Procedures for the PhD Preliminary Exam in CEE-IS

The purpose of this document is to outline the standard operating procedure for the Civil & Environmental PhD Preliminary Exam for students specializing in Intelligent Systems. Presently, the faculty who administrate this program are:

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Currently the Preliminary Exam Coordinator (PEC) is Jeff Scruggs.

Planning and Scheduling

Departmental Policy

Preliminary Exams in the CEE department are held at two standard times of the year – The first week of classes during the Winter semester (i.e., early January), and the week immediately after Winter semester final exams (i.e., early May). Specific dates for these two exam windows will vary from year to year, depending on the University's academic calendar, and can be obtained from the CEE Graduate Programs Coordinator.

Per the CEE departmental guidelines, each PhD student in Civil & Environmental Engineering must take the Preliminary Exam no later than 17 months after the beginning of their first semester as a PhD student at the University. Students may elect to take the exam sooner, but the exam will be administered the same way irrespective of how long a student has been enrolled at the University.

The research advisor of a student planning to take the Preliminary Exam is considered to be the Chair of the student's exam committee. As the Chair, they are required to send a memo to the Chair of the Graduate Committee, specifying the date of the exam, and requesting authorization to hold the exam. This memo should be sent no later than one week before the time of the exam. After the exam is over, the advisor is required to send another memo to the Chair of the Graduate Committee, notifying them of the outcome. Standard templates for both these memos can be obtained from the CEE Graduate Programs Coordinator. All memos sent to the Graduate Committee Chair should be CC'd to the Graduate Programs Coordinator, as well as the student's preliminary exam committee.

The student's research advisor is also responsible for notifying their advisee of the outcome of their exam. This should be done in the form of an official letter, sent to the student via email. A standard template for the letter can be obtained from the Graduate Programs Coordinator.

Standard Exam Schedule

Students specializing in Intelligent Systems, who plan to take the Preliminary Exam during a given academic year, should first consult with their advisor and then must notify (via email) the PEC. In their email, the student must also state the four areas of specialization (see below) on which their exam will be based. Regardless of whether the student takes the exam in January or May, he or she must send this notification email **no later than November 30** of the prior semester. This will allow time for scheduling all the exams, forming the committees, and developing the exam questions.

Each student's Preliminary Exam committee will consist of 4 members, including 3 CEE faculty members from the IS area. The specific members of the committee will be assigned by the PEC, in consultation with each student's advisor.

The following scheduling deadlines will be observed:

	January exam period	May exam period
Student notification to PEC of intent to take the QE	November 30	November 30
Committee assignments made by the PEC	December 15	April 1

Ad-hoc Exams

Students in the IS area are expected to take their exam at the standard January or May times, and students should begin planning for this exam upon arrival at the University of Michigan. However, if extenuating circumstances require a student to take the exam at a different time of the year, an ad-hoc exam can be administered on a case-by-case basis. However, ad-hoc exams should only be planned as a last resort.

A student wishing to plan an ad-hoc preliminary exam must petition to do so. Petitions should state the name of the student, the reason rescheduling the exam is required, and the proposed date for the rescheduled exam. These petitions should be emailed to Graduate Committee Chair, and CC'd to the Graduate Program Coordinator and the IS PEC. If approved, the ad-hoc exams are planned (including committee assembly, scheduling, and notifications to the Graduate Committee Chair) by the student's research advisor, not the IS PEC. However, petitions for nonstandard Specialization Areas (see below) must still be submitted to the IS PEC, and approved by the IS faculty.

Format

The CEE IS preliminary exam is an entirely oral exam, to be completed over two continuous hours. The student is not allowed to bring reference materials of any kind to the exam, unless explicit permission is given by their entire examination committee, prior to the day of the exam. The student is allowed to bring blank scratch paper, and a calculator. The student will be notified of the exam location at least 24 hours prior to the exam, but it will typically be held in a conference room.

At the beginning of the exam, the student is given four written questions – one in each of their areas of specialization. They are then given 20 minutes, alone, to read over the questions. During this time they may make some preliminary efforts on the problems but the intent is not for the student to solve the entirety of any of the problems during this time. Rather, the intent is to allow the student to collect their thoughts.

Following this 20 minute period, the examination committee will return, and for the remainder of the exam period (i.e., 100 minutes) the committee will ask the student questions about the four problems. The student is given the right to choose the order in which the four problems are discussed. However, once a problem is started, the student must continue the discussion on this problem until the committee decides to move on. It is not necessarily the case that the time for the four problems will be divided evenly. It is also not necessarily the case that the student must provide a complete solution to all parts of all the problems, in order to pass exam. Additionally, on each problem, the committee can (and usually does) ask impromptu questions to the student which were not on the written problems provided to the student, but involve related concepts. The student's answers to such questions are considered part of the exam, and will be taken into account when determining the outcome of the exam.

At some time after all the exams for the January exam period are administered, the examination committee will deliberate to determine the outcome of each exam. All faculty who participated on the exam committees for that year will deliberate as a group on all exams. Students will be notified of the decisions regarding the exams within 48 hours of the end of the last exam. This notification will be in the form of an official letter from the student's advisor, which states the outcome and provides feedback from the committee.

During the January exam period, all students choosing a given specialization area will be given the same question on that area. Students are prohibited from discussing the exam problems until after all exams have been administered, and violations of this rule will be considered a serious breach of the Honor Code.

Specialization Areas

Each student must choose 4 specialization areas relevant to some aspect of Intelligent Systems research, on which to be examined. The preliminary exam is designed to test a student's proficiency with the specialization area, taken broadly. It is not designed to test a student's proficiency with the specific topics covered in a specific class they may have taken. If a question is asked which pertains to a specific topic which was not covered in a class taken by the student, this is not considered a valid excuse for failing to answer the question.

It is nonetheless typical that the student will have taken at least one class, either at the University of Michigan or prior to arrival, on each specialization area. However, this is not explicitly required – If a student has acquired a good understanding of a specialization area without having taken a class in it, they will be permitted to choose this area. The student's performance in this subject will not be held to a different standard than for those who have taken courses in the subject, and the student should make such a decision carefully, and only after consulting with their advisor.

Standard specialization areas on which a student can be examined are given below. Below the name of the specialization area, a list of typical topics and concepts is given. These topics are listed here in order to give students an idea for the content of these areas. However, these lists are **not comprehensive** and the committee reserves the right to ask the student any question which they deem to be relevant to the area.

If a student wishes to be tested on a specialization area which is not on the list below, they may petition to the PEC. Petitions must be submitted by November 30, and are voted on by the IS faculty. Petitions will be granted, provided that four conditions hold for the proposed specialization area:

a) The scope is not overly narrow,
b) It has a fundamental scientific and/or mathematical foundation,
c) It involves core concepts of relevance to systems science and engineering in a general sense, not just one application area in CEE, and
d) It does not overlap significantly with the standard specialization areas.

List of Standard Specialization Areas

Linear System Theory

Vector spaces. Linear algebra. Linear operator theory. Least squares methods. Spectral analysis and eigenvalue problems. Singular value analysis. State space and Laplace-domain system models. Controllability, observability, and minimal realizations. Canonical state space realizations. Balanced realizations and model reduction. Techniques for linear time-varying systems. Lyapunov functions, and Lyapunov's direct method of stability assessment. Full-state feedback and full-order observers. Pole placement techniques. Separation principle.

Optimization Theory

Formulation of mathematical optimization problems in engineering applications. Linear programming problems. Simplex algorithm. Duality theory, including sensitivity analysis and interpretations. Interior point methods. Network flow and transportation problems. Gradient descent and Newton methods for unconstrained optimization. Conjugate Gradient methods. Constrained optimization via active set and gradient projection methods. Penalty function and Lagrange multiplier methods. Primal-Dual methods for constrained optimization.

Probabilistic Analysis

Concept of probability spaces – sample space, events, sigma algebras, and probability measures. Probabilistic analysis of events, including Bayesian inference. Discrete and continuous random variables, and commonly-used probability models for random variables. Expectations and moments. Multivariable probabilistic analysis, including conditional and marginal distributions, independence, and correlation. Uncertainty propagation. Extreme value distributions. Sampling distribution theorems, and laws of large numbers. Estimation theory, including moment-matching, maximum-likelihood, and least-squares estimators. Evaluation of estimator variance and bias. Statistical analysis, including confidence intervals, hypothesis testing, linear regression, and analysis of variance. Bayesian estimation methods. Monte Carlo methods.

Control Systems

Laplace-domain models of physical systems. Transfer function and convolution analysis, and their equivalency. Block diagrams and signal flow graphs. Initial and final-value theorems. Frequency response and Bode plots. Basic types of control objectives, including disturbance rejection, tracking, stabilization. Inference of closed-loop dynamics from open-loop properties. Internal model principle. Nyquist plots and the Nyquist stability criterion. Routh-Hurwitz techniques. Root locus techniques. PID control. Frequency-domain control design, including lead-lag compensators. Robustness techniques including stability margins and loop shaping techniques.

Sensing Theory and Technology

Sensor physics (capacitive, resistive, inductive, etc.). DC and AC circuits. Signal amplification and interface circuits. Analog-to-digital converters (ADC) architectures. Microelectromechanical systems (MEMS) sensor design. Nyquist sampling theory, and frequency analysis. Filter design. Application-specific sensor selection and placement.

Digital Signal Processing

Discrete-time sequences, difference equations, and convolution. Forward- and inverse z-transforms, and transfer function representations. Discrete-time networks and flow graphs. Conversion of continuous-time signals to discrete-time, and sampling techniques. Discrete-time Fourier transforms. Aliasing effects. Windowing techniques. Discrete Fourier Transform (DFT) and the Fast Fourier Transform (FFT). Autocorrelation and spectral techniques. Infinite impulse response (IIR), finite impulse response (FIR), and autoregressive moving average (ARMA) filter design techniques. Lattice filter structures. Classical filter archetypes (e.g., Butterworth, Chebychev, etc.). Filter transformation techniques (e.g., impulse-invariant, bilinear, spectral, etc.). Cascade filter designs. Multirate systems, interpolation, and decimation. Quantization effects.

Stochastic System Analysis

Discrete- and continuous-time stochastic processes. Mean-square analysis, including mean, autocorrelation, and autocovariance functions. Probability density evolution. Stationarity and ergodicity. Linear, discrete-time, Gaussian stochastic system analysis, including innovations realizations and the discrete-time Kalman filter. Continuous-time stochastic systems driven by jump processes. Wiener processes and Wiener process excited systems. Stochastic calculus and the Ito rule. Fokker-Planck and Komogorov equations. Stieltjes integral representations. Stationary response analysis, including spectral methods. Spectral factorization theorem.