ME/BMES 5764  Course Outline  Spring 2017
Modeling MEMS and NEMS

Lecturer:
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Tuesday and Thursday 11:00-12:15, 241 Goodwin Hall
Office hours: Wed 2:00-3:00, and by appointment.

Course Description:
This course is about the construction, analysis and interpretation of mathematical models of microelectromechanical and nanoelectromechanical (MEMS and NEMS) systems. The major goal will be to develop a physical intuition for the fundamental and dominant physics at these small scales. This knowledge is necessary to understand and contribute to the exciting technological and scientific developments occurring at the micron- and nanoscales. The material covered will be broad and interdisciplinary including: dimensional analysis and scaling, a review of continuum mechanics, microfluidics and low Reynolds number flow, biological applications, an introduction to the calculus of variations, the modeling of a variety of MEMS/NEMS systems, stochastic and deterministic approaches, an introduction to statistical thermodynamics, and approaches beyond the continuum theory.

Expanded Outline:

1. Introduction to MEMS and NEMS
   - A short history
   - Recent advances and current state of the art

2. A review of continuum mechanics
   - The continuum hypothesis

3. Elasticity
   - The Navier equations
   - Introduction to the calculus of variations
   - Vibrating strings and membranes
   - Elastic beams and plates

4. Linear thermoelasticity
   - Thermal expansion of a rod

5. Fluid dynamics
• The Navier-Stokes equations
• Incompressible flow
• The Euler equations
• The Stokes equations

6. Modeling microfluidic systems
• Microfluidic devices
• Fluidic scaling
• Applications to biological systems

7. Electromagnetism
• Maxwell’s equations
• Electrostatics and magnetostatics

8. Small is different
• Scaling at the micron- and nano-scales
• Viscosity of fluids
• Rigidity of structures
• Electrostatics and fluid interfaces

9. Modeling MEMS and NEMS systems
• Coupled thermal-elastic systems
• Electrostatic-elastic systems
• Magnetically actuated systems

10. Modeling of stochastic dynamics
• Introduction to statistical thermodynamics
• Brownian motion
• The Langevin equation
• Correlation functions and linear response theory
• The fluctuation dissipation theorem

11. Numerical approaches to modeling MEMS and NEMS
• First step: Formulating the right question to ask
• A survey of currently used approaches

12. Beyond the continuum theory
• Limits of continuum mechanics
• Devices and systems beyond the continuum theory