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4.450 Syllabus - Fall 2024

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**4.450J/1.575J/4.451 Computational Structural Design and Optimization**  //  Fall 2024

Instructor: Caitlin Mueller  //  TA: Keith Lee



**Subject Description**

This research seminar focuses on cutting-edge applications of computation for creative, early-stage structural design and optimization for architecture. Topics covered include computational design fundamentals, including problem parameterization and formulation; design space exploration strategies, including interactive, heuristic, and gradient-based optimization; and computational structural analysis methods, including the finite element method, graphic statics, and approximation techniques. A range of historical and contemporary examples of structural optimization in theory and practice are introduced and investigated as case studies. Students will also complete semester-long individual research projects, which will focus on the development, implementation, or application of an innovative computational approach for structural design.  In Fall 2024, the class will have a special focus on themes of reuse and circularity, linking with the [ODDS & MODS](https://www.google.com/url?q=https://oddsandmods.mit.edu/&sa=D&source=editors&ust=1725454592537645&usg=AOvVaw1DFA05mRJeg_JlRexJhzAL) program directed by Caitlin Mueller and Sheila Kennedy.

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| **Instructor**  Caitlin Mueller, Associate Professor  [https://mit.zoom.us/my/caitlinm](https://www.google.com/url?q=https://mit.zoom.us/my/caitlinm&sa=D&source=editors&ust=1725454592538683&usg=AOvVaw3gvNnZiUfzDMQ3He8C4QfP)  [caitlinm@mit.edu](mailto:caitlinm@mit.edu)  **Faculty Collaborator**  Sheila Kennedy, Professor  [SKennedy@kvarch.net](mailto:SKennedy@kvarch.net) | **Teaching Assistant**  Keith Lee, BT PhD candidate  [keithjl@mit.edu](mailto:keithjl@mit.edu)  **Office Hours**  To be announced |
| **Meeting Times**  Lecture: Wednesday, 2-5pm in 3-133  **Units and Level**  3-0-9 Undergraduate (4.451)  3-0-6 Graduate (4.450J/1.575J) | **Textbook**  Readings will be provided via Canvas website |

**Subject Canvas Website**

[https://canvas.mit.edu/courses/27995](https://www.google.com/url?q=https://canvas.mit.edu/courses/27995&sa=D&source=editors&ust=1725454592541995&usg=AOvVaw0y-XkU4yoWQapygv1ydMBZ)

**Subject Zoom Room\***

[https://mit.zoom.us/j/95435340888](https://www.google.com/url?q=https://mit.zoom.us/j/95435340888&sa=D&source=editors&ust=1725454592542470&usg=AOvVaw0nhutD1y8kjGZ0daXOqwl-)

\* Our Zoom room will only be used as a backup should in person class not be possible.

**Subject Slack Workspace**

mit-4-451-f2024.slack.com

**Learning Objectives**

After successfully completing this subject, students will gain the following knowledge, skills, and abilities:

* Understand the general context and history of structural optimization in the field of building design.
* Distinguish between types of structural optimization approaches (size, geometry, topology) and generalized optimization methods and algorithms, and make informed decisions about when to use which approach and method.
* Formulate rich design spaces that contain diverse and interesting solutions through variable selection/reduction, bound and constraint setting, and definition of relevant performance objective(s).
* Apply contemporary structural optimization and design space exploration methods to realistic design problems using one or more commercial software or programming environments.
* Visualize optimization and design space exploration results in meaningful, multivariate graphic representations.
* Contribute to the research field of structural computation and optimization through the development, implementation, and/or application of the techniques introduced in the class.
* Explore the potential of computational design in circular architecture and construction.

**Subject Meeting Structure and Interaction**

In Fall 2024, all class meetings will be in person, unless otherwise announced.  Attendance and participation are mandatory and evaluated as part of the semester grade (see below).  Class meetings will include lecture, discussion, collaborative problem solving, and software tutorials.  Additional asynchronous interaction related to class content will be available on Slack.

**Office Hours**

Meetings with the instructor will be by appointment, but class-related questions should first be directed to the TA. The TA will hold a weekly two-hour period in person (or on Zoom if necessary) for students to come and ask questions about the class’s content, assignments, etc.  There will also be ample opportunities to ask questions in class.  Students are asked to be respectful of the TA’s schedule and should prepare questions in advance of deadlines.  The TA will not be able to respond promptly outside of business hours, on weekends, etc.

**Assignments and Project**

The central focus of this subject is a semester-long original research/design project, supported by three (four for students taking the 12 units version) preliminary homework assignments, weekly readings, and class discussions.  Work is to be completed individually unless other arrangements are made.  Late assignments will result in a reduction of one letter grade per day after the deadline unless extreme circumstances warrant an extension (must be arranged with TA 24 hours before the deadline).

**Evaluation Criteria + Grading Breakdown**

|  |  |
| --- | --- |
| 10% | Attendance and Participation: Students are expected to attend the full session of each class and to actively contribute to the intellectual atmosphere via discussions, in-class exercises, and general participation.  Unexcused absences and/or non-participation will result in a grade reduction. |
| 45% | Assignments: Three (four for students taking the 12 units version) homework assignments must be submitted via the Canvas site in approximately the first half of the term.  At least six possible assignments will be distributed, and students may choose to submit three (four for 12-unit version).  If more are completed, the best three (four for 12-unit version) grades will be counted. |
| 10% | Final Project Milestones: Two interim milestones (5% each) for the final project will be distributed and submitted via the Canvas site for evaluation of preliminary progress. |
| 10% | Final Project Presentation: Students will each give a 10-minute research presentation highlighting the key contributions of their final projects.  Evaluation will consider both the content and the quality/clarity of the presentation. |
| 25% | Final Project Paper: The main deliverable for the course is the final research paper, which clearly and concisely presents the original research work completed during the course.  The paper should be written in the style of a scholarly, technical academic publication that could be presented at a conference or submitted to a journal.  The evaluation will consider creativity of the project concept, technical originality, scholarly quality, technical accuracy, and thoroughness of results.  More information about the final project will be distributed later in the term. |

**Office Hours**

Meetings with the instructor will be by appointment. The TA will hold a weekly two-hour period for students to come and ask questions about the class’s content, assignments, etc.

**Absence Policy**

Attendance and participation are mandatory and part of this subject’s grade (10%).

**Academic Integrity + Honesty**

MIT's expectations and policies regarding academic integrity should be read carefully and adhered to diligently:  [http://integrity.mit.edu](https://www.google.com/url?q=http://integrity.mit.edu&sa=D&source=editors&ust=1725454592547592&usg=AOvVaw1wd-Z4wtlglPlwAviotY-J)

**Semester Schedule**

|  |  |  |  |
| --- | --- | --- | --- |
| **Week** | **Date** | **Lecture Topic** | **Assignments + Project** |
| 01 | 09/04 | Introduction |  |
| 02 | 09/11 | Classical Structural Optimization I: Analytical Methods | HW 01 Assigned |
| 03 | 09/18 | Optional Homework Work Session |  |
| 04 | 09/25 | Classical Structural Optimization II: Numerical Methods | HW 02 Assigned, HW 01 Due |
| 05 | 10/02 | Structural Modeling and Performance Evaluation | Project Assigned |
| 06 | 10/09 | Formulating, Exploring, Visualizing the Design Space | HW 03 Assigned, HW 02 Due |
| 07 | 10/16 | Multi-Objective Optimization | HW 04 Assigned |
| 08 | 10/23 | Finite Element Analysis | HW 03 Due |
| 09 | 10/30 | Interactive Optimization and Design Space Guidance | HW 05 Assigned (+1), HW 04 Due |
| 10 | 11/06 | Interim Project Presentations | Project Milestone 1 Due |
| 11 | 11/13 | Form-Finding and Optimization of Surface Structures | HW 05 Due (+1), HW 06 Assigned |
| 12 | 11/20 | Optional Project Meetings |  |
| 13 | 11/27 | Combinatorial Search and Discrete Assemblies | HW 06 Due |
| 14 | 12/04 | Creative Machine Learning and Advanced Topics | Project Milestone 2 Due |
| 15 | 12/11 | Final Project Presentations I |  |
| Finals | TBA | Final Project Presentations II\* | Final Paper Due |

*\* Half of final project presentations will occur in Final Exam Week, with the exact date determined by MIT around the third week of classes.  Participation at the final project presentations is mandatory.*