



KTH Information and
Communication Technology

IH2653/2B5232 Simulation of Semiconductor Devices

This course gives an in-depth knowledge in simulation of device physics for advanced semiconductor devices for all application areas. The implementation of the semiconductor equations and the solution using the finite difference method, finite element method and finite volume method is explained.

After the course, the student should be able to

- *analyse boundary conditions*
- *analyse discretization in one and two dimensions*
- *analyse semiconductor device operation*
- *design geometries for physical problems*
- *use computer tools to solve simple problems*
- *use computer tools to solve partial differential equations*
- *use computer tools to simulate semiconductor devices*

Staff involved

Lectures and examination: Professor Carl-Mikael Zetterling, MAP, 08-790 4344, bellman@kth.se

Lab assistant: Dr. B Gunnar Malm, MAP, 08-790 4332, gunta@kth.se

Guest lecture: Sergei Popov, MAP, sergeip@kth.se

Prerequisites

Basic semiconductor physics, semiconductor devices, electromagnetic field theory.

Literature

Since there is no good course book available at reasonable price, we will use a combination of lecture slides, lecture notes, book sections and program manual chapters.

Syllabus

- Basic numerical methods (repetition)
- Fundamentals of electromagnetism and its numerical analysis
- Transport phenomena and their numerical analysis, discretization in one and two dimensions
- The semiconductor equations
- Numerical solution of PDEs using FDM, FEM and FVM
- PN junction diodes, Metal-Oxide-Semiconductor structures
- Kinetic transport models, including Monte Carlo simulation

Requirements

The only examination is through homework assignments from the parts covered during lectures and labs. The course is worth 7.5 hp (higher education credits, equivalent to 7.5 ECTS).

IH2653: (formerly 2B1248, Undergraduate course) Grading: A-F. You may work together in groups of at most two students, but the other person's name must be listed on the homework that is handed in. Each person should hand in a set of individual solutions, although figures may be identical to lab partner's figures.

2B5232: (PhD course) Grading: pass/fail. PhD students should solve all problems individually.

If you copy someone else's homework I may have to report you for plagiarism.

Project

If you want more points to achieve a higher grade, an individual project will be assigned which includes simplified analysis and use of Comsol Multiphysics or nanoHUB. Either one of the project suggestions or a device of your choice can be analyzed/simulated. If you want to do a project based on your research this is also possible, as long as it includes analysis and simulation. You can decide on doing a project after the other homework has been graded. There is no oral presentation of your work, only a written report.

Deadline: December 15th, 2008.

Lectures and Labs

Lectures and Labs will be given according to the schedule below (Oct 28th - Dec 4th), content is preliminary. The lectures will also repeat material on solution of differential equations, numerical methods, electromagnetic field theory and semiconductor physics. Lecture notes and other material will be available on the website (<http://www.ict.kth.se/courses/IH2653/>). There will also be lecture demonstrations of Comsol Multiphysics (CMP) and nanoHUB.

| Lecture | Day | Time | Place | Content |
|---------|-----------|-------|-------|---------------------------------------|
| 1 | Tue 28/10 | 10-12 | 539 | Introduction |
| 2 | Wed 29/10 | 15-17 | 532 | Solution of Differential Equations |
| LAB1 | Thu 30/10 | 8-12 | 539 | |
| 3 | Tue 4/11 | 10-12 | 539 | The Finite Difference Method (FDM) |
| 4 | Wed 5/11 | 15-17 | 532 | Using Comsol Multiphysics |
| LAB2 | Thu 6/11 | 8-12 | 539 | |
| 5 | Tue 11/11 | 10-12 | 539 | Electromagnetism and Vector Calculus |
| 6 | Wed 12/11 | 15-17 | 532 | Simulation of Diffusion |
| LAB3 | Thu 13/11 | 8-12 | 539 | |
| 7 | Tue 18/11 | 10-12 | 539 | The Finite Element Method (FEM) |
| 8 | Wed 19/11 | 15-17 | 532 | The Scharfetter-Gummel Discretization |
| LAB4 | Thu 20/11 | 8-12 | 539 | |
| 9 | Tue 25/11 | 10-12 | 539 | Transport in Semiconductors |
| 10 | Wed 26/11 | 15-17 | 532 | Simulation of waves (Photonics) (SP) |
| LAB5 | Thu 27/11 | 8-12 | 539 | |
| 11 | Tue 2/12 | 10-12 | 539 | Ballistic transport theory |
| 12 | Wed 3/12 | 15-17 | 532 | Monte Carlo Simulation |
| LAB6 | Thu 4/12 | 8-12 | 539 | |

Homework

There are 10 sets of homework problems to be solved for a maximum of 100 points. Some homework requires the use of Matlab/Comsol Script, Comsol Multiphysics or nanoHUB, see below. Doing a project is optional. Homework should be emailed to bellman@kth.se on the date below at 23.59 latest, with your name as filename. Very late homework will receive lower marks, and **homework received after December 15th 2008 may not be graded at all**. There are six Labs where practical help will be available. The problem texts are available on the website. Preliminary grading below.

| HW | Points | Matlab | CMP | NanoHUB | Deadline | Content |
|----|--------|--------|-----|---------|-----------|---------------------|
| 1 | 10 | Yes | | | Mon 3/11 | Solution ODEs |
| 2 | 10 | Yes | | | Mon 10/11 | FDM 1D |
| 3 | 10 | | Yes | Yes | Mon 10/11 | Diode |
| 4 | 10 | Yes | Yes | | Mon 17/11 | FDM 2D |
| 5 | 10 | Yes | Yes | Yes | Mon 17/11 | Diffusion |
| 6 | 10 | | | Yes | Mon 24/11 | MOSFET |
| 7 | 10 | Yes | | | Mon 24/11 | FEM, Sch-G |
| 8 | 10 | Yes | | Yes | Mon 8/12 | Transport, Scaling |
| 9 | 10 | | | Yes | Mon 8/12 | Ballistic transport |
| 10 | 10 | Yes | | | Mon 8/12 | Monte Carlo |

| Points | Grade |
|--------|-------|
| ≥ 90 | A |
| ≥ 80 | B |
| ≥ 70 | C |
| ≥ 60 | D |
| ≥ 50 | E |
| < 50 | Fx |

Computer and Software requirements

- You will need to install some software on a home computer or a laptop to do the homework. Comsol Multiphysics (CMP) is a general tool for solving partial differential equations and also includes Comsol Script which runs Matlab-compatible code. Comsol Multiphysics can be downloaded from KTH ProgDist: <http://progdist.ug.kth.se/public/>
- For the Labs, bring a laptop or work with someone else who has a laptop.
- You need internet access to register and use <http://www.nanohub.org> (it is free). You will use the specialized semiconductor device simulation tools PN Junction Lab and MOSFET which require login (both powered by PADRE).