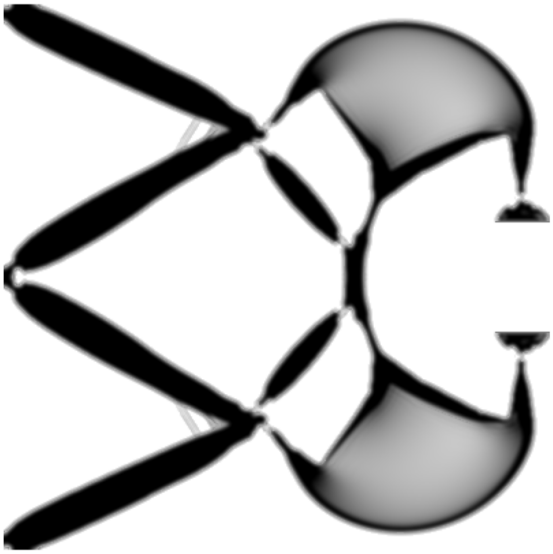

ME498 – Mechanical Design Optimization

Fall 2025 Syllabus

Prof. Tom Golecki, PhD, PE, SE
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Course Overview

This course is intended to introduce the basic concepts of design optimization with applications from multiple industries. The course will begin with a brief summary of numerical optimization and examples using parametric design and sizing optimization. Then the finite element method is introduced for use in topology optimization. Examples of optimal structures and mechanisms will demonstrate a reduction in material usage, improved product performance and shorter design cycles compared to heuristic design. The course includes assignments in the form of design challenges and a final project in which students will optimize an original design.

Learning Objectives

After this course, students will be able to:

- Develop an optimization framework for a design task
- Identify design parameters, objectives, and constraints
- Derive expressions for sensitivities of objective/constraint functions with respect to design variables
- Implement gradient-based numerical optimization for these design tasks using Python/Matlab
- Implement size/shape/topology optimization

Course Logistics

- **Term**: Fall 2025
- **Credits**: 3 for section TG3, 4 for sections TG4 or TGO
- **Duration**: Full Semester
- **Format**: In-person for sections TG3 and TG4, asynchronous remote for section TGO
- **Website**: https://canvas.illinois.edu
- **Communications**: https://campuswire.com/p/GBB3A3124 Code: 5024
- **Lecture**: Tues. & Thurs. 12:00–1:20 PM, 410B1 Engineering Hall.
- **TFG Office Hours**: TBD
- **TA**: Sebastian Pozo (pspozo2@illinois.edu)
- **SP Office Hours**: TBD
- **Workload Expectation**: 2-4 hours outside of class for every hour of class time.

Primary References

- Course Notes, to be distributed on canvas.

Supplimental References

- Engineering Design Optimization, Martins & Ning [M&N]
- Numerical Optimization, Nocedal & Wright [N&W]
- An Introduction to Structural Optimization, Christensen & Klarbring [C&K]
- A First Course In Finite Elements, Fish and Belytschko [F&B]
- Introduction to Finite Element Methods, Felippa [Felippa]
- Topology Optimization: Theory, Methods, and Applications, Bendsøe & Sigmund [B&S]

Assessments

Homework, 35%

Weekly homework assignments submitted via Gradescope. While working with peers is encouraged, everyone must submit entirely original work.

Midterm Exam, 30%

An in-class exam in early November.

Final Project, 35%

Students will develop original optimization code and apply it to a chosen design task. The project will be delivered in the style of a conference; OptiCon 2025. The initial submission of an abstract proposing the project will allow for instructor feedback. The final submission will include a report and a prerecorded presentation.

Course Outline

(Note: All times are estimates and subject to change.)

1. Introduction
   - Week 1 (8/25-8/29)
   - Topics: Motivation, Design Process, Background/Review
   - Suggested Reading:
     - M&N App. A
2. Optimization Basics
   - Weeks 2,3 (9/1 - 9/12)
   - Topics: Optimization Statements, Terminology, Optimality Conditions, Graphical Methods
   - Suggested Reading:
     - M&N Ch. 1
     - C&K Ch. 1
3. Numerical Methods
   - Weeks 4,5 (9/15 - 9/26)
   - Topics: 1D (Line Search) & nD (Linear Programming, Steepest Descent, Newton's Method) Unconstrained Methods, nD Constrained Methods
   - Suggested Reading:
     - M&N Ch. 4-5
4. Finite Element Analysis
   - Weeks 6,7,8 (9/29 - 10/17)
   - Topics: Truss Elements in 1D & 2D, Elasticity, Plane Stress Elements
   - Suggested Reading:
     - F&B
5. Sensitivity
   - Weeks 9,10 (10/20 - 10/31)
   - Topics: Finite Difference, Adjoint & Direct Methods
   - Suggested Reading:
     - M&N Ch. 6
     - C&K Ch. 6
6. Topology Optimization
   - Weeks 11,12,13 (11/3 - 11/21)
   - Topics: Size & Topology Optimization, Penalty (Material Interpolation), Filtering, Sensitivity, Model Updating, Numerical Implementation
   - Suggested Reading:
     - C&K Ch. 9

    - B&S Ch. 1

7. Special Topics (time permitting)
    - Weeks 15,16 (12/1 - 12/9)
    - Potential Topics: Compliant Mechanisms, Heat transfer, Dynamics, Uncertainty...
    - Suggested Reading: TBD

Course Policies

- **Assignments submitted late will receive zero credit.**
- **Academic Integrity:**
  - This course has a zero-tolerance policy with regards to academic integrity violations. This includes cheating, plagiarism, fabrication, and facilitating infractions by others.
  - You are expected to adhere to all of the rules pertaining to academic integrity outlined in the UIUC Student Code. https://studentcode.illinois.edu/article1/part4
- **Acceptable sources for assistance**
  - We will have adequate office hours distributed throughout the week, with the professor and with the TAs. You are free to make use of this time for assistance on the homework assignments.
  - You are also free to work in partnership with other students, as long as the work you submit is your own and represents your understanding of the course material.
  - Feel free to use other textbooks as aids.
- **Generative AI:**
  - You may use generative AI programs e.g. ChatGPT, Gemini etc. as a tool to aid in your work (not as a substitute for your own understanding). However, you should note that the material generated by these programs may be inaccurate, incomplete, or otherwise problematic. You are ultimately responsible for the correctness of your submitted work. Use of generative AI should be cited. Any code/programming generated by AI should be clearly designated as such.
- **Copyright:**
  - All materials that the instructors provide during the course are copyrighted (even if not explicitly stated on the materials). This copyright will apply to all course notes, homework problem sets, exams, Matlab code, solutions of any kind, etc.
  - You are not permitted to share the materials outside of the course (e.g. homework sharing websites). That is a copyright violation and may be prosecuted under the "facilitating infractions" clause of the academic integrity code.
  - Please remember that the course materials are the intellectual property of the instructors and TAs. We hope that you will act respectfully in this regard.
- **Mental Health:**
  - Diminished mental health, including significant stress, mood changes, excessive worry, substance/alcohol abuse, or problems with eating and/or sleeping can interfere with optimal academic performance, social development, and emotional wellbeing. The University of Illinois offers a variety of confidential services including individual and group counseling, crisis intervention, psychiatric services, and specialized screenings at no additional cost. If you or someone you know experiences any of the above mental health concerns, it is strongly encouraged to contact or visit any of the University's resources

provided below. Getting help is a smart and courageous thing to do – for yourself and for those who care about you.

Counseling Center: 217-333-3704, 610 East John Street Champaign, IL 61820

McKinley Health Center: 217-333-2700, 1109 South Lincoln Avenue, Urbana, Illinois 61801

- **Sexual Misconduct:**
  - The University of Illinois is committed to combating sexual misconduct. Faculty and staff members are required to report any instances of sexual misconduct to the University's Title IX Office. In turn, an individual with the Title IX Office will provide information about rights and options, including accommodations, support services, the campus disciplinary process, and law enforcement options.

    A list of the designated University employees who, as counselors, confidential advisors, and medical professionals, do not have this reporting responsibility and can maintain confidentiality, can be found at: https://wecare.illinois.edu/resources/students/#confidential. Other information about resources and reporting is available here: https://wecare.illinois.edu/.

- **Religious Accommodations:**
  - Illinois law requires the University to reasonably accommodate its students' religious beliefs, observances, and practices in regard to admissions, class attendance, and the scheduling of examinations and work requirements. You should examine this syllabus at the beginning of the semester for potential conflicts between course deadlines and any of your religious observances. If a conflict exists, you should notify your instructor of the conflict and follow the procedure at https://odos.illinois.edu/community-of-care/resources/students/religious-observances/ to request appropriate accommodations. This should be done in the first two weeks of classes.

- **Disability Services:**
  - To obtain disability-related academic adjustments and/or auxiliary aids, students with disabilities must contact the course instructor and the Disability Resources and Educational Services (DRES) as soon as possible. To contact DRES, you may visit 1207 S. Oak St., Champaign, call 217-333-4603, e-mail disability@illinois.edu or go to https://www.disability.illinois.edu. If you are concerned you have a disability-related condition that is impacting your academic progress, there are academic screening appointments available that can help diagnosis a previously undiagnosed disability. You may access these by visiting the DRES website and selecting "Request an Academic Screening" at the bottom of the page.

- **Anti-Racism and Inclusivity:**
  - The Grainger College of Engineering is committed to the creation of an anti-racist, inclusive community that welcomes diversity along a number of dimensions, including, but not limited to, race, ethnicity and national origins, gender and gender identity, sexuality, disability status, class, age, or religious beliefs. The College recognizes that we are learning together in the midst of the Black Lives Matter movement, that Black, Hispanic, and Indigenous voices and contributions have largely either been excluded

from, or not recognized in, science and engineering, and that both overt racism and micro-aggressions threaten the well-being of our students and our university community. The effectiveness of this course is dependent upon each of us to create a safe and encouraging learning environment that allows for the open exchange of ideas while also ensuring equitable opportunities and respect for all of us. Everyone is expected to help establish and maintain an environment where students, staff, and faculty can contribute without fear of personal ridicule, or intolerant or offensive language. If you witness or experience racism, discrimination, micro-aggressions, or other offensive behavior, you are encouraged to bring this to the attention of the course director if you feel comfortable. You can also report these behaviors to the Bias Assessment and Response Team (BART) (https://bart.illinois.edu/). Based on your report, BART members will follow up and reach out to students to make sure they have the support they need to be healthy and safe. If the reported behavior also violates university policy, staff in the Office for Student Conflict Resolution may respond as well and will take appropriate action.