chemical Engineers*, 2nd ed., Prentice Hall.
      - Bird, Stewart and Lightfoot, *Transport Phenomena*, 2nd ed., Wiley.
      - Others
    - HEAT TRANSFER –
      - Holman, J.P., *Heat Transfer, 9th ed.*, McGraw-Hill.
      - Cengel and Ghajar, *Heat and Mass Transfer*, 4th ed.m McGraw-Hill.
      - Others
- Preparatory courses:
    - ChE 2032 (Undergraduate Fluid Mechanics)
    - ChE 3031 (Undergraduate heat Transfer)
    - ChE 8564 (Graduate Fluids)
    - ChE 8565 (Graduate Heat Transfer)

3) Reaction Engineering:

- Subtopics:
    - Introduction, definition reaction rate, stoichiometry and thermodynamics of reactions. Conversion and extent of reaction, space time. Simple kinetic rate laws, rate laws versus mechanisms. Mass-action kinetics of irreversible reactions, heterogeneous kinetic expressions

- Temperature and pressure effects on rate laws, Arrhenius rate law and an introduction to transition-state theory. Reversible reactions and equilibrium thermodynamic effects on rate laws.
- Ideal Reactor Design: The batch, the continuous stirred tank reactor (CSTR) and ideal plug flow reactor (PFR). Reactor design for a single reaction
- Reactor design for a multiple reactions. Series versus parallel reactions. Design for selectivity
- Temperature and Pressure effects on reactor design, Energy balances for ideal reactors, non-isothermal reactor behavior, CSTR stability
- Reaction kinetics for heterogeneous catalyzed reactions, adsorption and surface reactions
- Fluid-solid catalytic systems: diffusion effects, effectiveness factors and Thiele modulus

· References:
  - Levenspiel, O., *Chemical Reaction Engineering, 3rd E.* (1999) John Wiley and Sons;
  - Fogler, H. S.; *Elements of Chemical Reaction Engineering- Fourth Edition*. (2005) Prentice Hall.
  - Schmidt, L.D.*The Engineering of Chemical Reactions* (2005) Oxford University Press.
  - Roberts, G.; *Chemical Reactions Kinetics and Chemical Reactors* (2002) John Wiley.
  - Davis, M.E. and Davis, R.J. *Fundamentals of chemical reaction engineering.* (2003) McGraw-Hill Higher Education, New York, NY. http://resolver.caltech.edu/CaltechBOOK:2003.001

· Preparatory courses: ChE / Equivalent
  - CHE 3332: Chemical Reaction Engineering I
  - CHE 8850: Chemical Reactor Engineering
  - CHE 8851: Chemical Kinetics and Reaction Engineering

4) Thermodynamics:

· Subtopics:
  - The first and second law for closed and open systems, steady and unsteady state
  - Equations of state, Gibbs Excess models, and partial molar properties
  - Single and multicomponent phase equilibrium, fugacity
  - Phase, energy, and property predictions
  - Reaction equilibrium
  - Partial derivative manipulations and applications

· References:
  - Tester and Modell, *Thermodynamics and Its Applications*, Prentice Hall
  - Smith, Van Ness, and Abbott, *Introduction to Chemical Engineering Thermodynamics*, McGraw-Hill
  - Poling, Prausnitz, and O'Connell, *The Properties of Gases and Liquids*, McGraw-Hill.

· Preparatory course:
  - CHE 2032: Chemical Engineering Thermodynamics I
  - CHE 3131: Chemical Engineering Thermodynamics II
  - CHE 8575: Thermodynamics

5) **An Engineering & Science Special Topic Based on Examinee's Research Area (e.g. Biochemical/Bioprocessing, Energy, Materials, Environmental, Sustainability, Process Control).**
   - Exams of the special topic will be prepared by faculty who are involved in the examinee's research's area program. Details (sub-topics, references, and preparatory course requirement) of special topic will be provided to the examinee separately.

C. REQUIREMENT FOR PASSING THE EXAM

1. A minimum grade of 4 on each problem selected using the 0-10 grading scale shown below; and

2. A minimum of 42 points out 60 points total or 70% overall.

D. GRADING SCALE:

0 - no work
2 - little correct work
4 - some correct work
6 - general approach acceptable but fundamental errors
8 - major concept correct but minor errors
10 - complete and correct

CIVIL AND ENVIRONMENTAL ENGINEERING
Mathematics Requirement
October 2020

Subject to change

CEE Doctoral students must meet one of the following in order to satisfy the Mathematics Qualification Examination requirements:

1. Taking an advanced math course and passing with min grade of B+
   Eligible advanced math courses: ME 7000; EGR 8000; ECE 8001; ECE 8007; BIO 7805; any 7000 or above level course offered by the Mathematics and Statistics Department except Independent Study and Seminar courses, or a course approved by the CEE Graduate Committee.

2. Minimum 80% on the mathematics portion (typically two questions) of discipline specific qualifying exam.

CIVIL AND ENVIRONMENTAL ENGINEERING

ENVIRONMENTAL ENGINEERING QUALIFYING EXAMINATION

Dr. Metin Duran (CEE) and Dr. Wenqing Xu (CEE)

October 2020
****Subject to change****

PROCEDURE AND FORMAT

The Environmental Engineering qualifying examination will be a two-part written examination; a math part and a field specific part. One hour is allowed for the math part while the field specific part will be four hours in duration. To pass, the student must earn at least a 70% on each part of the written exam. The general format of the qualifying will be the following.

- The math part contains two questions and students may choose to answer one out of the two. Students who have met the math requirements by taking a math course at the graduate level (7000 or above) do not need to take the math part of qualifying exam.
- For the math part, students are expected to be able to analyze and interpret data using statistics and solve engineering problems using mathematics (calculus I-III and differential equation).
- The field specific part contains five questions. Student may choose to answer any four questions.
- The field specific examination questions will be at the M.S. level and will be derived from the list of topics listed below.
- Sample problems will be provided (but no solutions).
- Both part of the examination will be open book and open notes. Students are allowed to use calculators, but no other electronic devices are allowed.

TOPICS

Environmental engineering fundamentals: Ideal and non-ideal flows and reactors, reaction kinetics, chemical equilibrium, stoichiometry, acid-base chemistry, oxidation-reduction reactions, elementary organic chemistry, coordination chemistry (complexation), precipitation and dissolution, Henry's law, basic cell biology (metabolism, growth, bioenergetics)

Biological treatment processes: Stoichiometry and kinetics of biological reactions, activated sludge processes, anaerobic processes, fixed-growth systems, nitrification and denitrification processes, Type 4 settling (state-point analysis)

Physical and chemical treatment processes: Advanced oxidation, adsorption, ion exchange, stripping, scrubbing, coagulation and flocculation, filtration, sedimentation, disinfection, emerging technologies

Fate and transport of contaminants: Physical, chemical, and biological processes governing the fate and transport of hazardous contaminants in natural and engineered systems: sorption, volatilization, biodegradation, bioconcentration/bioaccumulation, hydrolysis, photolysis, advection, dispersion and diffusion

REFERENCES

1. AWWA. *Water Quality and Treatment: A Handbook of Community Water Supplies*. 4th or 5th Edition. McGraw-Hill, Inc.
2. Benjamin, M.M. (2014) *Water Chemistry*, Waveland Press.
3. Benjamin, M.M. and Lawler, D.F. (2013) *Water Quality Engineering: Physical/Chemical Treatment Processes*.
4. Brown, L.C. and Paul Berthouex, P.M. (2002) *Statistics for Environmental Engineers*, Taylor & Francis (other editions are acceptable).
5. Harris, D.C. (2010) *Quantitative chemical analysis*. Macmillan.
6. Madigan, M.T., Martinko, J.M. Bender, K.S., Buckley, D.H. and Stahl, D.A. (2014) *Brock Biology of Microorganisms,* Benjamin Cummins.
7. Tchobanoglous, G., Stensel D.H., Tsuchihashi, R., and Burton, F.L. (2014) *Wastewater Engineering: Treatment and Resource Recovery,* McGraw-Hill, Inc., New York.
8. Rittmann, B.E. and McCarty, P.L. (2001) *Environmental Biotechnology: Principles and Applications,* McGraw-Hill, Inc., New York.
9. Snoeyink, V.L. and Jenkins D, (1980) *Water chemistry*, Wiley, New York, NY.

PREPARATORY COURSES

CEE 7011 Introduction to Environmental Engineering Processes
CEE 7511 Microbiology for Environmental Engineers
CEE 7513 Fate and Transport of Contaminants
CEE 7701 Aquatic Chemistry for Environmental Engineers
CEE 8708 Physical/Chemical Treatment Processes
CEE 8708 Biological Treatment Processes

CIVIL AND ENVIRONMENTAL ENGINEERING
STRUCTURAL ENGINEERING
QUALIFYING EXAMINATION

Dr. David W. Dinehart (CEE), Dr. Shawn P. Gross (CEE), Dr. Frank P. Hampton (CEE), Dr. Eric Musselman (CEE), Dr. Joseph R. Yost (CEE)

December 2014

**** Subject to change ****

PROCEDURE AND FORMAT

The discipline-specific Ph.D. qualifying examination in Structural Engineering will be a combination of a written and oral examination. The exam will consist of a 4 hour written examination followed by a 1-2 hour oral examination. The written examination will be held in the morning on the official college Qualifying Examination administration day, and the oral examination will be held either that afternoon or the following academic day. The student must earn at least a 70% on the written portion of the exam and majority of the committee must agree that the student has successfully completed the oral portion of the exam to pass.

The written exam will have the following format:

- The student will be given five questions and must answer any four of the questions
- The examination will be entirely open book/notes
- The level of the examination questions will be at the MSCE level
- Each problem will be derived from one or more of the general topical areas identified below.

TOPICAL AREAS

Structural Mechanics: Equilibrium; Internal Force Analysis; Friction, Sectional Properties; Stress & Strain; Mechanical Properties of Materials (metals, concrete, composites, wood, and masonry); Axial Load, Torsion, Shear, & Flexure; Combined Loadings; Stress & Strain Transformations; Stability

Structural Analysis: Structural Loading; Analysis of Statically Determinate and Indeterminate Trusses, Beams, and Frames by Classical and Approximate Methods; Cables and Arches; Influence Lines; Deflection Analysis; Development of Stiffness Matrices for Trusses, Beams, and Frames; Nonlinear Analysis of Frames; Numerical Solution of Plates

Structural Dynamics: Dynamic Response of Damped and Undamped Single, Multiple Degree-of-Freedom, and Continuous Structural Systems Subjected to Free Vibration; Forced Vibration for Harmonic and Dynamic Loading; Modal Superposition Method; Matrix Structural Analysis Approach to Dynamic Problems

Structural Steel: Analysis and Design of Tension, Compression, and Flexural Members; Torsion; Combined Loading; Simple Bolted & Welded Connections; Composite Design; Elastic and Plastic Analysis of Continuous Beams and Frames

Reinforced Concrete: Analysis and Design of Members Subjected to Flexure and/or Axial Loading; Shear and Torsion; Serviceability; Development of Reinforcement; Slenderness Effects; One-Way and Two-Way Slabs; Structural Walls; Strut-and-Tie Concepts

PREPARATORY COURSES

- All courses in the undergraduate “structural engineering track” (Mechanics I and II [Statics, Mechanics of Solids, and Civil Engineering Materials], Structural Analysis, Structural Steel Design, Reinforced Concrete Design, and Structural Engineering Capstone Design)
- CEE 7412: Modern Structural Analysis
- CEE 8434: Structural Dynamics
- CEE 8435: Reinforced Concrete
- CEE 8436: Structural Steel

CIVIL AND ENVIRONMENTAL ENGINEERING
TRANSPORTATION SYSTEMS
QUALIFYING EXAMINATION

Dr. Seri Park (CEE) and Dr. Leslie McCarthy (CEE)

December 2014
****Subject to change****

PROCEDURE AND FORMAT

The Transportation Systems qualifying examination will be a combination of a written and oral examination lasting 4 hours. The written portion will be administered in the morning for a period not to exceed three hours in duration. The oral portion will be administered on a separate day (either in person or by webconference), within two weeks of the written portion, for a period not to exceed one hour. The student must earn at least a 70% on the written portion of the exam and the majority of the committee must agree that the student has successfully completed the oral portion of the exam in order to pass. The qualifying exam will have the following format:

- The student will be given seven to eight questions.
- The student may choose to answer any five questions.
- The level of the examination will be at the senior or MS level depending upon the student's previous educational experiences.

- Each problem will be derived from the list of topics listed below and takes into consideration the courses completed by the individual students.
- Examination will be entirely open book and open notes.
- The oral portion of the exam will be an open period of questions, different from the written questions, that focus more on conceptual applications rather than detailed problem-solving.

TOPICS

Transportation systems design: Highway and railway alignment and cross-sectional design; design of highway, port, and airfield pavements; railway infrastructure design, life-cycle assessment, context sensitive solutions.

Traffic engineering: Traffic flow model, capacity analysis, traffic control and operation for highway and intersection, and intelligent transportation systems (ITS).

Highway safety: crash analysis techniques, countermeasure development and analysis, before/after analysis, safety performance function (SPF), safety evaluation methods, and work zone traffic control.

Transportation Planning: travel demand model, trip generation rate, gravity model, logit model, dynamic trip assignment, model calibration/validation, and network analysis.

Construction: Quality assurance techniques and testing; transportation project scheduling; transportation project cost estimating, project management techniques; specifications; construction methods for, and inspection of, infrastructure and other transportation elements.

Infrastructure Materials: Fundamentals of material science with applications to infrastructure materials. Composition and properties of asphalt, concrete, masonry, plastics, and wood; durability, fracture, and fatigue; materials design and nondestructive tests.

Research Topical: Additional topics identified by the committee pertaining to the student's intended research can be related to questions in the exam.

PREPARATORY COURSES

CEE 7300 Railway Engineering
CEE 7303 Pavement Design and Analysis
CEE 8202 Transportation Planning and Operations
CEE 8203 Traffic Engineering
CEE 8205 Highway Safety
CEE 8206 Construction Project Management
CEE 8207 Design of Sustainable Transportation Systems
CEE 8439 CEE Materials

CIVIL AND ENVIRONMENTAL ENGINEERING
GEOTECHNICAL ENGINEERING
QUALIFYING EXAMINATION

Dr. Andrea L. Welker and Dr. Kristin Sample-Lord

December 2014

Subject to change

PROCEDURE AND FORMAT

The Geotechnical Engineering qualifying examination will be a combination of a written and oral examination lasting for a period not to exceed four hours in duration (three hours for the written portion and one hour for the oral portion). The written examination will be open book and open notes; while the oral portion must be completed without outside materials. The student must earn at least a 70% on the written portion of the exam and majority of the committee must agree that the student has successfully completed the oral portion of the exam to pass. The written part of the exam will have the following format:

- The student will choose to answer three out of five written questions taken from the topics below. Any single question may not combine more than two topics.
- The oral portion will be an open period of questions.
- The level of the examination will be at the senior or MS level depending upon the student's previous educational experiences.

TOPICS

- Design of shallow and/or deep foundations
- Design of retaining walls
- Transport of fluids through porous media, either saturated or unsaturated
- Consolidation and settlement of soils
- Testing of soils to determine needed properties
- Additional topics identified by the committee pertaining to the student's previous coursework and/or intended research

CIVIL AND ENVIRONMENTAL ENGINEERING
WATER RESOURCES ENGINEERING
QUALIFYING EXAMINATION

Dr. Ronald Chadderton, Dr. Robert Traver,
Dr. Bridget Wadzuk, Dr. John Komlos, Dr. Andrea Welker

Dec 2014
****Subject to change****

PROCEDURE AND FORMAT

The Water Resources Engineering qualifying examination will be a combination of a written and oral examination lasting for a period not to exceed four hours in duration (three hours for the written portion and one hour for the oral portion). The written examination will be held in the morning on the official college Qualifying Examination administration day, and the oral examination will be held either that afternoon or the following academic day. To satisfy the qualifying examination, the candidate needs to pass both the written an oral portions.

Written Examination - The written portion will focus on the candidate's ability "*relate the mathematical techniques and physical principles … and apply these to engineering problems".*

- The student will choose to answer three out of five written questions taken from the topics below.
- The level of the examination will be at the senior or MS level depending upon the student's previous educational experiences.
- The examination will be open book and open notes.
- The student must earn 70% to pass.

Oral Examination - The oral portion will be an open period of questions, **"***to demonstrate the ability to think about problems in a logical and appropriate manner."*

- The oral examination is closed, no outside materials are allowed.
- A pass fail vote will be taken at the conclusion of the session.
- The majority of the committee must agree that the student has successfully completed the oral portion of the exam to pass.

TOPICS

Fluid Mechanics: Fundamentals of fluid mechanics; conservation of mass, momentum, energy; integral or control volume formulations; incompressible, inviscid and viscous flows; Navier-Stokes equations; laminar and turbulent flows.

Hydrology: basics of hydrologic cycle and all components; surface water hydrology; groundwater hydrology; design storms; hydrographs; runoff analysis; routing; storage (reservoir) design and operation.

Hydraulics: basics of open channel and closed channel hydraulics; design of distribution systems; design of control structures; steady and unsteady flow; gradually and rapidly varying flows.

Environmental engineering fundamentals: flows and reactors; reaction kinetics; chemical equilibrium; stoichiometry; acid-base chemistry; oxidation-reduction reactions; elementary organic chemistry; coordination chemistry (complexation); precipitation and dissolution; Henry's law; fate and transport.

Sustainability: water resources planning and management; stormwater management, lake, stream and wetland systems, stream geomorphology, water supply.

Research Topic – An additional topic identified by the committee pertaining to the student's intended research can be added at the discretion of the committee.

PREPARATORY COURSES

Undergraduate senior level electives and first year graduate courses in the Water Resources and Environmental Engineering curriculum will serve as preparatory courses for the qualifying exam.

REFERENCES

Course material from all courses in the undergraduate "water resources engineering track", and graduate courses from the topic areas.

ECE Department's Mathematics Qualification Requirements

a) **Computer Engineering and Cybersecurity**
   i) See discipline specific section.

b) **Electrical Engineering**
   i) Candidates must take ECE 8007, Matrix theory, and pass with a grade of B or better.

   ii) Candidates must take **either** ECE 8001, Engineering Math I **or** ME 7000, Advanced Engineering Analysis as directed by their advisor, and pass with a grade of B or better.

   iii) Candidates must take a qualifying math exam and pass with a grade greater than 70%. The exam will consist of two parts: Candidates should answer any 4 out of 6 questions in Part I which is based on topics in ECE 8001, or ME 7000. Candidates should answer any 2 out of 4 questions in Part II which is based on questions specific to student's area of specialization. The exam is a 4-hour closed book, written exam.

Computer Engineering Ph.D. Qualifying Examination

November 2021

Math Requirement:

Grade of B or better in one of the following courses:

- MAT 7660 Linear Algebra
- CSC 8301 Design & Analysis of Algorithms
- MAT 7770 Number Theory
- MAT 8435 Mathematical Modeling
- MAT 8650 Abstract Algebra

Discipline-Specific Exam:

The computer engineering discipline-specific exam is a written examination for a period not to exceed four hours in duration. The exam has the following format:

- The student is required to answer 8 questions with at least 2 from each of three subject areas out of the dour areas. Some questions may span more than one subject area, for example a programming problem related to computer security or networks.
- The examination is closed book, closed notes, and no calculator or computing devices are permitted. In some cases, reference material may be provided to the student as an appendix to the exam questions.
- Sample problems are generally not provided.
- The examination questions are at the MS level, as represented by the level expected of students who pass the preparatory courses listed below. The list of topics is provided below for each subject area. The examination questions are derived from these lists.

Subject Areas and Topics:

1. **Computer Architecture**
   Components and subsystems used to construct a digital computer and the manner in which those parts interact; instruction sets, central processing units, microprogramming, intersystem communications, interrupts, DMA, and memory hierarchy; operating system demands on hardware.
2. **Computer Security**
   Cryptography, privacy, and authentication including secret and public key cryptography, protocols, key management, hash functions, digital signatures, and secure electronic mail.
3. **Applied Programming**
   C or Java programming including arrays, pointers, strings, structures, dynamic memory allocation, recursion, and list processing. Unix operating system including basic commands, the file system, system calls, and shell scripts.

4. **Computer Networks**

    - Broad Concepts: The layered reference models: ISO OSI and TCP/IP reference model, their functions and relevance, example protocols at each layer; circuit and packet switching; connection-oriented and connectionless service; LANs, MANs, WANs; network performance in terms of latency, bandwidth, throughput and utilization and their calculation; the delay-bandwidth product.
    - Signal Transmission: wired and wireless transmission media - twisted pair, coax, single and multi-mode fiber, RF, satellites; communication frequency spectrum; baseband and AC signaling; modulation concepts - ASK, FSK, PSK; Nyquist's and Shanon's theorems and data rate computation; bit encoding schemes - NRZ, NRZI, Manchester, and 4B/5B.
    - Channel Access and Error Control: Fragmentation, Framing using character counts, byte and bit flags with associated stuffing; error detection - parities, checksums, CRC; ARQ, stop-and-wait, sliding windows; the MAC sublayer in TCP/IP - Ethernet, hubs and learning bridges, spanning tree protocol, CSMA/CD; IEEE 802.11 protocols, CSMA/CA and the hidden and exposed terminal problems.
    - Routing: Routing tables for datagrams and virtual circuits, source routing, switching/routing architectures - workstations, cross-bars and self-routing (Batcher-Banyan) fabrics; IPv4 addressing and subnetting; ARP and DHCP; VPNs and tunneling; Intra-domain routing - DV and OSPF; Interdomain routing - BGP.
    - Transport: TCP state diagram, timers and handshakes for connection setup/teardown; TCP congestion control, optimizations, wireless TCP
    - Other Concepts: DNS, Portmapping, NAT and Firewalls, QoS - RSVP and Diff-Serv models; traffic shaping and policing - leaky buckets, token buckets and combinations thereof.
    - Introduction to Queuing Theory: Markovian system models; the M/M/1/infty, M/M/1/N, M/M/m/infty and M/M/m/N queuing systems (both state-independent and statedependent); global and local balance; system stability condition and computation of steady state probabilities; performance analysis - queue occupancy, utilization, throughput, response time and idleness; Little's law; Pollaczek-Khinchin mean value formula for M/G/1/infty systems.

Preparatory Courses

- ECE 8405 - Computer Organization & Design
- ECE 8476 - Cryptography & Network Security
- ECE 8473 - Unix and C Programming
- ECE 7428 - Computer Communication Networks

References

- Textbooks from the preparatory courses
- Notes on network performance analysis from Dr. Sarvesh Kulkarni.

Electrical and Computer Engineering

Computing Systems/Network Fundamentals Qualifying Examination

ECE Computer Engineering Professional Group
(Char, Gupta, Kresch, Kulkarni, Perry, Wang)

Drafted: 4 May 2011

Procedure and Format

The Computing Systems/Network Fundamentals examination will be a written examination for a period not to exceed four hours in duration. It will have the following format:

- The student will be required to answer 8 questions with at least 2 from each of 3 subject areas. Some questions may span more than one subject area, for example a programming problem related to computer security or networks.
- The examination will be closed book, closed notes. In some cases, reference material may be provided to the student as an appendix to the exam questions.
- Sample problems will generally not be provided.
- The examination questions will be at the Senior/M.S. level, as represented by the level expected of students who pass the preparatory courses listed below. The list of topics is provided below for each subject area. The examination questions will be derived from these lists.

Subject Areas and Topics

Applied Programming and Numerical Methods: C or Java programming [1] including arrays, pointers, strings, bitwise operators, structures, dynamic memory allocation, recursion, and list processing. Unix operating system [2] including basic commands, the file system, system calls, and shell scripts.

Computer Security: Cryptography, privacy, and authentication [3] including secret and public key cryptography, protocols, key management, hash functions, digital signatures, and secure electronic mail.

Computer Networks:

- **Broad Concepts**: The layered reference models: ISO OSI and TCP/IP reference model, their functions and relevance, example protocols at each layer; circuit and packet switching; connection-oriented and connectionless service; LANs, MANs, WANs; network performance in terms of latency, bandwidth, throughput and utilization and their calculation; the delay-bandwidth product.
- **Signal Transmission**: wired and wireless transmission media - twisted pair, coax, single and multi-mode fiber, RF, satellites; communication frequency spectrum; baseband and AC signaling; modulation concepts - ASK, FSK, PSK; Nyquist's and Shanon's theorems and data rate computation; bit encoding schemes - NRZ, NRZI, Manchester, and 4B/5B.
- **Channel Access and Error Control**: Fragmentation, Framing using character counts, byte and bit flags with associated stuffing; error detection - parities, checksums, CRC; ARQ, stop-and-wait, sliding

windows; the MAC sublayer in TCP/IP - Ethernet, hubs and learning bridges, spanning tree protocol, CSMA/CD; IEEE 802.11 protocols, CSMA/CA and the hidden and exposed terminal problems.

- **Routing**: Routing tables for datagrams and virtual circuits, source routing, switching/routing architectures - workstations, cross-bars and self-routing (Batcher-Banyan) fabrics; IPv4 addressing and subnetting; ARP and DHCP; VPNs and tunneling; Intra-domain routing - DV and OSPF; Interdomain routing - BGP.
- **Transport**: TCP state diagram, timers and handshakes for connection setup/teardown; TCP congestion control, optimizations, wireless TCP
- **Other Concepts**: DNS, Portmapping, NAT and Firewalls, QoS - RSVP and DiffServ models; traffic shaping and policing - leaky buckets, token buckets and combinations thereof.
- **Introduction to Queuing Theory**: Markovian system models; the M/M/1/infty, M/M/1/N, M/M/m/infty and M/M/m/N queuing systems (both state-independent and state-dependent); global and local balance; system stability condition and computation of steady state probabilities; performance analysis - queue occupancy, utilization, throughput, response time and idleness; Little's law; Pollaczek-Khinchin mean value formula for M/G/1/infty systems.

Communications:

Computer Architecture:

Machine Learning and AI:

References

1. A Book on C, 4th edition, by Al Kelley and Ira Pohl, Benjamin/Cummings, 1998.
2. Unix Shell Programming, 3rd Edition, by Stephen Kochan and Patrick Wood, Sams Publishing, 2003.
3. Cryptography and Network Security: Principles and Practice, Fourth Edition, by William Stallings, Prentice Hall, 2006.
4. Computer Networks (4th Ed), by Andrew S. Tanenbaum, Prentice Hall, NJ, ISBN: 0-13-066102-3
5. Computer Networks and Systems - Queuing theory and performance evaluation (3rd Ed), by Thomas G. Robertazzi, Springer.

Preparatory Courses

ECE 4470 - Computer Networks
ECE 7428 - Computer Communication Networks
ECE 8473 - Operating Systems & Programming
ECE 8476 - Computer Communication Security

Cybersecurity Ph.D. Qualifying Examination

November 2021

Math Requirement:

Grade of B or better in one of the following courses:

- MAT 7660 Linear Algebra
- CSC 8301 Design & Analysis of Algorithms
- MAT 7770 Number Theory
- MAT 8435 Mathematical Modeling
- MAT 8650 Abstract Algebra

Discipline-Specific Exam:

The cybersecurity discipline specific exam is a written examination for a period not to exceed four hours in duration. The exam has the following format:

- The student is required to answer 8 questions: 4 from the cybersecurity area, and 4 from the other areas. Some questions may span more than one subject area, for example a programming problem related to computer security or networks.
- The examination is closed book, closed notes, and no calculator or computing devices are permitted. In some cases, reference material may be provided to the student as an appendix to the exam questions.
- Sample problems are generally not provided.
- The examination questions are at the MS level, as represented by the level expected of students who pass the preparatory courses listed below. The list of topics is provided below for each subject area. The examination questions are derived from these lists.

Subject Areas and Topics:

1. **Cybersecurity**
   Cryptography, privacy, and authentication including secret and public key cryptography, protocols, key management, hash functions, digital signatures, and secure electronic mail. Malware and cyber threats: computer network defense; software for data protection and privacy, security information and event management, governance, risk and compliance; trusted computer systems and secure applications; identity and access management including biometrics; next generation security concepts.
2. **Applied Programming**
   C or Java programming including arrays, pointers, strings, structures, dynamic memory allocation, recursion, and list processing. Unix operating system including basic commands, the file system, system calls, and shell scripts.

3. **Cryptographic Engineering**
Software and hardware Implementation techniques and skills for both pre- and post-quantum cryptosystems. Fast implementation-oriented algorithmic and architectural innovations for cryptographic systems, including emerging computer arithmetic techniques, algorithm-to-architecture co-design, and hardware-software co-design. Side-channel attacks to post-quantum cryptographic implementations and related countermeasures such as masking.
4. **Computer Networks**
   - Broad Concepts: The layered reference models: ISO OSI and TCP/IP reference model, their functions and relevance, example protocols at each layer; circuit and packet switching; connection-oriented and connectionless service; LANs, MANs, WANs; network performance in terms of latency, bandwidth, throughput and utilization and their calculation; the delay-bandwidth product.
   - Signal Transmission: wired and wireless transmission media - twisted pair, coax, single and multi-mode fiber, RF, satellites; communication frequency spectrum; baseband and AC signaling; modulation concepts - ASK, FSK, PSK; Nyquist's and Shanon's theorems and data rate computation; bit encoding schemes - NRZ, NRZI, Manchester, and 4B/5B.
   - Channel Access and Error Control: Fragmentation, Framing using character counts, byte and bit flags with associated stuffing; error detection - parities, checksums, CRC; ARQ, stop-and-wait, sliding windows; the MAC sublayer in TCP/IP - Ethernet, hubs and learning bridges, spanning tree protocol, CSMA/CD; IEEE 802.11 protocols, CSMA/CA and the hidden and exposed terminal problems.
   - Routing: Routing tables for datagrams and virtual circuits, source routing, switching/routing architectures - workstations, cross-bars and self-routing (Batcher-Banyan) fabrics; IPv4 addressing and subnetting; ARP and DHCP; VPNs and tunneling; Intra-domain routing - DV and OSPF; Interdomain routing - BGP.
   - Transport: TCP state diagram, timers and handshakes for connection setup/teardown; TCP congestion control, optimizations, wireless TCP
   - Other Concepts: DNS, Portmapping, NAT and Firewalls, QoS - RSVP and Diff-Serv models; traffic shaping and policing - leaky buckets, token buckets and combinations thereof.
   - Introduction to Queuing Theory: Markovian system models; the M/M/1/infty, M/M/1/N, M/M/m/infty and M/M/m/N queuing systems (both state-independent and statedependent); global and local balance; system stability condition and computation of steady state probabilities; performance analysis - queue occupancy, utilization, throughput, response time and idleness; Little's law; Pollaczek-Khinchin mean value formula for M/G/1/infty systems.

Preparatory Courses

- ECE 8476 - Cryptography & Network Security
- ECE 8484 - Cybersecurity Threats and Defense
- ECE 8473 - Unix and C Programming

- ECE 7428 - Computer Communication Networks

References

- Textbooks from the preparatory courses
- Notes on network performance analysis from Dr. Sarvesh Kulkarni.

ELECTRICAL AND COMPUTER ENGINEERING

ANTENNAS, MICROWAVES and RF CIRCUIT DESIGN QUALIFYING EXAMINATION

Dr. Moeness Amin (ECE), Dr. Robert Caverly (ECE)
Dr. Ahmad Hoorfar (ECE)

****For general information only. Subject to change*****

PROCEDURE AND FORMAT

The Antennas, EM Fields, Microwaves, and RF Circuit Design examination will be a written examination lasting for a period not to exceed four hours in duration. The exam may consist of two periods, separated by a lunch break, or a single four hour period. It will have the following format.

- The student will be given 5 to 9 questions, and will be given the choice to answer 3 to 6 of these questions.
- The examining committee will inform the students taking the exam whether the examination will be entirely open book, or entirely closed book, at least four weeks before the examination date.
- The level of the examination questions will be at the Senior / M.S. level, as represented by the level expected of students who pass the preparatory courses listed below
- Each problem will be derived from the list of topics listed
- Sample problems will be provided (but no solutions).

TOPICS

Antenna Theory: Topics will include those covered in the Antenna Theory 1 with emphasis on:

- Antenna fundamentals (gain, directivity, polarization, efficiency, Friis equation, etc)
- Formulation of radiating structures using auxiliary potentials
- Dipole, wire and loop antennas
- Antennas above ground
- Antenna arrays and antenna synthesis
- Input impedance and mutual coupling effects

References:

- Chapters 2 through 7 of <u>Antenna Theory</u> by Balanis.

Electromagnetic Field theory: Topics will include:

- Maxwell's equations, boundary conditions, EM power and energy, wave polarization
- Basics of electrostatics and magnetostatics
- Wave equation, Green's functions
- Wave propagation in isotropic, lossy and anisotropic media
- Reflection and transmission at dielectric interface
- Metallic and dielectric waveguides and cavity resonators

References:

- *These are at the senior/first year graduate level.*

Microwave Theory and Technique, and RF Circuit Design: Topics will include:

- Transmission line theory
- Metallic and dielectric waveguides, cavity resonators
- Microwave network analysis/scattering matrix
- Design of planar transmission lines (stripline, microstrip, coplanar)
- Matching - narrow and wide band
- Filter design - band pass, band notch, low pass, high pass (lumped element, transmission line, transmission line resonator)
- Narrowband amplifier matching using S-parameters - matching, stability, gain

References:

- *These are at the senior/first year graduate level*
- Chapters 2 –6, 8 and 11 of <u>Microwave Engineering</u> by Pozar

PREPARATORY COURSES

ELECTRICAL AND COMPUTER ENGINEERING

COMMUNICATIONS AND SIGNAL PROCESSING
QUALIFYING EXAMINATION

Dr. Moeness Amin (ECE), Dr. Bijan Mobasseri (ECE), Dr. Yimin Zhang (ECE)

****For general information only. Subject to change****
January 2015

PROCEDURE AND FORMAT

The discipline-specific Ph.D. qualifying examination on Communications and Signal Processing will be a written examination lasting for a period not to exceed four hours in duration. The exam may consist of two periods, separated by a lunch break, or a single four hour period. It will have the following format.

- The student will be given 8 questions, and will be given the choice to answer 6 of these questions.
- The examination will be entirely open book.
- The level of the examination questions will be at the Senior / first-tier M.S. level.
- Each problem will be derived from the list of topics listed.
- Sample problems will be provided (but no solutions).

Communications

Topics will include those covered in the Communication System Engineering with emphasis on:

- Matched Filtering
- Power Spectra of Line Codes
- Digital Modulations (BPSK, QPSK, FSK, QAM), Bandwidth, and Probability of Error Analysis
- Inter-Symbol Interference and Pulse Shaping
- Coherent and Noncoherent Detections

References:
- Communication System, 4th Edition (by Haykin).

Signal Processing

Topics will include those covered in the Digital Signal Processing with emphasis on:

- z-Transform
- Sampling of Continuous-Time Signals
- Quantizations
- Discrete Fourier Series and Discrete Fourier Transform
- Frequency Analyses
- Linear Time-invariant Systems
- Digital Filter Design

References:

- Discrete-Time Signal Processing, 2nd Edition (by Oppenheim et. al).

PREPARATORY COURSES

- ECE-8700 Communication System Engineering
- ECE-8231 Digital Signal Processing

ELECTRICAL AND COMPUTER ENGINEERING

ENERGY SYSTEMS
QUALIFYING EXAMINATION

Dr. Frank Mercede (ECE), Dr. Pridpal Singh (ECE)

****For general information only. Subject to change*****

PROCEDURE AND FORMAT

The discipline-specific Ph.D. qualifying examination on Energy Systems will be a written examination lasting for a period not to exceed four hours in duration. The format of the examination will be as follows:

- The examination will contain a total of fifteen (15) questions equally divided among the five subject areas of Control Systems, Power Systems, Renewable Energy Systems, Electric Machines, and Power Electronics. The examinee will be required to answer six (6) of these questions from at least three (3) of the subject areas.
- The examination will be entirely open book.
- The examination questions will be at the senior undergraduate / first-tier graduate masters levels.
- A list of topics is provided below for each subject area. The examination questions will be derived from these lists.
- Sample questions will not be provided.

Control Systems

Control Systems Topics:

The topics that may be covered by the Control Systems examination questions include:
- Mathematical Modeling of Physical Systems
- Transfer Functions, Block Diagrams, and Signal Flow Graphs
- State Space Representation and Analysis
- Time-domain Specifications and Analysis
- Frequency-domain Methods of Analysis
- Root Locus Compensation
- Cascade Compensation in the Frequency Domain
- State Variable Feedback

Typical Control Systems Reference:

A typical reference in Control Systems at the undergraduate senior / first-tier graduate masters levels is the second edition of *Linear Control System Analysis & Design - Conventional and Modern* by John J. D'Azzo and Constantine H. Houpis. (The later edition of this reference is not as comprehensive as the second edition.) Certainly, there are numerous other comparable texts on this subject.

Power Systems

Power Systems Topics:

The topics that may be covered by the Power Systems examination questions include:

- Complex Power
- Per-unit Normalization
- Per-unit Analysis of Symmetrical Three-phase Systems
- Power Transformer Modeling and Analysis
- Static Power Capability Limits of Short Transmission Line
- Power Flow Control
- Power Flow Analysis
- Symmetrical Components
- Sequence Network Representations of Power System Components
- Analysis of Unbalanced Faults

Typical Power Systems Reference:

A typical reference in Power Systems at the undergraduate senior / first-tier graduate masters levels is *Electric Energy Systems Theory - An Introduction* by Olle I. Elgerd. Certainly, there are numerous other comparable texts on this subject.

Renewable Energy Systems

Renewable Energy Systems Topics:
The topics that may be covered by the Renewable Energy Systems examination questions include:

- Power in the Wind
- Wind Turbine Generators
- Wind Turbine Performance Calculations
- The Solar Resource
- Characteristics of Photovoltaic Modules
- Grid-Connected Photovoltaic System Design
- Stand-Alone Photovoltaic System Design
- Fuel Cells
- Batteries
- Renewable Energy Economics

Good Renewable Energy Systems Reference:

Renewable and Efficient Electric Power Systems by Gilbert M. Masters.

Electric Machines

Electric Machines Topics:

The topics that may be covered by the Electric Machines examination questions include:

- Magnetic Circuits and Magnetic Materials
- Transformers
- Electromechanical Energy Conversion Principles
- Synchronous Machines
- Polyphase Induction Machines
- DC Machines
- Speed and Torque Control of Electric Machines

Typical Electric Machines Reference:

A typical reference in Electric Machines at the undergraduate senior / first-tier graduate masters levels is *Electric Machinery* by A.E. Fitzgerald and Charles Kingsley, Jr. Certainly, there are numerous other comparable texts on this subject.

Power Electronics

Power Electronics Topics:

The topics that may be covered by the Power Electronics examination questions include:

- Power Semiconductor Devices
- Line-frequency Diode Rectifiers
- Line-frequency Phase-controlled Rectifiers and Inverters
- dc-dc Switch-mode Converters
- Switch-mode dc-ac Inverters
- Resonant Converters

Typical Power Electronics Reference:

A typical reference in Power Electronics at the undergraduate senior / first-tier graduate masters levels is *Power Electronics: Converters, Applications, and Design* by Ned Mohan, Tore M. Undeland, and William P. Robbins. Certainly, there are numerous other comparable texts on this subject.

Preparatory Courses

The following courses or their equivalents are necessary to prepare for this examination.

ECE 7800 – Renewable Energy Systems
ECE 8320 - Control Systems Engineering
ECE 8580 - Power Electronics
ECE 8800 - Electric Machines
ECE 8810 - Power System Modeling

V I L L A N O V A   U N I V E R S I T Y

Mechanical Engineering Department

Ph.D. Math Requirement

November 2022

Ph.D. students in Mechanical Engineering must meet one of the following in order to satisfy the ME Ph.D. Math Requirement.

1. Take ME 7000 (Advanced Engineering Analysis) and pass the course with a minimum grade of B. ME 7000 is usually offered in the Fall semester of the academic year.

OR

2. Take the ME Ph.D. Math Qualifying Exam and pass it according to the criteria defined below in the section titled ‘ME Ph.D. Math Qualifying Exam Guidelines’.

NOTE: ME Ph.D. students who take ME 7000 to satisfy the Ph.D. math requirement need to score a grade of B or better. A student who is unable to obtain a grade of B or better in ME 7000 can be given a second opportunity to satisfy the ME Ph.D. Math Requirement through the ME Ph.D. Math Qualifying Exam.

ME Ph.D. Math Qualifying Exam Guidelines

- This exam is usually held twice yearly, once in spring and once in fall.
- It is a test of proficiency in engineering math at both the undergraduate and graduate level.
- There are two parts, A and B, to the exam. Part A is a test of undergraduate engineering math while part B is devoted to graduate level engineering math topics. The topic areas for each part are defined in the SYLLABUS section.
- Each part will be comprised of FIVE problems. Examinees are required to solve THREE of FIVE problems in each part.
- To pass the qualifying exam, students will need to obtain a minimum of 70% in part A and a minimum of 70% in part B.
- Reference textbook titles are provided in the REFERENCES section.
- Sample problems are provided in the SAMPLE PROBLEMS section.
- The time duration of the exam is FOUR hours.
- The entire exam is closed book.
- The use of calculators is not permitted.
- The formulae pages provided in the exam may be used to solve the problems. These formulae are provided in the FORMULAE section.
- Questions related to the exam can be directed to the faculty on the ME PhD Math QE committee (see last page for faculty).

SYLLABUS

Topic areas for the Mechanical Engineering Ph.D. Math Qualifying Exam are:

- Part A
  - Linear Algebra (Vectors in Euclidian space, Linear independence of vectors, Matrix rank and its properties, Determinants, Eigenvalues and eigenvectors)
  - Ordinary Differential Equations (Linear first and second order ODEs; Variation of parameters; simultaneous ODEs; nonlinear first-order ODEs)
  - Fourier Series (Sine and Cosine series; Complete Fourier Series)
  - Laplace Transforms (Using Laplace transforms to solve ODEs)
  - Multivariable Calculus (Parametric equations; polar, cylindrical, and spherical coordinates; vectors and the geometry of space; vector functions (derivatives, integrals, curvature, etc.); partial derivatives; multiple integration and its applications)
  - Vector Calculus (Line Integrals, Surface integrals, volume integrals, Gauss Divergence theorem, Stokes' theorem, Green's theorems)

- Part B
  - Linear Algebra (Matrix transformations, Matrix decompositions, Sign definite matrices and their properties, Various problems on proving matrix properties, Engineering applications of linear algebra)
  - Series Solutions for ODEs (Power series solutions, Singular points, Method of Frobenius)
  - Homogeneous Boundary Value Problems (Sturm-Liouville problems, Characteristic values and functions, Orthogonality)
  - Bessel and Legendre Functions (Bessel's Equation, Bessel functions, Differential equations reducible to Bessel's equation, Fourier-Bessel Series, Legendre's Equation, Legendre series and polynomials)
  - Partial Differential Equations (Separation of variables, Laplace's equation, Heat flow equation, Wave equation, Applications to engineering problems)

REFERENCES

- Hildebrand, F. B., Advanced Calculus for Applications, Prentice Hall, 1976.
- Kreyszig, E., Advanced Engineering Mathematics, Wiley, 2011.
- Noble, B., and Daniel, J.W., Applied Linear Algebra, Prentice Hall, 1988.
- Strang, G., Linear Algebra and its Applications, Harcourt-Brace-Jovanovich, 2009.
- O'Neil, P.V., Advanced Engineering Mathematics, PWS-Kent Publishing, 1995.
- Stewart, Calculus, Early Transcendentals, 7th Edition, Cengage, 2012.
- Edwards and Penney, Differential Equations and Linear Algebra, 3rd Edition, Prentice Hall, 2009.

SAMPLE PROBLEMS

(Note: These are not in any particular order, nor are they classified as Part A or Part B problems. Solutions are not being provided. Students are urged to solve these problems by themselves before approaching the ME Math QE committee faculty for assistance.)

1. Obtain the general solution to the following ordinary differential equation

$$\frac{dy}{dx} + xy = e^{\left(\frac{x^2}{2}\right)} y^2$$

2. A complex valued matrix $A \in \mathbb{C}^{n\times n}$ is called *positive definite* $(A > 0)$ if

$$\begin{aligned} A^* &= A, \\ x^* A x &> 0, \quad x \in \mathbb{C}^n, \quad x \neq 0, \end{aligned}$$

   where A^* and x^* are complex conjugate transposes of A and x, respectively. Show that if $A > 0$, then

   - All eigenvalues of A are real,
   - All eigenvalues of A are positive.

3. Derive the Fourier series expansion for

$$f(t) = \begin{cases} 0 & -\pi < t < 0 \\ \sin t & 0 < t < \pi \end{cases}$$

4. Use the Laplace transform method to solve for $y(t)$ given the following simultaneous ordinary differential equations if $y(0) = 1$ and $z(0) = -1$

$$\begin{aligned} \frac{dy}{dt} + 2y + 6\int_0^t z\,dt &= -2u(t) \\ \frac{dy}{dt} + \frac{dz}{dt} + z &= 0 \end{aligned}$$

   Here $u(t)$ is the unit step function.

5. Obtain a power series solution for the following ODE, valid near x=0.

$$x^2 \frac{d^2y}{dx^2} + 6x\frac{dy}{dx} + (x^2 + 6)y = 0$$

6. Consider the homogeneous boundary value (Sturm-Liouville) problem.

$$\frac{d^2y}{dx^2} + \lambda y = 0, \quad \text{with boundary conditions} \quad \frac{dy}{dx} = 0 \ \text{ at } \ x = 0, \quad \frac{dy}{dx} = 0 \ \text{ at } \ x = \pi$$

   (a) Obtain the characteristic functions for the problem.

   (b) Expand the function $f(x) = 1$ as a series of the characteristic functions.

7. Determine the value of the surface integral of the vector function F.

$$F = xy\hat{i} + xz\hat{j} + (1 - z - yz)\hat{k}$$

   The surface S is the closed surface composed of the portion of the paraboloid $z = 1 - x^2 - y^2$ for which $z \geq 0$ and the circular disk $x^2 + y^2 \leq 1$, $z = 0$. (The surface integral of the vector function F is the integral $\int_S F \cdot \hat{n}\, dS$ where $\hat{n}$ is the unit normal to the surface S.)

8. Assume a thin pole (the cross section area is infinitely small) has a length of L. The two ends of this pole are located at $x = 0$ and $x = L$, along the x axis. The lateral surface of this pole is perfectly insulated from heat transfer. At $x = 0$, the temperature is zero, $T(x = 0) = 0$. At the other end, $x = L$, the heat exchanges with the air through natural convection (the heat transfer coefficient is h). The air temperature is 10. The initial temperature distribution of the pole, at time $t = 0$, is $\varphi(x)$. The governing partial differential equation for heat transfer in the pole is:

$$\frac{\partial T}{\partial t} = a\frac{\partial^2 T}{\partial x^2}, \qquad 0 < x < L, \qquad 0 < t$$

   where a is the thermal diffusivity of the pole material. The boundary condition at $x = L$ can be expressed as:

$$k\frac{\partial T}{\partial x}_{(x=L,t)} = -h(T_{(x=L,t)} - 10)$$

   where k is the thermal conductivity of the pole material.

   (a) Obtain an expression for the temperature distribution of this pole as a function of time (t) and position (x).

   (b) What kind of initial condition will result in only one exact solution?

9. A circular thin plate has a radius of 1. The thickness of the plate is infinitely small and its top and bottom surfaces are insulated. Its perimeter temperature is 10 ($T(r = 1) = 10$). Initially, the temperature distribution of the plate is $T(r, t = 0) = 1 - r^2$. The governing partial differential equation for heat transfer in the plate is:

$$\frac{\partial T}{\partial t} = a\{\frac{\partial^2 T}{\partial r^2} + \frac{1}{r}\frac{\partial T}{\partial r}\}$$

where a is the thermal diffusivity of the plate material.

(a) Determine the temperature distribution in the plate as a function of time (t) and radial location (r).

(b) What kind of initial condition will result in only one exact solution?

(Note: Your solution will involve Bessel functions.)

FORMULAE

Elementary Trigonometry:

$$\sin(\theta_1 \pm \theta_2) = \sin\theta_1 \cos\theta_2 \pm \cos\theta_1 \sin\theta_2$$

$$\cos(\theta_1 \pm \theta_2) = \cos\theta_1 \cos\theta_2 \mp \sin\theta_1 \sin\theta_2$$

$$\sin(-a) = -\sin(a)$$

$$\cos(-a) = +\cos(a)$$

Integrations:

$$\int x\cos(ax)\,dx = \frac{1}{a^2}\cos(ax) + \frac{x}{a}\sin(ax)$$

$$\int x\sin(ax)\,dx = \frac{1}{a^2}\sin(ax) - \frac{x}{a}\cos(ax)$$

$$\int x^2\cos(ax)\,dx = \frac{2x}{a^2}\cos(ax) + \frac{a^2x^2 - 2}{a^3}\sin(ax)$$

$$\int x^2\sin(ax)\,dx = \frac{2x}{a^2}\sin(ax) - \frac{a^2x^2 - 2}{a^3}\cos(ax)$$

$$\int \sin^2(ax)\,dx = \frac{x}{2} - \frac{\cos(ax)\sin(ax)}{2a}$$

$$\int \cos^2(ax)\,dx = \frac{x}{2} + \frac{\cos(ax)\sin(ax)}{2a}$$

Euler's formula:

$$e^{i\theta} = \cos\theta + i\sin\theta$$

Divergence theorem:

$$\iint_S \mathbf{F}\cdot\hat{n}\,dS = \iiint_V \nabla\cdot\mathbf{F}\,dV,$$

where $\hat{n}$ is normal to S which bounds the volume V.

Bessel functions:

$$J_{n+1}(z) = \frac{2n}{z} J_n(z) - J_{n-1}(z)$$

$$\frac{d}{dz}\left[J_n(z)\right] = J_{n-1}(z) - \frac{n}{z} J_n(z)$$

$$\frac{d}{dz}\left[z^n J_n(z)\right] = z^n J_{n-1}(z)$$

$$\frac{d}{dz}\left[z^{-n} J_n(z)\right] = -z^{-n} J_{n+1}(z)$$

Hankel functions:

$$H_p^{(1)}(x) = J_p(x) + iY_p(x)$$

$$H_p^{(2)}(x) = J_p(x) - iY_p(x)$$

Solution in terms of Bessel Function:

The solution to

$$x^2 y'' + x(a + 2bx^r) y' + \left[c + dx^{2s} - b(1 - a - r)x^r + b^2 x^{2r}\right] y = 0$$

is

$$y = x^{\frac{1-a}{2}} e^{-\frac{bx^r}{r}} Z_p\left(\frac{\sqrt{d}}{s} x^s\right)$$

where,

$$p = \frac{1}{s}\sqrt{\left(\frac{1 - a}{2}\right)^2 - c}$$

and, Z_p consists of J_p and J_{-p} (or J_p and Y_p) if $\sqrt{d}/s$ is real, and I_p and I_{-p} (or I_p and K_p) otherwise. Recall that if p is zero or a positive integer, the latter situation applies in each case.

Table of Laplace Transforms

	$f(t)=\mathfrak{L}^{-1}\{F(s)\}$	$F(s)=\mathfrak{L}\{f(t)\}$		$f(t)=\mathfrak{L}^{-1}\{F(s)\}$	$F(s)=\mathfrak{L}\{f(t)\}$
1.	1	$\frac{1}{s}$	2.	$\mathbf{e}^{at}$	$\frac{1}{s-a}$
3.	$t^n,\quad n=1,2,3,\ldots$	$\frac{n!}{s^{n+1}}$	4.	$t^p,\ p>-1$	$\frac{\Gamma(p+1)}{s^{p+1}}$
5.	$\sqrt{t}$	$\frac{\sqrt{\pi}}{2s^{\frac{3}{2}}}$	6.	$t^{n-\frac{1}{2}},\quad n=1,2,3,\ldots$	$\frac{1\cdot 3\cdot 5\cdots(2n-1)\sqrt{\pi}}{2^n s^{n+\frac{1}{2}}}$
7.	$\sin(at)$	$\frac{a}{s^2+a^2}$	8.	$\cos(at)$	$\frac{s}{s^2+a^2}$
9.	$t\sin(at)$	$\frac{2as}{(s^2+a^2)^2}$	10.	$t\cos(at)$	$\frac{s^2-a^2}{(s^2+a^2)^2}$
11.	$\sin(at)-at\cos(at)$	$\frac{2a^3}{(s^2+a^2)^2}$	12.	$\sin(at)+at\cos(at)$	$\frac{2as^2}{(s^2+a^2)^2}$
13.	$\cos(at)-at\sin(at)$	$\frac{s(s^2-a^2)}{(s^2+a^2)^2}$	14.	$\cos(at)+at\sin(at)$	$\frac{s(s^2+3a^2)}{(s^2+a^2)^2}$
15.	$\sin(at+b)$	$\frac{s\sin(b)+a\cos(b)}{s^2+a^2}$	16.	$\cos(at+b)$	$\frac{s\cos(b)-a\sin(b)}{s^2+a^2}$
17.	$\sinh(at)$	$\frac{a}{s^2-a^2}$	18.	$\cosh(at)$	$\frac{s}{s^2-a^2}$
19.	$\mathbf{e}^{at}\sin(bt)$	$\frac{b}{(s-a)^2+b^2}$	20.	$\mathbf{e}^{at}\cos(bt)$	$\frac{s-a}{(s-a)^2+b^2}$
21.	$\mathbf{e}^{at}\sinh(bt)$	$\frac{b}{(s-a)^2-b^2}$	22.	$\mathbf{e}^{at}\cosh(bt)$	$\frac{s-a}{(s-a)^2-b^2}$
23.	$t^n\mathbf{e}^{at},\quad n=1,2,3,\ldots$	$\frac{n!}{(s-a)^{n+1}}$	24.	$f(ct)$	$\frac{1}{c}F\left(\frac{s}{c}\right)$
25.	$u_c(t)=u(t-c)$ Heaviside Function	$\frac{\mathbf{e}^{-cs}}{s}$	26.	$\delta(t-c)$ Dirac Delta Function	$\mathbf{e}^{-cs}$
27.	$u_c(t)f(t-c)$	$\mathbf{e}^{-cs}F(s)$	28.	$u_c(t)g(t)$	$\mathbf{e}^{-cs}\mathfrak{L}\{g(t+c)\}$
29.	$\mathbf{e}^{ct}f(t)$	$F(s-c)$	30.	$t^n f(t),\quad n=1,2,3,\ldots$	$(-1)^n F^{(n)}(s)$
31.	$\frac{1}{t}f(t)$	$\int_s^\infty F(u)\,du$	32.	$\int_0^t f(v)\,dv$	$\frac{F(s)}{s}$
33.	$\int_0^t f(t-\tau)g(\tau)\,d\tau$	$F(s)G(s)$	34.	$f(t+T)=f(t)$	$\frac{\int_0^T \mathbf{e}^{-st}f(t)\,dt}{1-\mathbf{e}^{-sT}}$
35.	$f'(t)$	$sF(s)-f(0)$	36.	$f''(t)$	$s^2F(s)-sf(0)-f'(0)$

37. $f^{(n)}(t)$ $\qquad s^nF(s)-s^{n-1}f(0)-s^{n-2}f'(0)\cdots-sf^{(n-2)}(0)-f^{(n-1)}(0)$

ME PhD Math QE Examination Committee

- Hashem Ashrafiuon
- Sergey Nersesov
- Sridhar Santhanam

COLLLEGE OF ENGINEERING
CONTROL SYSTEMS QUALIFYING EXAMINATION

H. Ashrafiuon, G. Clayton, V. Gajic, C. Nataraj, S. Nersesov, J. Peyton Jones, Z. Huang

The College of Engineering Qualifying Examination in the control systems area will be a written four-hour closed book examination where equations will be provided as needed.

EXAM FORMAT

The exam will have six questions from six topics selected from the list of topics provided below. The six topics will be selected by members of Center for Nonlinear Dynamics and Control (CENDAC) after consultation with the student's advisor. Students work will be evaluated based on best 4 questions answered out of 6.

TOPICS

EGR 8301 - Control Systems Engineering (or equivalent): Feedback control system design in the frequency and time domains: Root Locus analysis, Bode and Nyquist plots; State-Space formulation: Controllability; Observable design; Multivariable control.

EGR 8302 - Digital Control (or equivalent): Introduction to digital control analysis & design techniques applied to discrete-time & sampled continuous-time systems. Sampling, difference equations, the Z-transform & modified Z-transform, discrete transfer function & state-space models, discrete-time regulator & observer design, stability of discrete-time systems, discrete linear quadratic regulator & linear quadratic Gaussian formulation.

EGR 8304 - Nonlinear Control (or equivalent): Advanced treatment of nonlinear dynamical systems and control theory using modern techniques with applications. Topics include: Lyapunov stability theory, partial stability finite-time stability and control design, control Lyapunov functions, nonlinear optimal control, sliding mode control, and adaptive control.

EGR 8305 - System Identification (or equivalent): Introduction to system identification techniques for linear systems. Topics include: non-parametric time- and frequency-domain methods, parametric model structures, noise models, parametric estimation methods, recursive estimation, bias and data pre-filtering, validation methods.

EGR 8306 - Nonlinear Dynamics (or equivalent): Introduction to nonlinear dynamic analysis using analytical, graphical & numerical techniques. Linear system theory, the nonlinear pendulum, stability concepts, bifurcation theory, self-excited oscillations, overview of asymptotic methods, Floquet theory, Poincare maps, & chaos.

EGR 8308 - Feedforward Control (or equivalent): Introduction to feedforward control techniques with an emphasis on model-based methods. Design of feedforward inputs for linear systems, nonlinear systems, nonminimum phase systems, and systems with actuator redundancy; integration of feedforward and feedback; iterative control; dealing with plant uncertainty.

ADDITIONAL TOPICS

In addition, other topics may be included based on faculty advisor request and subject to approval by members of CENDAC. These topics include but are not limited to:

- Optimal Control
- System Dynamics
- Process Control
- Undergraduate level control
- Autonomous Control

COLLLEGE OF ENGINEERING
DYNAMICS AND CONTROL QUALIFYING EXAMINATION

H. Ashrafiuon, G. Clayton, J. Karlsson, J. Koller, C. Nataraj, S. Nersesov, J. Peyton-Jones

Last updated: July 23, 2021

The College of Engineering qualifying examination in the dynamics and control research areas is a written four-hour closed-book exam covering topics from the undergraduate curriculum where equations will be provided as needed. Prior to the exam, the student, in consultation with his/her advisor, must select four out of seven topics listed below. The written exam consists of four questions based on the topics selected. The questions are mainly prepared by the faculty members in Dynamics and Control area. At least three faculty members will prepare the exam with no more than two questions prepared by the same faculty member.

If the student's average score is 70% or above, then the student has passed the exam unconditionally. If the student's average score is below 70%, then the student has failed the exam.

Listed below are the exam topics and the typical textbooks are suggested for each topic to help better understand the scope of the exam.

TOPICS

1. DYNAMICS

Kinematics, velocity, and acceleration of particles in Cartesian, cylindrical, and spherical reference frames, projectile motion, dynamics of particles, momentum principles, systems of particles, rigid body kinematics and dynamics. Suggested textbook: "Engineering Mechanics – Volume 2 Dynamics" by J. L. Meriam, L. G. Kraige, and J. L. Bolton.

2. VIBRATIONS

Free and forced vibration of one degree-of-freedom mechanical systems, response to harmonic excitation, general excitation, transient response, transfer function analysis, higher order systems including two degree-of-freedom systems. Suggested textbook: "Vibrations of Mechanical Systems" by C. Nataraj; "Mechanical Vibrations" by Singiresu S. Rao.

3. SYSTEM DYNAMICS

Modeling of mechanical and electrical systems, Laplace transforms, transfer functions, analysis and design of transient and steady state response. Suggested textbook: "System Dynamics" by Katsuhiko Ogata.

4. CONTROLS

Feedback control, PID controllers, block diagrams, analysis and design of the steady state response, transient response, and stability of control systems, root-locus technique, frequency domain analysis and design, state space methods. Suggested textbook: “Control Systems Engineering” by Norman Nise.

5. SOLID MECHANICS

Stress, strain, stress-strain relations, stress analysis, tension, torsion, beading, buckling, failure criteria. Suggested textbook: “Mechanics of Materials” by F. Beer and E. Johnston

6. SIGNAL PROCESSING

Signal representation, Fourier series, Fourier transform, discrete-time systems, convolution, discrete-time Fourier transform, Z-transform. Suggested textbook: “Engineering Signals and Systems, Theory and Applications” by T. Fawwaz T. Ulaby and Andrew E. Yagle.

7. EMBEDDED SYSTEMS

Logic design and digital computer fundamentals, computer arithmetic, Boolean algebra and logical design, basic concepts of computer architecture, programming and interfacing microcontrollers. Suggested textbook: “Digital Design and Computer Architecture” David M. Harris & Sarah L. Harris.

COLLEGE OF ENGINEERING Ph.D.
DISCIPLINE-SPECIFIC QUALIFYING EXAMINATION

MECHANICS/MATERIALS

October 2016

The objective of the discipline-specific Ph.D. qualifying examination in Mechanics/Materials is to determine the proficiency and the readiness of the student to undertake rigorous research in the areas of mechanics and/or materials science. Students will be tested on their knowledge in these subject areas. The specific graduate level topics for testing will be determined by the student's research supervisor after consultation with the student. It is imperative that students consult with their research supervisor prior to officially indicating their desire to take this qualifying exam.

EXAM TOPICS

Ph.D. candidates should, in consultation with their research supervisor, undertake an appropriate plan of study in preparation for the qualifying exam and for their research. The plan of study should include multiple courses from the following:

1) Continuum Mechanics (ME 7002)
2) Introduction to FEM (ME 7040)
3) Nano/Micro Scale Behavior of Materials (ME 7250)
4) Mechanical Behavior of Materials (ME 7260)
5) Reinforced Composite Materials (ME 7501)
6) Fiber Composites (ME 7502)
7) Biomechanics of Hard Tissues (ME 7550)
8) Biomechanics of Soft Tissues (ME 7560)
9) Thermoelasticity (ME 8140)
10) Elasticity (ME 8200)
11) Applied Fracture Mechanics (ME 8350)

Content for the qualifying exam will be drawn from three graduate level courses selected from the above.

EXAM FORMAT

- For each of the three courses, two problems will be given, i.e., totally SIX questions will be given.
- FOUR of the SIX questions must be answered. Furthermore, students MUST answer AT LEAST ONE problem from EACH course.
- Exam will be closed-book. However, students will be provided with an appropriate packet of equations to use during the exam. The packet will be made available to the students prior to the exam.
- A calculator will be permitted. No other computational device will be allowed.
- The exam will last for a period not to exceed FOUR hours in duration.
- The passing grade for the exam is 70%.

QUALIFYING EXAM COMMITTEE

Gang Feng, Associate Professor
Bo Li, Assistant Professor
Ani Ural, Associate Professor
Sridhar Santhanam, Professor

VILLANOVA UNIVERSITY

MECHANICAL ENGINEERING
THERMAL-FLUID SCIENCE

QUALIFYING EXAMINATION

Dr. Gerard Jones (ME), Dr. Calvin Li (ME), Dr. Chengyu Li (ME), Dr. Sylvie Lorente (ME), Dr. Alfonso Ortega (ME), Dr. Aaron Wemhoff (ME), Dr. Qianhong Wu (ME)

June 2023

PROCEDURE AND FORMAT

The student must take a minimum of 2 core thermal-fluid graduate classes before taking the Qualifying Exam (QE): fluid dynamics, thermodynamics, convection heat transfer, and conduction/radiation heat transfer (conduction portion only). If the core courses are not given within the first 12 months after entering the PhD program, the student can request a delay for taking the QE by 1 semester (limit of 1 delay request).

If the student has a B+ (or better) in each of the 2 courses (X1 and X2), the student does not need to take the written exam of the 2 core classes, and their grades are X1=100% and X2=100%.

If the student has a B+ (or better) in only one core course, the grade is X1=100% for this course. The student must take a written exam (graduate level) for the other course and the new grade X2 is kept.

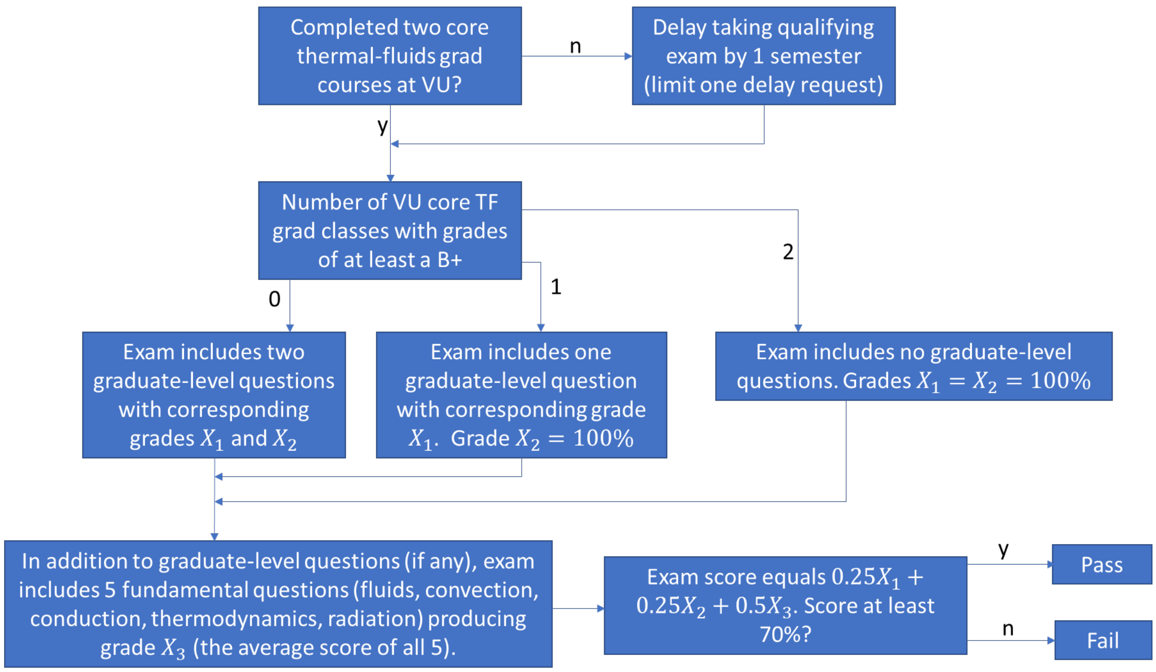
If the student does not have a B+ (or better) in any of the core courses, the student must take a written exam (graduate level) for the 2 courses and the grades are X1 and X2.

All students must take a written exam with 5 fundamental questions at advanced undergraduate level (fluid dynamics, thermodynamics, convection, conduction, radiation), the result of which is X3 (the average score of all 5 questions).

The overall exam score is 0.25 X1 + 0.25 X2 + 0.5 X3. The passing grade is 70%.

Written Examination

- Graduate level exam: 75 min per topic
- Fundamental questions: 2.5 hours
- The examination will be closed book and notes. Relevant equations will be provided for reference in a Thermal/Science Equation Reference Guide prior to the examination.
- A calculator may be required for one or more of the questions. Any calculator with internet connection is NOT allowed. Cell phones are NOT allowed to be used as calculators and cannot, under any circumstances, be taken into the examination room.



TOPICS

Fluid Dynamics: Fundamentals of fluid mechanics; conservation of mass, momentum, energy; integral or control volume formulations; incompressible inviscid and viscous flows; Navier-Stokes equations; laminar and turbulent boundary layers; laminar and turbulent internal flows; laminar and turbulent jets and wakes [References 1-2, plus 3 for general undergraduate topics].

Thermodynamics: Questions will focus on classical thermodynamics, not statistical thermodynamics; Energy balances in closed and open systems, steady and non-steady; second law applications and derivations of limiting trends in systems; state principles and equations of state; applications to cycles [Reference 4, plus 5 & 6 for general undergraduate topics].

Convection: Fundamental mechanisms; laminar and turbulent regimes; forced and free convection; internal and external flows; closed-form solutions; boundary layer approximations; scaling; asymptotic limits of high and low Prandtl numbers [Reference 7, plus 10 for general undergraduate topics].

Conduction: Fundamentals of heat conduction; steady, 1-d conduction; steady, multi-dimensional conduction; fin performance and optimization; transient conduction with steady boundary conditions; transient conduction with time dependent boundary conditions [Reference 8 & 9, plus 10 for general undergraduate topics].

Radiation: Definitions of radiative intensity, properties and fluxes, characteristics of blackbody radiation, basic laws (Planck's Law, Wien's Law, the Stefan-Boltzmann Law, Kirchhoff's Law), view factors, radiative exchange between diffuse, gray surfaces in an enclosure. [Reference 10, Chap 12, 13].

In addition to familiarity with the subjects listed above, the candidate is expected to be able to use thermal-fluids theory and basic physical principles in application. Familiarity with the course content of ME 7103 (Advanced Engineering Thermodynamics), ME 8100 (Fundamentals of Conduction and Radiation Heat Transfer), ME 8120 (Convection Heat Transfer), and ME 8103 (Advanced Fluid Mechanics) is recommended. References are given as suggestions to indicate the level of the material covered. Selected undergraduate references are given as general references, not to indicate level of treatment (except in the case of the Radiation topic).

REFERENCES

1. Deen, W. M., Analysis of Transport Phenomena, Oxford University Press (any edition)
2. Currie, Fundamental Mechanics of Fluids, CRC Press, (any edition).
3. Fox, R.W., McDonald, A.T., and Pritchard, P.J., Introduction to Fluid Mechanics, Wiley, (any edition).
4. Bejan, A., Advanced Engineering Thermodynamics, Wiley, (any edition).
5. Kroos, K., Potter, M., Thermodynamics for Engineers, Cengage Learning, (any edition).
6. Cengel, Y., Boles, M., Thermodynamics: An Engineering Approach, McGraw-Hill, (any edition).
7. Kays, W., Crawford, M., and Weigand, B., Convective Heat and Mass Transfer, McGraw-Hill, (any edition).
8. Arpaci, V., Conduction Heat Transfer, Pearson Custom Publishing, (any edition).
9. Yener, Y. and Kakaç, S., Heat Conduction, Taylor and Francis, (any edition).
10. Bergman, T.L. Lavine, A.S , Incropera, F.P., DeWitt, D.P., Fundamentals of Heat and Mass Transfer, (any edition).

A. SUSTAINABLE ENGINEERING MATHEMATICS PHD QUALIFICATION REQUIREMENTS

To fulfill the Mathematics PhD Qualification Requirements, candidates must successfully complete one of the currently offered graduate level mathematics courses listed below with a grade of B+ or better:

1. MAT 7404 - Statistical Methods I

   Description: Data summarization and display, distributions; binomial, Poisson, normal, t, chi-square and F, estimation, hypothesis testing, linear regression, correlation, statistical software packages.

   Credit Hours: 3. Offered: Each fall

   or

2. BIO 7805 - Biostatistics & Exper. Design

   Description: Conceptualization of experimental design, hypothesis testing, execution of statistical analyses, expression of statistical results, and effective graphical presentation of quantitative data. Includes a written exercise emulating peer-reviewed journal publication.

   Credit Hours: 4. Offered: Each spring and summer.

   or

3. Another graduate level math course e.g. modeling or optimization may be substituted with the approval of the advisor and coadvisor.

B. SUSTAINABLE ENGINEERING QUALIFYING EXAMINATION

PROCEDURE AND FORMAT

The discipline specific PhD qualifying examination on Sustainable Engineering will be a combination of a written and oral examination lasting for a period not to exceed a total of 4 hours in duration, 3 hours for the written and 1 hour for the oral. It will have the following format.

- The student will be given 5 questions and will be given the choice to answer 3 of these questions. One of the selected questions must be a designated question relating to engineering discipline specific topics.
- The examination will be entirely open book/notes.
- The level of the examination questions will be at the MS level.
- Each question will be derived from the list of topics listed below

- The oral portion of the exam will be an open period whereby the student will be presented with a question posed by the examining committee.

TOPICS

- **Sustainable Materials & Design**: Embodied Energy in Materials, Sustainable Material Alternatives incl. renewably sourced and sustainable end of life, Benefits/Issues of Today's Materials, Design Principles for Material Solutions that build in sustainability from the start (reduced material intensity, biomimicry), sustainable packaging
- **Life Cycle Assessment (LCA) & Impact Assessment**: Goals/Scope/Challenges, LCA Inventory Analysis, Software, Unit Process Definition, Cutoff Criteria, LCA Impact Assessment, Traci methodology, Definitions, LCA Integration-Recommended solutions, Incorporation of Social, Technical, Economic, Political
- **Climate Change**: Energy Transformation, Planetary Boundaries, Whole Systems Thinking, LCAs
- **Social/Economic Aspects**: Stakeholder Engagement, Sustainable Consumption, Integrated Reporting/Measurement, Ecosystem Services, Appropriate Technology for Developing Countries, Public /Private Partnerships-NGOs, Role of Gov't Policy and Control
- **Sustainable Supply Chain**: Supply Chain Process (Procurement, Manufacturing, Delivery, Distribution, Disposal); Applying sustainability principles to each process step; Green product design; transparency; reporting; supplier management and partnership; stakeholder engagement; risk management/resilience; eco-efficiency; sustainable packaging; extended producer responsibility; leadership practices.
- **Core Engineering (Track) Competencies**: Water hydrology; Environmental and Industrial Process Control systems; Building and transportation design and modeling; Finite Element Analysis; Polymer science and engineering; Material properties; Thermal energy management; Hydraulics and Fluids; Energy conversion and modeling.

REFERENCES

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Sachs, Jeffrey D. *The Age of Sustainable Development* Columbia University Press New York 2015

Ashby, M.F. *Materials and the Environment* 2nd Ed. Butterworth-Heinemann Oxford 2013 (online edition – Villanova U. Library

United Nations Environmental Program, SETAC, *Guidelines for Social Life Cycle Assessment of Products,* 2009

Business for Social Responsibility (BSR), *How to Make Stakeholder Engagement Meaningful for Your Company*, Jan.2012

Pullman, M., Sauter, M. *Sustainability Delivered –Designing Socially and Environmentally Responsible Supply Chains*, 2012

United Nations Global Compact, BSR***;*** *Supply Chain Sustainability -A Practical Guide for Continuous Improvement*, 2010

MIT/Sloan Management Review, ***"****Greening" Transportation in the Supply Chain*, Winter 2010

PREPARATORY COURSES

CORE:

EGR7110: Introduction to Sustainability and Climate Change
EGR7113: Sustainable Materials and Design
EGR7111: Life Cycle Assessment and Impact
EGR7112: Social and Economic Drivers

TRACK:

As appropriate based on chosen track. See:
http://www1.villanova.edu/villanova/engineering/grad/masters/sustainable.html#tracks