Design, modeling and integration of compliance into systems that enable performance which is impractical to obtain via rigid mechanisms. Students learn multiple strategies (pseudo-rigid body modeling, topology synthesis, freedom and constraint topology) to engineer compliant mechanisms for modern mechanical systems. Emphasis is placed upon the use of first principles to optimize planar and spatial kinematics, stiffness, energy storage/release, load capacity, efficiency and integration with actuation/sensing. Students apply the preceding to synthesize concepts, optimize them via computational models and test prototype(s) for prototype-based mechanical problem sets and a term project. Mechanical problem sets and projects are drawn from areas that include biological systems, prosthetics, energy harvesting, precision instrumentation, robotics, space-based systems and others.

**Date** | **Lecture** | **Reading quiz** | **Mini project** | **Laboratories**
---|---|---|---|---
01/09/06 | Fundamental issues, concepts, principles; elements/systems | | | - No lab -
02/09/06 | Boot camp: Practical application of 2.001, 2.002 and 2.003 | Engineering bootcamp worksheet | | Engineering bootcamp I Units, magnitudes, basics
03/09/06 | Boot camp: Practical application of 2.005, 2.007 & 2.008 | | | Engineering bootcamp II Decision making
04/09/06 | Approach: Constraint-based design [Theory] | Blanding | | - No Lab -
05/09/06 | Approach: Constraint-based design [Examples] | | | CBD
06/09/06 | Project work and coaching sessions | | | Flexure building blocks
08/09/06 | Approach: Freedom and constraint topology [Practice] | | | CBD: Satellite or CBD examples
09/09/06 | Project work session (on your own) [Jury Duty] | | | - No Lab -
10/10/06 | No class [Student holiday] | | | - No Lab -
11/10/06 | Approach: Freedom and constraint topology [Practice] | Howell | | FACT: Screw motions Screw drive & AFM stage
12/10/06 | Approach: Pseudo-rigid body modeling [Theory] | | | PRBM
13/10/06 | No class [MC at ISAM] | FACT: Screw motions | | Lect: [Practice] 4 bar/airfoil
14/10/06 | Approach: Pseudo-rigid body modeling [Examples] | | | PRBM
15/10/06 | Project work and coaching sessions | | | CBD: Satellite or CBD examples
16/10/06 | Approach: Topological synthesis methods (overview) | Kota (Ext Cr) | | Optional: Project coaching session
17/11/06 | Modeling: Stiffness matrices I | SM | | Modeling: Stiffness matrices
18/11/06 | Modeling: Stiffness matrices II | PRBM: Robot gripper | | Modeling: Stiffness matrices
19/11/06 | Modeling: FEA | | | Optional: Project coaching session
20/11/06 | Analysis & optimization: Energy | | | Project coaching session
21/11/06 | Project work and coaching sessions | | | MODELING
22/11/06 | Project work and coaching sessions | | | Energy
23/11/06 | Analysis & optimization: Kinematics & elastomechanics | | | MODELING
24/11/06 | Analysis & optimization: Dynamics | | | Motion, stiffness, vibrations
25/11/06 | Project work and coaching sessions | ENERGY: Bi-stable mechanism | | CASE STUDY
26/12/06 | Integration: Sensors and actuators | | | Microtome actuators/sensors
27/12/06 | Integration: Fabrication, assembly & calibration | | | - No lab -
28/12/06 | Project work and coaching sessions | BIOMIMETIC: Insect skeleton | | - No lab -
29/12/06 | Final day of class, recap & share projects | | | - No lab -

**GRADING**

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Teaching philosophy

“The man who sets out to carry a cat by its tail learns something that will always be useful and which never will grow dim or doubtful.” --Mark Twain

Many students misunderstand the purpose of the modeling content they are exposed to. This leads to a misperception that equations embody all abilities required to practice engineering. Models are critical, but your decisions and actions must be based on:

(1) Understanding that engineering models are idealizations of real systems. The only thing that “perfectly” models a real system is a physical embodiment of that system. The process of “synthesizing-modeling-fabricating-testing” a prototype helps to provide this insight.

(2) Mastering how to judiciously combine a, b and c… vs relying on them alone:
   (a) Concepts, principles and design processes are necessary, but not sufficient alone
   (b) Mathematics, physics and engineering modeling are necessary, but not sufficient alone
   (c) Practical skills and familiarity with best practices are necessary, but not sufficient alone

Project design notebooks

Each student must keep a design notebook. Notebooks will be collected without warning. Notebooks must adhere to best practices guidelines. No 3-ring binders or digital notebooks will be accepted and class notes may not be included.

Useful texts (not necessary to purchase for this class)

1. Topology optimization of compliant mechanisms; Xianmin Zhang, Benliang Zhu
2. Handbook of compliant mechanisms; Larry Howell, Spencer Magleby, Brian Olsen
3. Compliant mechanisms: Design of flexure hinges; Nicolae Lobontiu
4. Designing compliant mechanism suspensions; Thorsten Schrader
5. Flexures: Elements of elastic mechanisms; Stuart Smith
6. Exact constraint machine design using kinematic processing; Douglass Blanding
7. Principles/techniques for designing precision machines; Layton Hale
8. A treatise on the theory of screws; Robert Ball
9. The Art of Flexure mechanism design; Florent Cosandier, Simon Henein, Murielle Richard, Lennart Rubbert

Lab sessions

Labs may resemble recitations, sometimes design reviews, sometimes case studies, and sometimes hands-on labs. Much of lab will focus on applying theory in practice. You must attend all labs to pass the class, unless you’re pre-approved or excused by Prof. Culpepper.

Use of the Maker Workshop

You may make components for your assignments and project in any shop you choose. The Maker Workshop is available for any MechE student, or student in a MechE class. HOWEVER, respect the student mentors and strive to make judicious use of the facility. Be respectful of their time, the materials they have in the shop, and the tools/machines. If you break something accidentally… it happens when you are learning engineering - just make sure to let them know so they can take care of the problem and get reimbursed for expenses from the class.

Excused absences due to COVID and other

If a student misses a lecture, lab or presentation due to COVID, Prof. Culpepper will work with them to create a plan to make up the work. If a student misses a quiz, they will be scheduled for a make-up after they return, with suitable time to prepare. Students that test positive for COVID may ask for additional time to complete assignments. This will be worked out between the student and Prof. Culpepper.

Your physical and mental well-being

An MIT education is analogous to training for the Olympics. No athlete believes that being trained as an amateur will help them win a medal. This course is training you to become an “elite” engineer, and sometimes that means making you work in ways that will stretch you… ways that don’t seem obvious as to how they will prepare you to do engineering work that you have not done before. This is a rigorous course in which you’ll be expected to demonstrate that you’ve mastered the material and are capable of operating on your own to realize designs that meet requirements. With that said, your physical and mental well-being are of utmost importance. Just as an athlete can over-train, students can be overwhelmed, burn-out and be stressed in ways that are not helpful. There is no shame in admitting this if it happens to you. If so, know that Prof. Culpepper is very open to discussing your situation and working with you to make necessary and reasonable adjustments.