

### Steps to a Doctoral Degree in CEE

1. Begin planning Doctoral Program with academic advisor [Fall Academic Year 1 (AY1)]
2. Approval of **Doctoral Program** and admission to general exam through **Student Interview** [Fall AY2]
3. Selection of Exam Committee and Scheduling of **General Exam Part 2** for April or May AY2 [scheduling done in January AY2]
4. Complete **General Exam Part 1 and Part 2** [by end of AY2]
5. Complete **Responsible Conduct of Research** course [by end of AY2]
6. Formation of Doctoral Thesis Committee following completion of General Exam
7. **Approval of Doctoral Research Proposal** [by Dec. 31, AY3]
8. Meet regularly [minimum of twice per year] with Doctoral Thesis Committee
9. Doctoral Degree earned with satisfactory defense of the Ph.D. thesis [AY 5 or 6].

### Doctoral Program

A Doctoral Program in CEE consists of 120 units of graduate level coursework, including a **3-Subject Core** and one breadth subject. The student should consult their faculty advisor when preparing their Doctoral Program. The **3-Subject Core** reflects core knowledge in the student's chosen field, which is tested in **Part 1 of the General Exam** (below). The three subjects are selected from an approved list of 4 to 5 subjects within a specific sub-group of CEE. The approved subjects are available at the CEE graduate forms page of the CEE website, <https://cee.mit.edu/resources/> and are also included at the end of this document.

The remainder of the doctoral program consists of graduate subjects that complement the Core. In addition, the Doctoral Program must include one breadth subject. The breadth subject is drawn from a discipline that is distinct from the Core. Students may consider subjects in science writing, global languages (excluding ELS subjects), political science, business, law, and other branches of science and engineering. The Doctoral Program may incorporate subjects completed during a CEE Masters degree. In addition, up to 24 units of graduate credit taken outside MIT or taken in a non-CEE MIT SM degree may be transferred to the CEE Doctoral Program. All transfer credits must be related to the proposed doctoral research area. Students may petition for additional transfer credit [up to 24 additional units] if MIT does not have a comparable subject offered and the subject is not counted toward a different degree at MIT or elsewhere. The Academic Programs Office must approve transfer credits from outside of MIT. The Doctoral Program form can be downloaded from the CEE web site <https://cee.mit.edu/resources/>.

### Thesis Supervision

A student's thesis supervisor can be 1/MIT CEE Faculty member(s), 2/CEE Senior Research Scientist/Engineer, 3/ co-advised by a CEE and other MIT faculty member, 4/WHOI Scientist with an MIT CEE academic advisor (Joint Program students only). A thesis supervisor is responsible for certifying and signing the thesis. In the case of co-supervisors, both must certify and sign thesis

#### *Emeritus faculty*

Emeritus faculty can be involved in mentorship of graduate students at their discretion, without compensation. They can serve as co-advisors as long as there is a primary advisor who will provide funding and who is actively engaged in supervising a student. It is acceptable for emeritus faculty to serve as PhD committee chair.

### Student Interview [Fall Term AY2]

During the Fall term, second year students are sent an email from the Graduate Academic Administrator (Kiley Clapper) announcing the upcoming Student Interview and requesting them to indicate if they wish to participate. Students select which of the two interviews to attend by contacting the appropriate Doctoral Program Officer listed below. Approval of the Doctoral Program and admittance to the General Exam are based on a review of academic and research performance.

Students are expected to have a GPA  $\geq 4.5$  to be considered for the General Exam. The Student Interview is held with a group of faculty and research staff, organized by research area (see below). A minimum of one week before the Student Interview, the following should be submitted to one of the following Doctoral Program Officers

Prof. Dennis McLaughlin – Environmental Science and Engineering, CSE  
dennism@mit.edu

Prof. Oral Buyukozturk - Mechanics of Materials, Structures, Geomechanics, Systems, CSE  
obuyuk@mit.edu

- 1) A one-page summary of proposed doctoral research written for a general scientific audience.
- 2) The Doctoral Program form with advisor signature. Be sure to make a copy for your records.
- 3) A one-paragraph letter from the student's research advisor stating the student's strengths and weaknesses, and stating whether, or not, they support admission to the General Exam. If the advisor supports admission to the General Exam, they should also indicate willingness to supervise the student for the proposed doctoral work and willingness to provide and/or seek funding necessary for the duration of the degree. Also indicate if the student is on full or partial fellowship. This letter (or email) is sent directly from the faculty advisor to the Doctoral Program Officer, with a copy sent to the Graduate Academic Administrator, Kiley Clapper.

At the interview, the student briefly describes the research they plan to pursue, explaining how the proposed set of subjects supports their research and career plans. The student will also identify their breadth class. Faculty may give advice on classes to add or take away from the proposed Doctoral Program. After the student leaves the room, there is a 5 to 10 minute discussion, beginning with a reading of the faculty advisor letter. At the end of the discussion, a formal recommendation is made to admit or decline the student for the General Exam, and the recommendation may include formal requirements to alter the Doctoral Program.

After the Student Interviews: The Academic Administrator [Kiley Clapper] will confer with the Doctoral Program Officers to review decisions and recommendations made by the faculty. The Academic Administrator will 1) send an email (copy to advisor and Doctoral Program Officer) to the student with the outcome, admit or decline, and any recommendation by the faculty; and 2) send the hard-copies of the research summaries and Doctoral Program forms to the respective program Officers, and 3) collect signature from the Graduate Program Chair [Jesse Kroll].

Once the Doctoral Program form has been submitted, students may not change their selection of Core subjects. Exceptions are rarely permitted, and require approval by the Graduate Officer. The remaining subjects in the Doctoral Program may be altered, with approval from the doctoral thesis committee. A Petition for Revision of Doctoral Program is available at the CEE grad-forms web site - <https://cee.mit.edu/resources/>.

### Research Requirement and 1.THG

Research plays an integral role in the PhD degree, and this research effort is tracked academically through enrollment in 1.THG. In Course 1, we require graduate students to register for 1.THG every semester. The number of credit hours is determined in consultation with your advisor. If a student is registered only for 1.THG during a term, the department recommends a load of 48 units. Through enrollment in 1.THG, students are formally graded on research performance each semester, in accordance with MIT Faculty Rules and Regulations 2.62.3. <http://facultygovernance.mit.edu/rules-and-regulations>

**Responsible Conduct of Research**

Each PhD student is required to complete MIT’s online course on the Responsible Conduct of Research within the first two years, i.e. by the end of Spring term AY2. If you are paid on an NSF grant, you are required to complete the course within 60 days of being assigned to the grant. You can access the course from this web site and following the instructions below. You will need an MIT certificate.

<http://osp.mit.edu/compliance/responsible-conduct-research/take-training>

1. On the bottom of the page, click on “accessing the site for the first time”

**Quickcards**

Quickcards in PDF format for RCR training can be downloaded here.

Accessing the CITI site for the first time ←

Accessing CITI for additional training

Affiliating CITI training with MIT

2. From there CITI will ask you to create a password.

3. After you have created your new password, click on “Add a course or Update Learner Group”

My Learner Tools for Massachusetts Institute of Technology

! You are not enrolled in any courses for this institution. Click here to complete your enrollment.

- ⊕ Add a Course or Update Learner Groups ←
- ⊕ View Previously Completed Coursework
- ⊕ Update Institution Profile
- ⊕ View Instructions page
- ⊕ Remove Affiliation

4. Go to question 4 and select, RCR for Engineers

5. You should then see that the course has been added

Massachusetts Institute of Technology Courses		
Course	Status	Completion Report
Responsible Conduct of Research for Engineers	Not Started	Not Earned

6. Complete The Integrity Assurance Statement before beginning the course

7. Once you have completed the course (12 modules with 80% or better on the individual quizzes) send a screen shot of your completion report to the graduate academic administrator, Kiley Clapper (kclapper@mit.edu).

### General Exam Part 1 [Core Knowledge]

The General Exam Part 1 tests core knowledge within the students selected field of study, as represented by the **3-Subject Core** designated in the Doctoral Program. To pass General Exam Part 1, the student must receive a grade of A (including A-) in each of the subjects selected for the Core. The subjects identified in the 3-Subject Core are firm and rarely are exceptions permitted. In the circumstance where a subject is not offered for two consecutive academic years and there are no other options within the 3-Subject core list, a comparable level graduate subject may be substituted with approval from a student's advisor. The process for substitution is a memo, that includes the rationale for the substitution and the advisor's signature of approval, which is reviewed by the CEE faculty during the Student Interview.

If the student receives a grade less than A, they have the option of re-taking the subject to improve the grade, or taking and passing a separate written exam. The subject instructor prepares the written exam. It consists of an open-book question, which the student will have eight (8) hours to complete, e.g. 9 am to 5 pm. During the written exam, the student may not request information from any person other than the instructor and may not use information from the internet. All texts used by the student must be cited. The written exam should be completed in the term following the completion of the course to allow the student to study the material more deeply and improve their understating. If the instructor is not a member of CEE and declines to provide a question, a designated CEE faculty or Senior research staff within the appropriate area will write the exam.

### General Exam Part 2 [Research Aptitude]

This exam tests the following skills. First, can the student formulate a research question, set out a plan of research, and interpret the results. Second, can the student clearly present and defend this research. Third, does the student have sufficient understanding of the field to answer a broad range of questions and to comment on relevant literature. The research presented by the student can be drawn from their SM or MEng thesis, their RA at MIT, or research conducted as part of a previous position. The research must be in the same field as the subgroup core listed in the Doctoral Program.

Part 2 of the General Exam must be completed by the end of the fourth academic term. In most cases, this exam occurs in April or May of AY2. Students should consult their research advisors when choosing the members of the evaluation committee (see requirements below). Your Part 2 general exam committee is encouraged to be similar or identical to the thesis committee. Students *must* submit the Part 2 Schedule Form [available at <https://cee.mit.edu/resources/>] before the beginning of the term in which the exam will be held, which in most cases will be by end of January for exams on April/May of AY2.

The exam has three components.

- 1) A written document describing research completed.
- 2) A review of a relevant publication chosen by your advisor. The paper will be assigned one week before the presentation meeting.
- 3) A 30-minute oral presentation of research with significant questioning from committee.

#### *Research Paper*

The research paper should have a maximum of 10 pages, single-spaced, 12-pt font. The page limit includes figures, but not references. Students may ask their advisor for advice in the preparation of this document. Students may also get assistance from MIT's Writing and Communication Center, <http://writing.mit.edu/wcc>. The following elements must be included:

Abstract - A concise summary of the motivation, research objectives, methods, and key results. A person unfamiliar with the topic should be able to understand the abstract.

Introduction - Introduce the general topic and explain its relevance, e.g. what is the practical or fundamental importance of this topic. Demonstrate familiarity with previous studies related to the research. Clearly state the specific goals of the project.

Methods – Describe and defend the methods.

Results - Describe specific results from the research.

Discussion - Compare and contrast the results with other studies. Explain the implications of the results to broader questions and/or applications contained in the motivation.

The student distributes the research report to their committee a minimum of one week before the presentation. The student should inquire whether each committee member prefers a pdf or hard copy, and deliver the preferred format.

### *Review of a Relevant Publication*

Your advisor, in consultation with the others in the GE2 committee, will select a single journal publication in your field. It may be a seminal paper from years ago or a brand new paper. It should not be longer than 20 pages and cannot be too broad, e.g. no general reviews of the field. You should be prepared to informally discuss the paper (no slides), focusing on a set of 3 to 5 questions that will be provided by the committee when the paper is assigned. The questions may include some of the following, or they may be more specific to the paper. Please prepare for the paper review on your own.

What is the most important result and why is it significant?

What is the value of the paper to the broader field?

What are the limitations of the work and results presented?

What is the most significant uncertainty and how could it be reduced?

How do the results of this paper relate to your research?

Please show the full derivation of equation (5).

Are all of the conclusions justified by the results?

Are the boundary conditions realistic?

Explain in physical (chemical, biological) terms why the relationship shown in Figure 7 makes sense, or does not make sense.

How does this paper challenge the existing theory regarding \_\_\_\_\_ ?

Propose a new research question or hypothesis that expands on the work presented in this paper, i.e. where would you go next? Defend your choice.

### *Oral Presentation Meeting*

The student should schedule the committee meeting for 2 hours, with the expectation that the meeting will last between 1.5 and 2 hours. The student will begin by informally presenting their response to the question(s) posed by the committee beforehand regarding the paper chosen by the committee (see *Review of a Relevant Publication* above). The student should not prepare slides for this response. Necessary visuals or equations can be sketched on the black board. Committee members may ask questions for clarification or to go into further depth. After twenty to thirty minutes, the committee chair will end this discussion and instruct the student to begin their research presentation. The student should plan a 30-minute presentation, but the actual presentation will take longer as faculty can interrupt with questions. The committee members are expected to have read the report and come prepared with questions. The committee members should push questions to the point at which the student says, "I don't know". The student should not be afraid of saying, "I don't know". It is at this point that the real scientific discourse begins, an exchange of ideas that provides a learning experience for the student. It is important to note that the research advisor is encouraged to ask questions, but he/she *should not answer questions*. The advisor may prompt the student with further questions to help the student answer on their own. This is a test of the student's understanding and

research ability, not a test of the advisor's research ideas. The GE oral presentation also serves as a practice for the student in preparation for their thesis proposal, which has a similar format.

#### *Evaluation Committee for General Exam Part 2*

The evaluation committee for Part 2 is comprised of three people, including a student's thesis advisor and a minimum of two faculty or senior research staff in CEE. In many cases this group will become the Doctoral Thesis Committee. The chair of the evaluation committee must be within CEE and a faculty member or Senior Research Staff and cannot be the thesis advisor. The student invites the committee members and includes their names on the Part 2 Schedule Form. After the form is submitted, one additional CEE faculty member from outside the core area will be assigned to the committee. The role of the outside person is to promote active questioning, especially on a basic level. The goal is to test the student's ability to answer questions in a way that a non-expert will understand.

#### *General Exam Part 2 Outcomes*

After the exchange of questions and ideas has finished, or at the 1hr 40 min mark, which ever comes sooner, the committee chair will ask the student to leave and wait nearby. The faculty advisor will be given a few minutes to add their perspective on the student's performance that day, on the student's broader research ability, and any specific requirements for the student. The committee chooses one of the following outcomes, which must be communicated with the student immediately following the meeting.

- 1) Pass with no additional requirements (may include minor changes to paper)
- 2) Re-take (may include additional requirements as noted below)
- 3) Fail with no option to retake (only if this is a second attempt)

*Additional requirements* could include any activity that the committee feels will improve on a perceived deficiency in core knowledge or research skill. Here are some examples,

- Repeat a class as a listener to strengthen weakness in fundamental knowledge
- Write a detailed review of a particular experimental method or paper
- Take a public speaking course
- Meet with writing center staff to go over research paper
- Do a literature search in a specific area
- Re-write a section of the research paper
- Complete additional analyses on the data presented in the paper

The student is informed of the outcome directly after the meeting. The student should be waiting nearby. In addition, the outcome is officially recorded with an email written by the Committee Chair and sent to the Graduate Academic Administrator (kclapper@mit.edu) with copy to all committee members and the student. The following information should be included.

- Who was on the committee?
- What was the outcome?
- What are the deficiencies and/or what additional requirements have been made?

Completion of the additional requirements will be monitored by the faculty advisor and communicated to the Graduate Academic Administrator (Kiley Clapper) when completed.



### Doctoral Thesis Committee and Approval of Doctoral Research Proposal

After passing Part 1 and Part 2 of the General Exam (typically at end of AY2), the student forms a Doctoral Thesis Committee and within one academic term schedules a defense of Doctoral Research Proposal, i.e. typically by the end of Fall Term AY3. The Doctoral Thesis Committee consists of a minimum of three MIT faculty or senior research staff, including a minimum of two members from CEE. The committee may have the same membership as the Part 2 Evaluation Committee. If appropriate, the student may invite members from outside MIT. The student invites one committee member to be the Chair. The Committee Chair must be a member of CEE and cannot be the student's advisor. Once the Thesis Committee is formed, the student prepares a Research Proposal and schedules a date to present the proposal orally to the Doctoral Thesis Committee. The proposed research must be in the field defined by the student's Core area. The objectives of the research should be prepared with guidance from the advisor. Because most doctoral research is funded by existing projects developed by the advisor, it may need to meet specific benchmarks. The proposed work must accommodate these constraint. The proposal should be a maximum of 15 single-spaced pages. The necessary components are given below. The oral presentation is 45 minutes, followed by 45 minutes of questions.

#### *Required Components in the Research Thesis Proposal*

The thesis proposal should be a maximum of 15-pages of single-spaced, 12-point font. Figures are included in the page count, but references are not. The following sections must be included.

**Abstract** - A one-page (or less) summary of the topic, the objectives/hypotheses to be achieved/tested, and the methods. The abstract should be written for a general scientific audience, i.e. a person unfamiliar with the topic should understand what is being proposed and why it is important.

**Introduction** - The goal of this section is to motivate the research. Convince the reader why the project is important. The following progression is recommended. Introduce the topic and explain the broader relevance, e.g. what is the practical or fundamental importance. Demonstrate familiarity with previous studies. Identify knowledge gaps and connect to the proposed research.

**Objectives and Hypotheses** - Clearly state the research question to be answered and/or hypotheses to be tested and support it by explaining the logic that led to it. Preliminary data may be used as support.

**Proposed Research** - Describe the methods in sufficient detail to give a clear picture of how each research question will be answered and/or how each hypothesis will be tested. Include a time-line to demonstrate that the proposed work is feasible within the duration of a PhD degree. Describe specific expected results.

#### *Defense of Thesis Proposal to Doctoral Thesis Committee*

At least 10 days prior to the proposal defense, the student e-mails copies of the written proposal to the committee members with a final schedule of when and where the presentation will take place. After e-mailing the proposal to the committee, the candidate should neither solicit nor expect to receive feedback from any of the committee members, including the advisor, prior to the presentation. On the day of the proposal defense, the student brings a copy of the form, Record of Approval of Doctoral Thesis Research, which is available at <https://cee.mit.edu/resources/>.

During and after the oral presentation, the Committee members ask questions related to the presentation, the written proposal, and the general topic of the proposed research. The Committee may raise questions about the motivation, novelty, potential impact, and feasibility. As in the Part 2 evaluation, the research advisor is encouraged to ask questions, but should not answer questions. If necessary, the advisor may prompt the student with further questions to help them answer on their

own. Remember that this is a test of the student's understanding and research ability. It is not a test of the advisor.

At the end of the question period, the student is asked to leave the room while the Committee (including the advisor) evaluates the candidate's performance in these areas: quality of written presentation, quality of oral presentation, technical quality of proposed research, feasibility of research within duration of degree, ability to respond to questions. The possible outcomes are:

- 1) Accept as written
- 2) Accept with modification
- 3) Fail with encouragement to retake within 6 months - the committee must include a list of specific deficiencies
- 4) Fail with specific notes on deficiencies (Only if this is second attempt)

The Committee Chair records the outcome and any specific requirements for alteration on the form Record of Approval of Doctoral Thesis Research. The Committee Chair forwards the completed form to the Graduate Academic Administrator (Kiley Clapper) at the Academic Programs Office (Room 1-290) and provides a copy to the student.

After the approval of the thesis proposal, the student schedules regular meetings with the doctoral committee to demonstrate progress and receive feedback. Two meetings per year are strongly recommended, with a minimum requirement of one per year. In addition, the committee chair may require additionally meetings in response to significant problems or changes in research direction. The student should bring a copy of the form, Record of Doctoral Thesis Committee Meeting, to each meeting. The form is available at <https://cee.mit.edu/resources/>. The student should bring the original, signed form to the CEE Academic Programs Office (1-290), and should keep a copy of the form for their own records. The minimum requirement will be assessed during each CEE Grades Meeting (January and May) using the forms on file at the Academic Programs Office.

### **Approaching the Defense of a Doctoral Thesis**

A few months before an anticipated doctoral defense date, the student must convene a final committee meeting. During this meeting the student's presentation should include an outline of the full thesis, highlighting results from each chapter, indicating papers published, in review or in prep, and including a detailed timeline for completion. The committee will provide the student with their opinion of what is the weakest component of the work and what they foresee as possible stumbling blocks for completion. The committee will then decide whether to approve the outline and allow the student to proceed in scheduling the thesis defense; if the committee members all agree they will sign the "Green Light" *Thesis Committee Meeting* form, which then will be sent to the academic administrator. Only after the committee has given their approval, can the student move forward with planning his or her doctoral thesis defense.

### **Checklist for Doctoral Thesis**

MIT has three degree-granting cycles per year: February, June and September. Several months prior to the defense date, the student should register to be on the appropriate degree list, by going to [student.mit.edu](http://student.mit.edu), selecting "online degree application" and following the instructions. Once this registration is complete, the academic administrator will send the student a detailed email outlining the steps needed to complete the degree and organize the thesis defense.

### **Preparing for and Scheduling your Defense**

The date of a doctoral defense must be at a minimum two weeks prior to the department's thesis submission deadline. The date changes each year, so the student must check with academic administrator to find out the date for a particular degree list. Note that the first draft of the thesis must be sent to the committee two weeks before the scheduled defense date. At least 10 days prior



to the defense date the student should communicate the date, time and location with the academic administrator and fill out the abstract template, which is available from the academic administrator. The student should also send an electronic copy (pdf preferred) of the thesis draft to be shared with the CEE faculty prior to the defense.

**Planning the Public Presentation.**

The formal thesis defense has two components, the public presentation, which anyone can attend, and a closed session with only the thesis committee. The entire thesis committee must attend the defense, either in person or remotely via web-conferencing. The public presentation should be 40 minutes long, with ten minutes for questions at the end. The student is welcome to encourage labmates to attend the public portion and ask good questions. The defense (particularly the introduction) should thus be understandable to a broad audience. The closed session will range from 30 minutes to 1.5 hours long.

To book a room, the student should work with the administrative assistants in Pierce or Parsons. We suggest a reservation of 2.5 hours – with a start time 15 to 20 minutes before the scheduled defense start time and an end time 15 to 20 minutes past the projected meeting end.

**Publicizing the Defense Date**

The student should make flyers publicizing the defense. This should include the student's name the abstract, the title and abstract of the thesis, the thesis supervisor's name, the day, and time, and location of the defense. The abstract should be no more than 350 words long. Images that represents the work, like an interesting graph or chart on the template, and/or a picture of the student, are encouraged. Once the template has been completed, the student should send a pdf copy to the academic administrator, who will distribute the announcement electronically to the CEE community. In addition, the student should print off 11 copies and post 5 in Parsons, using the public bulletin space in the hallways and kitchen, and 5 in Pierce, using the public bulletin space in the hallways and lounge, and also drop one off in 1-290.

**Submitting the Thesis to the Academic Programs Office**

After a successful defense the committee will usually request small edits to to the document. Once the updates have been completed and communicated to the committee, the student submits two signed copies of the thesis printed on acid-neutral or archival bond paper, by 5 pm the day of the department's deadline. (The academic administrator will provide this date.) The academic administrator will be responsible for retrieving the signature of the Chair of the Graduate Program Committee, so the student should not contact him/her directly. The copies must be unbound but secured between heavy cardboard covers with a binder clip. The front cardboard cover of each thesis copy should feature a photocopy of the top half of the thesis signature page (from the copyright up), which can be simply taped or glued on.

**Congratulations!!**

We look forward to the hooding ceremony and graduation to celebrate. Please let us know what is next by filling out the Graduate Student Exit Form: <http://cee.mit.edu/graduate/exitform>

The 3-Subject Core reflects core knowledge in the student's chosen field, which is tested in Part 1 of the General Exam. The subjects are selected from an approved list within one of the following sub-groups. All three subjects must come from the same core list.

## **Atmospheric Physics and Chemistry** [choose three]

- 1.84 Atmospheric Chemistry
- 1.841 Atmospheric Composition in the Changing Earth System
- 1.842 Aerosol and Cloud Microphysics and Chemistry
- 1.83 Environmental Organic Chemistry
- 12.815 Atmospheric Radiation and Convection **/OR/** EPS 238 Spectroscopy & Radiative Transfer of Planetary Atmospheres

## **Engineering Physics for Urban Systems** [choose three]

- 1.204 Computer Modeling: From Human Mobility to Transportation Networks
- 1.631 Fluid Dynamics and Disease
- 1.57 Mechanic of Materials: An Energy Approach
- 4.433 Modeling Urban Energy Flows for Sustainable Cities and Neighborhoods
- 8.333 Statistical Mechanics I

## **Environmental Chemistry** [choose three]

- 1.75 Limnology and Wetland Ecology
- 1.76 Aquatic Chemistry
- 1.83 Environmental Organic Chemistry
- 1.84 Atmospheric Chemistry
- 1.841 Atmospheric Composition in the Changing Earth System

## **Environmental Fluid Mechanics** [choose three]

- 2.25 Fluid Mechanics
- 1.63 Advanced Fluid Mechanics or 1.686 Nonlinear Dynamics and Turbulence
- 1.69 Introduction to Coastal Engineering or 1.685 Nonlinear Dynamics and Waves or 1.138 Wave Propagation
- 1.72 Groundwater Hydrology
- 1.77 Water Quality Control

## **Environmental Microbiology**

- 1.87 Microbial Genetics and Evolution
- 1.89 Environmental Microbiology
- and one of the following:*
  - 1.871 Computational Ecology
  - 6.874 Computational Systems Biology

## **Ecological Dynamics**

- pick three:*
  - 1.871 Computational Ecology
  - 1.TBD Modeling Community Dynamics
  - 1.631 Fluid Dynamics and Disease
  - 8.591 Systems Biology
  - 12.849 Mechanisms and Models of the Global Carbon Cycle
  - 12.586 Modeling Environmental Complexity

**Geotechnics / Geomechanics**

- 1.361 Advanced Soil Mechanics  
*and two of the following*
- 1.364 Advanced Geotechnical Engineering
- 1.37 Geotechnical Measurements and Exploration
- 1.38 Engineering Geology
- 1.72 Groundwater Hydrology

**Hydrology** [choose three]

- 1.72 Groundwater Hydrology
- 1.714 Surface Hydrology
- 1.731 Water Resource Systems
- 1.723 Computational Methods for Flow in Porous Media

**Materials** [choose three, but only one from outside CEE]

- 1.545 Atomistic Modeling and Simulation of Materials and Structures
- 1.570 Micromechanics and Durability of Solids
- 1.573 Structural Mechanics
- 3.22 Mechanical Behavior of Materials
- 3.36 Cellular Solids: Structure, Properties, Applications

**Structures Mechanics / Engineering** [choose three, but only one from outside CEE]

- 1.541 Mechanics and Design of Concrete Structures
- 1.573 Structural Mechanics
- 1.581 Structural Dynamics and Vibrations
- 2.093 Finite Element Analysis of Solids and Fluids I
- 3.22 Mechanical Behavior of Materials

**Systems Engineering**

Select one course each from two different methods

Probability and Statistics: 6.436, 1.203, 6.431

Optimization: 15.093, 15.081

Machine Learning: 15.077, 6.867

Select one CEE domain course

- 1.208 [Resilient Networks]
- 1.202 [Demand Modeling]
- 1.260 [Logistics Systems]
- 1.271 [Supply Chain]
- 1.731 [Water Systems]
- 1.001 [Eng Computation and Data Science]

**Computational Science and Engineering [CSE/CEE]**

for students enrolled in the CSE PhD program in the Center for Computational Engineering (CCE) and residing in CEE; or for students entering the CEE PhD program after completing the CDO SM program from the CCE.

**Software Systems in CSE/CEE [choose three]**

- 1.125 Arch & Eng. Software Sys - CSE approved Subject
- 1.001 Engineering Computation and Data Science
- 6.255 Optimization Methods
- 6.337J Introduction to Numerical Methods - CSE approved Subject

**Flow Models in CSE/CEE [choose three]**

- 1.204 Computer Modeling: From Human Mobility to Transportation Networks
- 1.208 Resilient Infrastructure Networks
- 1.723 Computational Methods for Flow in Porous Media
- 2.097 Numerical Methods for Partial Differential Equations – CSE approved Subject
- 2.096 Intro to Numerical Simulation – CSE approved Subject

**Computational Science for Resource Engineering CSE/CEE [choose three]**

- 1.723 Computational Methods for Flow in Porous Media
- 1.545 Atomistic Modeling and Simulation of Materials and Structures.
- 1.125 Architecting and Engineering Software Systems - CSE approved Subject
- 6.337 Introduction to Numerical Methods - CSE approved Subject
- 2.096 Introduction to Numerical Simulation – CSE approved Subject