Class Syllabus Spring 2009

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

Room & Schedule: 310 Hearst Memorial Bldg, MWF 9:10-10:00 a.m.
Class Web Site: **http://www.me.berkeley.edu/ME219**

Instructor: **Professor Albert P. Pisano**
appisano@me.berkeley.edu
Office Hours: MWF 10:10-11:00 a.m. in 6143 Etcheverry Hall

Teaching Assistants: Jim Cheng (chengjcm@eecs.berkeley.edu)
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Discussion Section: **TBD**

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

Num	Date	Topic
	January	
1	21	MEMS Overview: Unique Characteristics of MEMS; Typical Application Areas of MEMS
2	23	MEMS Overview: Examples of MEMS; Future Directions of MEMS
3	26	MEMS Solutions for Data Storage: Technical Rationale; HexSil Linear Actuator;
4	28	MEMS Solutions for Data Storage: V-HARM; Fabrication Issues; Other Technologies
5	30	MEMS Flexures: Overview; Technical Rationale; Examples
	February	
6	2	MEMS Flexures: Optimal Design; Basic Flexure Types: Hammock, Crab-leg and Double-folded
7	4	MEMS Flexures: Stress Analysis; Flexible Design Method
8	6	MEMS Flexures: Unified Beam Bending Theory
9	..9	MEMS Accelerometer: Dynamic Principles; Design; Analysis; Survey of Accelerometers
10	11	MEMS Flexures: Meandering Flexures; Solving Procedures
11	13	MEMS Flexures: Non-linear limits; Shear and Axial Effect
	16	**Presidents' Day (Class Holiday)**
12	18	MEMS Flexures: Electrostatic Actuation: Derivation
		PROJECT 1: Parametric Design of MEMS Accelerometer
13	20	MEMS Materials: Mechanical Properties of Materials; MEMS Material Deposition Process

14	23	MEMS Materials: Failure of Materials; MEMS Materials Tests
15	25	MEMS Anchors: Background; Fabrication; Finite Element Model
16	27	Distributed Parameter Oscillator: Rayleigh’s Principle; Rayleigh’s Energy Method

March

17	2	MEMS Angular Accelerometer: Design Concept; Analysis
18	4	MEMS Optimization: Design; Optimization Paradigm; Examples
19	6	MEMS Optimization: Monotonicity Analysis
20	..9	MEMS Optimization: Monotonicity Analysis
21	11	MEMS Optimization: Monotonicity Analysis
22	13	MEMS Optimization: Parametric Optimization; Constrained Optimization
23	16	MEMS Optimization: Penalty Function Method
24	18	MEMS Optimization: Unconstrained Optimization; Method of Steepest descent

PROJECT 2: Optimal Design of MEMS Angular Accelerometer via Monotonicity Analysis and Grid Study

25	20	MEMS Optimization: MATLAB Package of Optimization Routines

23-27 Spring Recess (Class Holiday)

26	30	MEMS Optimization: Quadratic Approximation; Conjugate Directional Method

April

27	..1	MEMS Optimization: Lagrange Multiplier Method
28	..3	MEMS Pivots: Stress Analysis
29	..6	MEMS Pivots: Stress Evaluation; Design Approach
30	8	MEMS Fluidics: Overview
31	10	MEMS Fluidics: Micro Mixers
32	13	MEMS Fluidics: Micro Needles
33	15	MEMS Fluidics: Micro Valves and Pumps
34	17	MEMS Flow: Newtonian Fluids; Couette Flow; Viscous Damping of Resonators

PROJECT 4: Optimal Design of Linear MEMS Suspension via Penalty Function Method

35	20	MEMS Flow: Stokes Solution; Effect of Reynolds Number
36	22	MEMS Flow: Stokes Flow; Poiseuille Flow; Pressure Drop; Entrance Effects
37	24	MEMS Flow: Surface Energy; Bubble Actuators; Bubble Valve
38	27	MEMS Visualization: Methods and Results
39	29	MEMS Simulation: Micromirror

May

40	1	MEMS Inertial Instrument: Rotary Internal Combustion Engine
41	4	MEMS Inertial Instrument: Angular Rate Sensing
42	6	MEMS Inertial Instrument: Review of Gyroscopes
43	8	MEMS Inertial Instruments: ADXL50
44	11	MEMS Research: Programs at DARPA

GRADING

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

DEADLINES

Unless otherwise specified on the Project assignment sheet, Projects #1, 2, and 3 are due in class on the Wednesday of 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. An auxiliary text will be provided free of charge: “An Introduction to Microelectromechanical Systems Engineering,” by Nadim Maluf, Artech House, 2000.

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.

CLASS EMAIL LIST

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