Ph.D. Qualifying Exam in Civil Systems

1. Overview

The purpose of the Ph.D. Qualifying Exam (QE) in Civil Systems is to see if doctoral students have a mastery of the basic material and are ready to proceed with research. Typically it will be offered during the last part of January/first weeks of the spring semester.

2. Specifics

The QE will consist of both a written and an oral part.

2.1 Written Portion of the QE

The written segment will have four questions as follows:

a. One on <u>Systems</u>, based in part on ENSE 621 but also including other topics (see below for the complete list).
b. One on <u>Operations Research/Optimization</u>, based in part on ENCE 603/ENCE 677 but also including other topics (see below for the complete list).
c. One <u>on Sensing and Control</u>, based in part on ENCE688A but also including other topics (see below for the complete list).
    a. Sensor specification and characteristics (performance measure, basic components, modeling)
    b. Sensing principle of dynamic sensors (e.g., accelerometer) and frequency response characteristics
    c. Sensor data acquisition and basic sensor data processing, noise characteristics
    d. System modeling, Laplace transform, transfer function, identification of system parameters
    e. Classical feedback control theory, control objectives, PID control, bode diagram
    f. Modern control theory: state space, controllability, observability
d. One question from one of the specialty areas designated by the student. The following are the approved specialty areas; the question will focus on the intended research of the student:
    a. Energy/Environmental Systems
    b. Transportation Systems
    c. Emergency Preparedness/Response and Infrastructure Security
    d. Civil Information Systems
    e. Sustainable Engineering
    f. Operations Research/Management Science Methodologies

The student will need to contact the Civil Systems faculty <u>at least two months prior</u> to the exam indicating both their intention to take the exam as well as their specialty area question from the list above. This specialty question will be graded by two faculty members, typically including the advisor if one is determined at that point. If a student withdraws from the qualifying exam, this must be done in writing at least two weeks prior to the written exam date.

Depending on the year, each question may have a different format (e.g., limited take-home or on-campus). The student is responsible for making sure that the written portions get to the designated faculty members who will grade the questions by the indicated dates.

2.2 Oral Portion of the QE

Using the written part of the QE as a starting point, the student will need to present their responses to the Civil Systems faculty in the oral part of the exam. Each faculty member will have the opportunity to ask questions about the exam responses or related topics.

2.3 Grading for the QE

The grade for this exam will consider both the written and oral parts as well as any other relevant achievements/progress the student has made. For each question there will only be a grade of “pass” or “fail” (no numerical grade). The student will be contacted soon after completing the oral exam as to whether they passed or failed particular questions. In the event that a student failed a question, they will have the opportunity to re-take that question one more time when the QE is next offered (typically one year later). Only those areas whose questions were unsuccessfully answered will need to be re-taken. Once the student passes the exam, they will advance to candidacy.

2.4 List of Topics That Can Be Asked on the QE

2.4.1. Systems Question

1. Strategies and Economics of Systems Engineering Development
2. Foundations of Model-Based Systems Engineering
3. Modeling abstractions for System Behavior and System Structure
    a. Object- and component-based development of systems
    b. Actor-based system models
    c. Languages for visual modeling of systems (e.g., UML and SysML).
4. Requirements Engineering
    a. Gathering and organization
    b. Requirements allocation and flowdown
    c. Requirements traceability
5. Principles of System-Level Design
    a. Functional allocation
    b. Platform-based design

2.4.2 Operations Research/Optimization

1. Linear programming
    a. model formulation
    b. duality theory,
    c. solutions methods
2. Integer programming
    a. model formulation
    b. Branch and Bound solution method
    c. computational complexity
3. Nonlinear Programming
    a. Karush-Kuhn-Tucker conditions
    b. convexity of functions and sets
    c. constraint qualifications
4. Multiobjective Decision-Making
    a. model formulation
    b. Pareto optimality
5. Stochastic linear programming
    a. model formulation for recourse problems (two-stage)
    b. value of the stochastic solution
    c. value of perfect information

2.4.3 Sensing and Control

1. Sensor specification and characteristics
    a. Performance measure: sensitivity, dynamic range, frequency response, error, repeatability, measurement range, linearity, noise floor, saturation, calibration
    b. Basic components of sensors: sensing element, signal conditioning unit, wires
    c. Sensor categorization: zero-order, 1st order, and 2nd order sensor.
2. Sensing principle of dynamic sensors
    a. 2nd DOF oscillator model for 2nd order dynamic sensor
    b. Frequency response characteristics,
    c. Resonant frequency
    d. Damping
    e. Rise time
3. Sensor data acquisition and basic sensor data processing
    a. Sampling and digitization
    b. Nyquest frequency and Shannon sampling theorem
    c. Filter and anti-aliasing filter
    d. Noise characteristics
4. System modeling,
    a. Laplace transform
    b. Transfer function
    c. Block diagram, basics of Simulink model
    d. Identification of system parameters

5. Classical feedback control theory,
    a. Control objectives
    b. PID control
    c. Bode diagram
6. Modern control theory
    a. State space model
    b. Controllability and observability