MG2816
Micro-Electro-Mechanical Systems (MEMS)

Professor: Denis Aubry

Language of instruction: French – **Number of hours**: 36 – **ECTS**: 3

Prerequisites: MG1100 or equivalent. Basic knowledge in Continuum Mechanics, Solids and Fluids

Period: S8 Elective 10 February to June IN28IE3, SEP8IE3

Course Objectives

In many technological areas, the miniaturization of systems is a major industrial issue. Micro-Electromechanical-Systems (MEMS) are often preferred to purely electronic systems for applications of measurement and control because they offer signicant advantages in terms of energy consumption (low insertion losses and insulation), reliability, fast response time. They are used in a variety of industrial applications such as automobiles, aeronautics, medicine, biology, telecommunications (ABS, smart phones, micro-switches, sensors, actuators).

Our objective is to present the operating principles, industrial applications, and fabrication processes for selected MEMS. In these examples, the main *multiphysics coupling mechanisms* will be described: vibrations, flow-structure interactions, thermal and electrical interactions. Numerical simulations of these coupling mechanisms will be presented through *intensive use of a multiphysics software*.

On completion of the course, students should be able to

- MEMS technology: applications, micromachining, design process and principles
- Design of sensors, actuators, gyroscopes, switch, micromotor
- Mutiphysics problems solving including: mechanics, temperature, fluids, electric and magnetic fields
- Applied skills with a multiphysics finite element software

Course Contents

- Interest and use of MEMS
- Main fabrication processes
- Multiphysics coupling: vibrations of microsystems, distortion by ohmic or capacitve effects, piezo-electric effects, microflow-structure coupling and fluid dampening in thin films
- Numerical simulations of real MEMS

Course Organization

Lectures: 12 hr, Tutorials: 12 hr, Project : 9 hr, Exam: oral presentation

Teaching Material and Textbooks

- Minhang Bao, Analysis and Design Principles of MEMS devices, Elsevier, 2005
- J. A. Pelesko, D. H. Bernstein, Modeling MEMS and NEMS, Chapman Hall/CRC, 2003

Evaluation

Written report and oral defense of the project.

MG2817
Applications of the Finite Element Method

Professor: Guillaume Puel

Language of instruction: English – **Number of hours**: 36 – **ECTS**: 3

Prerequisites: Some knowledge of functional analysis

Period: S8 Elective 12 March to June IN28IE5, SEP8IE5

Course Objectives

The finite element method has become a method of choice for computational engineering and science simulations. The main objective of the course is to develop skills to effectively use the finite element method for the analysis of problems in solid and fluid mechanics. Students will learn the basic principles of the method, how to develop suitable finite element models, and how to interpret the numerical results. A second objective is to familiarize students with the COMSOL Multiphysics software. The skills acquired in this course will be useful for the supervision of conception and design projects.

On completion of the course, students should be able to

- derive the weak formulation of any initial- and boundary- value problem
- write the corresponding finite element formulation
- implement the model in COMSOL Multiphysics and solve the problem
- assess the accuracy of the finite element solution

Course Contents

The course will present the main theoretical aspects of the finite element method and its application to engineering problems using COMSOL Multiphysics. Topics will include:

- Variational formulation of classical 1D BVPs
- Finite element space and solution procedures
- Variational formulation of classical 2D BVPs
- Finite elements in 2D and in 3D
- Matrix assembly
- Mesh generation, convergence analysis, and discretization errors
- Adjoint problems
- Initial and boundary-value problems
- Multimodel/multiphysics applications

The theory will be illustrated by the development of COMSOL models drawn from applications in solid and fluid mechanics such as: linear elastic stress analysis, large deformations, thin plate and shell modeling, heat transfer, incompresible flows, etc.

Course Organization

Lectures: 15 hr, Labwork: 18 hr, Exam: 3 hr

Teaching Material and Textbooks

Lecture notes in English

Evaluation

3-hr written final exam (no document allowed, but computer allowed for the practical part). The project reports may count as up to 4 bonus points added to the mark of the final exam