Southern Illinois University at Carbondale
Syllabus
ECE 557 Computational Electronics I

Catalog Description: Computers and computing. High-performance clusters or supercomputers and essential software tools. Essential numerical methods. Fundamentals of charge transport in semiconductor devices. Modeling electrostatics. Solving continuity equations. Electronic bandstructure calculations. Modeling scattering processes and carrier mobility. Phonon transport and thermoelectrics. Fundamentals of optical processes. Commercial and non-commercial semiconductor device modeling tools.

Course Total Credit Hours: 3
Lecture: 3
Prerequisites: ECE 447 or Instructor consent.

Objectives:

- Give a general introduction to *high-performance* large-scale scientific computing.
- Understand how advanced scientific modeling and simulation can pave the way for semiconductor device optimization and discovery.
- Understand the essential *physical processes* governing the operation of current state-of-the-art semiconductor devices.
- Develop software for modeling classical and semi-classical transport processes
- Students will be using both commercial and available non-commercial software tools to validate their models and study various aspects of semiconductor devices.
- Write reports/articles as per IEEE Author Guidelines and publish on www.

Laboratory Fees: None

Laboratory safety equipment: None
Instructor: Dr. Shaikh S. Ahmed, Associate Professor, ECE Department, SIUC.
Course Committee: *Department of Electrical and Computer Engineering Faculty*.

Text Book: *The subject matter for this course will be heavily drawn from the research literature and extensive references will be provided in the class notes*. A useful book:

Dragica Vasileska, Stephen M. Goodnick, and Gerhard Klimeck, *Computational Electronics: Semiclassical and Quantum Device Modeling and Simulation*, 1st Edition, CRC Press, June 2, 2010.

References:

- Mark Lundstorm, Jing Guo, *Nanoscale Transistors: Device Physics, Modeling and Simulation,* Springer Verlag, December, 2005.
- Mark Lundstorm, *Fundamentals of Carrier Transport*, Cambridge University Press; 2nd edition, July 2, 2009.

Topical Outline:

Introduction:	1 lectures	2.2%
Different classes of semiconductor devices What is meant by TMS (theory-modeling-simulation)? Why modeling and simulation? Multiscale modeling: Why modular approach? Device modeling: Industry and Academia		
Computers and computing:	5 lectures	11%
Computer hardware, Linux clusters, Top supercomputer centers in the world Computer software: (a) Operating system: Linux operating system, shell commands and shell scripting, X11, accessing Linux machine from Windows, cygwin (b) Editing text with the vi editor (c) Development tools: C/C++, FORTRAN; Makefile, debug, XML, parallel programming, CVS/subversion, valgrind, doxygen, scripting with Tcl/Python (d) Publishing tools: data visualization, Illustrator (image creation and editing), LaTeX, IEEE and APS author guides (e) Software deployment using Rappture		
Essential numerical methods:	4 lectures	8.8%
Finding roots, integration, differentiation Solving differential equations: Discretization into a matrix equation, solving matrices, eigenvalues and eigenvectors Polynomial fitting Monte Carlo method		
Fundamentals of carrier transport:	3 lectures	6.6%
Drude's model Landauer's model and ballistic transport Wave equations Quantum transport equations Boltzmann Transport Equation Drift-Diffusion model Hydrodynamic model Ballistic model		
Modeling electrostatics	4 lectures	8.8%
Poisson's equation Analytical solution Numerical solution: Discretization, Boundary conditions, Matrix inversion		
Solving continuity equations:	3 lectures	6.6%
Numerical solutions of the electron-hole continuity equations		

Electronic bandstructure calculation: Numerical solution of Schrödinger equation Wave packet dynamics Periodic potential and the Kronig-Penny model Bandstructure calculation using the tight-binding method: Theory, implementation, case study on a graphene lattice Electron density of states and effective mass	5 lectures	11%
Modeling scattering processes and carrier mobility: Phonon modes Perturbation theory Scattering rate calculation RTA and Rhode's iterative method for mobility modeling Various mobility models	5 lectures	11%
Phonon transport and thermoelectrics: Thermal conductivity Self-heating in semiconductor devices *ZT* figure-of-merit of thermoelectric devices	3 lectures	6.6%
Fundamentals of optical processes: Optical transition rate Internal and external quantum efficiency Efficiency *droop* and lumen depreciation	3 lectures	6.6%
Commercial and non-commercial semiconductor device modeling tools:	4 lectures	8.8%

Grading:

Homework	50%
Project	25%
Final Exam	25%

Letter grade: **A**: 90-100 **B**: 80-89 **C**: 70-79 **D**: 60-69 **F**: <60