

COURSE SYLLABUS SPRING 2011

ME C219 & EE C246 Parametric and Optimal Design of Microelectromechanical Systems

Room & Schedule: 3113 Etcheverry Hall, Tu & Th 3:30-5:00 p.m.

Class Web Site: <http://www.me.berkeley.edu/ME219>

Instructor: **Dr. Debbie G. Senesky**

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Office Hours: Tu & Th 5:10-6:00 p.m. in 5101 Etcheverry Hall

Teaching Assistant: **Ms. Nuo Zhang**

TA Office Hours: W 3:30-4:30pm in 5101 Etcheverry Hall

CLASS DESCRIPTION

Parametric design and optimal design will be applied to MEMS, with an emphasis on design and not on fabrication. The format of the course will be oriented toward design projects. The student will learn to rigorously formulate MEMS design problems analytically and then determine the correct dimensions of MEMS structures so that the specified function is achieved. The formulation will allow the student to trade off various performance requirements and thereby develop a rational design compromise solution when faced with conflicting design requirements. A variety of MEMS structures will be treated in this class, including flexure systems, accelerometers and rate sensors. A variety of design and optimization methods will be used to numerically and analytically determine the design. This course presumes the student is already familiar with a variety of basic MEMS fabrication processes. ME 119 and ME C218 / EE C245 are highly recommended (but not mandatory) prerequisites.

LECTURE SCHEDULE

Week 1 (Tu, Jan. 18 & Th, Jan.20)

MEMS Overview: Unique Characteristics of MEMS; Typical Application Areas of MEMS

MEMS Overview: Examples of MEMS; Future Directions of MEMS

MEMS Solutions for Data Storage: Technical Rationale; HexSil Linear Actuator

Week 2 (Tu, Jan. 25 & Th, Jan. 27)

MEMS Solutions for Energy Storage: Overview; MEMS Energy Harvesters; Other Technologies

MEMS Flexures: Overview; Technical Rationale; Examples

MEMS Flexures: Optimal Design; Basic Flexure Types: Hammock, Crab-leg and Double-folded

Week 3 (Tu, Feb. 01 & Th, Feb. 03)

****PROJECT 1: Parametric Design of MEMS Flexures for X- and Y-Stiffness**

MEMS Flexures: Stress Analysis; Flexible Design Method; Unified Beam Bending Theory

MEMS Accelerometer: Dynamic Principles; Design; Analysis; Survey of Accelerometers

MEMS Flexures: Meandering Flexures; Solving Procedures

Week 4 (Tu, Feb. 08 & Th, Feb. 10)

MEMS Flexures: Non-linear limits; Shear and Axial Effect

MEMS Flexures: Electrostatic Actuation: Derivation

MEMS Materials: Mechanical Properties of Materials; MEMS Material Deposition Process

Week 5 (Tu, Feb. 15 & Th, Feb. 17)

MEMS Materials: Failure of Materials; MEMS Materials Tests

MEMS Anchors: Background; Fabrication; Finite Element Model
Distributed Parameter Oscillator: Rayleigh's Principle; Rayleigh's Energy Method

Week 6 (Tu, Feb. 22 & Th, Feb. 24)

****PROJECT 2: Parametric Design of MEMS Accelerometer**
MEMS Angular Accelerometer: Design Concept; Analysis
MEMS Optimization: Design; Optimization Paradigm; Examples
MEMS Optimization: Monotonicity Analysis

Week 7 (Tu, Mar. 01 & Th, Mar. 03)

MEMS Optimization: Monotonicity Analysis
MEMS Optimization: Monotonicity Analysis
MEMS Optimization: Parametric Optimization; Constrained Optimization

Week 8 (Tu, Mar. 08 & Th, Mar. 10)

**** PROJECT 3: Optimal Design of MEMS Angular Accelerometer via Monotonicity Analysis and Grid Study**
MEMS Optimization: Penalty Function Method
MEMS Optimization: Unconstrained Optimization; Method of Steepest descent
MEMS Optimization: MATLAB Package of Optimization Routines

Week 9 (Tu, Mar. 15 & Th, Mar. 17)

MEMS Optimization: Quadratic Approximation; Conjugate Directional Method
MEMS Optimization: Lagrange Multiplier Method
MEMS Pivots: Stress Analysis

Week 10 (Tu, Mar. 22 & Th, Mar. 24)

Spring Break (No Class)

Week 11 (Tu, Mar. 29 & Th, Mar. 31)

MEMS Pivots: Stress Evaluation; Design Approach
MEMS Fluidics: Overview
MEMS Fluidics: Micro Mixers

Week 12 (Tu, Apr. 05 & Th, Apr. 07)

****PROJECT 4: Optimal Design of Linear MEMS Suspension via Penalty Function Method**
MEMS Fluidics: Micro Needles
MEMS Fluidics: Micro Valves and Pumps
MEMS Flow: Newtonian Fluids; Couette Flow; Viscous Damping of Resonators

Week 13 (Tu, Apr. 12 & Th, Apr. 14)

MEMS Flow: Stokes Solution; Effect of Reynolds Number
MEMS Flow: Stokes Flow; Poiseuille Flow; Pressure Drop; Entrance Effects
MEMS Flow: Surface Energy; Bubble Actuators; Bubble Valve

Week 14 (Tu, Apr. 19 & Th, Apr. 21)

MEMS Visualization: Methods and Results
MEMS Simulation: Micromirror
MEMS Inertial Instrument: Rotary Internal Combustion Engine

Week 15 (Tu, Apr. 26 & Th, Apr. 28)

MEMS Inertial Instrument: Angular Rate Sensing
MEMS Inertial Instrument: Review of Gyroscopes
MEMS Inertial Instruments: Analog Devices' ADXL50

Week 16 (Tu, May 03 & Th, May 05)

MEMS Research: Programs at DARPA

Extra Class

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GRADING

Projects 1, 2, 3 & 4 carry equal weight. Projects 1 and 2 are joint projects (two partners, maximum), jointly executed and jointly submitted. Projects 3 and 4 are submitted in “reduced format.”

DEADLINES

Unless otherwise specified on the Project assignment sheet, Projects #1, 2, 3 and 4 are due in class on the Thursday of the week that the following project is assigned. **Unannounced late projects are not guaranteed to be accepted.** Even if accepted, late projects receive a 20% penalty. Five days notice must be given to negotiate submission of late projects without grading penalties.

REQUIRED TEXTBOOKS

The required textbook for this class is the class reader that is available on the Class Web Site. If requested, a hardcopy of the class reader will be made available at a local copy store.

OPTIONAL TEXTBOOK

(Recommended as Primary Reference, Purchase Encouraged but Not Required)

“*Foundations of MEMS*,” by Chang Liu, Pearson Prentice Hall, 2006.

AUXILIARY TEXTS

(Reference Only, No Purchase Required)

“*Formulas for Stress and Strain*,” by R. J. Roark and W. C. Young (6th Ed) or “*Roark’s Formulas for Stress and Strain*,” by W. C. Young (7th Ed) 2002. Also found at <http://www.knovel.com/knovel2/Toc.jsp?BookID=475> Web access requires the campus proxy server access (Calnet ID and pass) and has all chapters available in PDF format. No downloads of the PDFs allowed.

“*Micro Flows: Fundamentals and Simulation*,” by G. E. Karniadakis and A. Beshkok, Springer-Verlag, 2002.

“*Microsystem Design*,” by S. D. Senturia, Kluwer Academic Publishers, 2001.

“*Silicon Micromachining*,” by H. Elwenspoek and H. Jansen, Cambridge University Press, 1998.

“*Micromachined Transducers Sourcebook*,” by Gregory T. A. Kovacs, WCB/McGraw-Hill, 1998.

“*Fundamentals of Microfabrication*,” by Marc Madou, CRC Press, 1997.

“*MATLAB User’s Guide*,” The Mathworks, Inc., 1992.

“*Principles of Optimal Design*,” by P. Y. Papalambros and D. J. Wilde, Cambridge University Press, 1988.

“*Optimization Methods for Engineering Design*,” by R. L. Fox, Addison-Wesley, 1971.

“*Applied Optimal Design*,” by E. J. Haug and J. S. Arora, John Wiley & Sons, 1979.

“Numerical Optimization Techniques for Engineering Design,” by G. N. Vanderplatts, McGraw-Hill, 1984.

“Introduction to Optimum Design,” by J. S. Arora, McGraw-Hill, 1989.

“Engineering Optimization -- Methods and Applications,” by G. V. Reklaitis, A. Rivindran, and K. M. Ragsdell, John Wiley and Sons, 1983.

“Mechanical Engineering Design,” by J. E. Shigley and L. D. Mitchell, McGraw-Hill, NY, 1983.

“Fundamentals of Mechanical Design,” by R. M. Phelan, McGraw-Hill, 1970.

“Machine Design,” by R. H. Creamer, Addison-Wesley, 1984.

“Mechanical Analysis and Design,” by A. H. Burr and J. B. Cheatham, Prentice-Hall, 1993.