

**COURSE INFORMATION****Instructor:**

Professor Clark Nguyen, 574 Cory Hall, Tel: (510)642-6251  
E-mail Address: [ctnguyen@berkeley.edu](mailto:ctnguyen@berkeley.edu)

Office Hour: M 1-2 p.m., in 574 Cory

**Teaching Assistant (TA):**

Mr. Kieran Peleaux, 373 Cory Hall, Tel: (412)254-3088  
E-mail Address: [kpeleaux@berkeley.edu](mailto:kpeleaux@berkeley.edu)

Office Hours: M 3:30-5 p.m., in 367 Cory  
W 10-11 a.m., in 367 Cory

**Lecture:** Tuesday, Thursday 9:30-11 a.m. in 521 Cory

**Discussion:** Friday, 10-11 a.m. in 9 Evans

**Office Hours:**

Office hours are the primary mechanism for individual contact with Professor Nguyen and your TA. All students are strongly encouraged to make use of office hours.

**Course Description:**

In its most common definition, the field of microelectromechanical systems (or MEMS) encompasses tiny (generally chip-scale) devices or systems capable of realizing functions not easily achievable via transistor devices alone. Among the useful functions realized via MEMS are:

- 1) Sensing of various parameters that include inertial variables, such as acceleration and rotation rate; other physical variables, such as pressure and temperature; chemicals, often gaseous or liquids; biological species, such as DNA or cells; and a myriad of other sensing modes, e.g., radiation.
- 2) Control of physical variables, such as the direction of light (e.g., laser light), the direction of radiated energy, the flow of fluids, the frequency content of signals, etc. ...
- 3) Generation and/or delivery of useful physical quantities, such as ultra-stable frequencies, power, ink, and drug doses, among many others.

Although useful, the above definition and functional list fall short of describing some of more fundamentally important aspects of MEMS that allows this field to accomplish incredible things. In particular, MEMS design and technology fundamentally offer the benefits of scaling in physical domains beyond the electrical domain, to additionally include the mechanical, chemical, and biological domains. We are all well aware of the benefits of scaling when applied to integrated circuits. Specifically, via continued scaling of dimensions over the years, integrated circuit transistor technology has brought about transistor-based circuits with faster speed, lower power consumption, and larger functional complexity than ever before. All of these benefits have come about largely through sheer dimensional scaling.

By scaling the features of devices that operate in other physical domains (e.g., mechanical), MEMS technology offers the same scaling benefits of

- 1) Faster speed, as manifested by higher mechanical resonance frequencies, faster thermal time constants, etc., as dimensions are scaled.
- 2) Lower power or energy consumption, as manifested by the smaller forces required to move tiny mechanical elements, or the smaller thermal capacities and higher thermal isolations achievable that lead to much smaller power consumptions required to maintain certain temperatures.
- 3) Higher functional complexity, in that integrated circuits of mechanical links and resonators, fluidic channels and mixers, movable mirrors and gratings, etc., now become feasible with MEMS technology.

Unfortunately, although scaling does bring about significant benefits, it can also introduce penalties. For example, although miniaturization of accelerometers lowers cost and greatly enhances their g-force survivability, it also often results in reduced resolution—a drawback that must be alleviated via proper design strategy. This course will examine the pros and cons of scaling via MEMS technology, with a specific focus on the physical principles, tools, and methodologies needed to properly model MEMS devices and concepts to the point of being able to identify methods for maximizing the advantages while suppressing any drawbacks.

There will be two hour-and-a-half lectures and a one-hour discussion session per week. The lectures will be supplemented by reading assignments (indicated on the COURSE SYLLABUS), additional reading material to be distributed throughout the course, problem sets (at the rate of one per week, occasionally per two weeks), one midterm exam, a project, and a final exam. Although the material covered in the lectures and in the reading is fundamentally the same, the perspectives differ, and you are all strongly encouraged to both attend the lecture and complete your reading assignments. Furthermore, there will be occasional announcements in lectures that will affect your problem sets and exams.

Lectures and discussion, 4 units.

### Prerequisites:

Graduate standing in engineering or science; undergraduates with consent of instructor.

Note that the prerequisite requirement (or apparent lack of one) for this course reflects the fact that the course itself is meant to serve all engineering departments. This is not to say that no prior knowledge is required for this course; rather, it is more a statement that if you lack the necessary background knowledge, you will need to study and learn the material somewhat independently. Specifically, although some of the background material will be covered in lecture, there is simply not enough time to do a thorough job of it. Thus, those less familiar with the material will need to turn to supplementary materials, such as the reference texts.

Note that this course will rely on concepts from numerous disciplines, from electrical engineering, to mechanical engineering, to materials science, to chemical engineering. Thus, it is likely that nearly everyone will need to struggle with unfamiliar material at some point in the course.

### Texts:

- |                |  |
|----------------|--|
| Required:      | S. Senturia, <i>Microsystem Design</i> , 2 <sup>nd</sup> Printing<br>Various material to be distributed throughout the course.   |
| Supplementary: | G. Kovacs, <i>Micromachined Transducers Sourcebook</i><br>Jaeger, <i>Introduction to Microelectronic Fabrication (Vol. V of the Modular Series on Solid State Devices)</i> , 2 <sup>nd</sup> Edition |
| References:    | (on reserve)<br>C. Liu, <i>Foundations of MEMS</i><br>N. Maluf, <i>An Introduction to Microelectromechanical Systems Engineering</i>   |

J. Pelesko & D. Bernstein, *Modeling MEMS and NEMS*

**Reading Assignments:**

Reading assignments include sections of the required textbook, distributed readings, and supplementary notes handed out in lecture. Reading assignments are indicated in the COURSE SYLLABUS and will also be included in problem assignments where appropriate. Supplementary notes will be handed out for topics where lecture coverage is substantially different from the textbook. Students are responsible for all material in the reading. In particular, the scope of coverage for problem sets, the midterm, the project, and the final examination includes the reading assignments as well as lecture material.

**Problem Sets:**

There will be a number of problem sets over the course of the semester, assigned over 1, 1.5, or 2 week periods, depending upon difficulty and complexity. Each new problem set will normally be posted on the course website the day the previous problem set is due, which will be on a Tuesday or Thursday morning, 9 a.m. Problem sets should be turned in via Gradescope. Late homework assignments lose 10% per day.

**Project:**

A project will be assigned during the latter half of this course. During this period, the homework load will be smaller, and assignments will be designed to aid you in completing the project.

**Midterm:**

The approximate date of the midterm exam in this course is indicated in your COURSE SYLLABUS. We will try to adhere to this date so much as possible. The midterm will be a 1.5 hour exam.

**Final Exam:**

The final exam will be comprehensive, covering all of the material in the course. This includes everything covered in problem sets, lectures, and readings.

**Computer Accounts/CAD Tools:**

All CS and EE students can have “named” accounts on the EECS instructional computers, which include UNIX, Windows, and MacOSX platforms. Matlab runs on all of them. Students can use the computer labs in 199 and 105 Cory, or in other labs listed in the link:

<http://inst.eecs.berkeley.edu/~inst/iesglabs.html>

Most of you should already have computer accounts that work in those labs. If not, then you can get a “named” account by going to the link:

<http://inst.eecs.berkeley.edu/connecting.html#accounts>.

and following the instructions.

Before doing the above, however, wait to see if accounts will be distributed in a different manner this semester. In particular, in recent semesters accounts have been prepared in advance for the whole class and distributed in class on handouts containing account names and temporary passwords.

Once you create your account, you should have access to all of the necessary software for your course work.

**Grading Policy:**

Course grades will be assigned according to the following tentative grading formula.

Problem Sets:	20%
Project:	25%
Midterm Exam:	20%
Final Exam:	35%