

TO: Faculty of the Schools of Engineering

FROM: The Faculty of the School of Chemical Engineering

DATE: October 6, 2003

RE: Conversion of CHE 597W to a permanent course number CHE 517

On September 25, 2003, the Faculty of the School of Chemical Engineering has approved the conversion of CHE 597W to CHE 517, which is to be co-listed with ME 517. This action is now submitted to the Engineering Faculty with a recommendation for approval.

CHE 517(ME 517) Micro/Nanoscale Physical Processes (ME 517) Sem. 2. Class 3, cr. 3.

Prerequisite: CHE 377 and CHE 378 (or equivalent), or consent of instructor.

Study of physical processes encountered in small scale systems like Micro-Electromechanical Systems (MEMS) and nanoscale analogs. Introduction of tools for micron to molecular scale analysis of statics, dynamics, electricity and magnetism, surface phenomena, fluid dynamics, heat transfer, and mass transfer. Quantitative analysis of specific MEMS devices using finite element analysis.

Reason: This course provides a fundamental foundation for students wanting to learn how to analyze physical phenomena that occur in micro/nanoscale devices. With the growing emphasis in MEMS, this is an essential course to foster continued interest in this emerging area.

The course, with a temporary number 597W, has been offered three times as a co-listed course with the School of Mechanical Engineering. Enrollment in the course was 43 students in Spring 2001, 28 students in Spring 2002, and 20 students in Spring 2003, with roughly 50% Mechanical Engineering students and 25% Chemical Engineering students, graduate, and senior undergraduates.

G.V. Reklaitis, Head
School of Chemical Engineering

CHE 517/ME 517 Micro/Nanoscale Physical Processes
Spring Semester

Proposed Course Desc.: CHE 517/ME 517 Micro/Nanoscale Physical Processes Sem. 2. Class 3, cr. 3. Prerequisite: CHE 377 and CHE 378 (or equivalent) or consent of instructor.

Study of physical processes encountered in small scale systems like Micro-Electromechanical Systems (MEMS) and nanotechnology. Introduction of tools for micron to molecular scale analysis of statics, dynamics, electricity and magnetism, surface phenomena, fluid dynamics, heat transfer, and mass transfer. Quantitative analysis of specific MEMS devices using finite element analysis.

Textbook:

1. *Fundamentals of Microfabrication*, MJ Madou, CRC Press, 1997. ISBN 0849394511.
2. *Schaum's Outline of Finite Element Analysis*, GR Buchanan, McGraw-Hill, 1995. ISBN 0070087148.

Reference:

1. *An Introduction to Microelectromechanical Systems Engineering*, Nadim Maluf, Artech House, 1999. ISBN 0890065810.
2. *Micromechanics and MEMS: Classic and Seminal Papers to 1990*, W. Trimmer, IEEE, 1997. ISBN 0780310853.
3. *Micromachined Transducer Sourcebook*, GTA Kovacs, WCB/McGraw-Hill, 1998. ISBN 0072907223.
4. *Finite Element Analysis: Theory and Application with ANSYS*, S. Moaveni, Prentice Hall 1999. ISBN 0137850980.

Instructors: Gil Lee, Associate Professor of CHE and Professor Steve Wereley. **Prepared:** July 2003

Prerequisites by Topic: The student should be of advanced undergraduate or graduate standing. The student should have had experience at the undergraduate level with the following topics: statics, dynamics, electricity and magnetism, fluid dynamics, heat transfer, and mass transfer.

Computer Usage: The students will need to use ANSYS to perform some of the computations necessary for the course. Matlab experience would be helpful but not necessary.

Laboratory Projects: No lab projects

Nature of the Design Content:

The design component of this course will consist of students designing a microscale system to meet a particular need. The students will solve several of these design problems as part of the regular course homework.

Assessment Methods: Grades will be based on a mid-term (15%), final (20%) and homework assignments (65%).

Category content as estimated by faculty member who prepared this course description:

Engineering Science: 2.4 credit or 80%.

Engineering Design: 0.6 credit or 20%.

CHE 517/ME 517
Micro/Nanoscale Physical Processes

Course Objectives

1. To study physical processes in *micro/nanoscale systems*.
2. To determine *when to expect those processes to behave differently* than at macroscopic length scales.
3. To learn *how and when to use these behavior differences* to accomplish tasks at microscopic length scales.
4. To learn how to use *analysis tools* (ANSYS, Matlab) to study these systems and predict their behavior.

**Introduction
(2 weeks)**

1. What is MEMS?
2. Why MEMS? Scaling laws.
3. Fundamentals of microfabrication;
i. wet bulk micromachining

**Mechanics and Dynamics
(2.5 weeks)**

1. Steady state deformation of cantilevers and membranes
2. Dynamical behavior of cantilevers and membranes
3. Introduction to ANSYS
4. Applications: ANSYS analysis of atomic force microscopy and pressure

**Electricity and Magnetism
(3.5 weeks)**

1. Maxwell's Equations
2. Applications: electrophoresis, electrostatic force transduction, and magnetic force

**Heat and Mass Transfer
(2.5 weeks)**

1. Fourier's Law
2. Fick's Law
3. Convection
4. Applications: LIGA heat exchangers, magnetic

**Surface Phenomena
(1.5 weeks)**

1. Surface Tension/Adhesion
2. Surface forces: DLVO, hydration, hydrophobic
3. Applications: Electromosmosis, thermocapillarity, electrowetting

**Fluidics
(3 weeks)**

1. Low Reynolds number hydrodynamics: flow through a rectangular pipe
2. Nonlinear Phenomena: acoustical streaming
3. Applications: Electrohydrodynamics/magnetohydrodynamics