ENSC 2xx-3: Electronic Devices

***Instructor**:* Karim S. Karim

***Other potential instructors (listed alphabetically)**:* Colombo Bolognesi, Glenn Chapman, Bonnie Gray, James Kuo, Albert Leung, Lakshman One, Ash Parameswaran, Marek Syrzycki

***Grading**:* 50% final, 20% midterm, 30% laboratory work

***Prerequisites**:*
ENSC 220

***Course Description**:*
This course is targeted towards engineering undergraduate students and covers the essential physics of silicon semiconductor devices that form the heart of integrated circuits today. The course will begin with an introduction to semiconductor device physics upon which device models are based leading to the development of the drift-diffusion equations. The static and dynamic behavior of PN junction diodes, bipolar junction transistors, and field effect transistors (in particular, MOSFETs) will be covered.

This course is to be taken concurrently with or prior to ENSC 225 and is targeted towards 2nd year Engineering Science undergraduate students to provide them essential background to fully appreciate prerequisite undergraduate courses such as ENSC 225 and ENSC 325 as well as upper year electives such as ENSC 450, 451, and 495. Also, it will provide the essential background for graduate courses such as ENSC 851, 852, 853, 854, 855, 856 and various special topics courses being taught by the faculty in microelectronics.

***Detailed Description**:*
1) **Introduction to Semiconductor Physics**: metals, insulator, semiconductors, intrinsic and extrinsic semiconductors, direct and indirect band gap, free carrier densities, Fermi distribution, density of states, Boltzmann statistics, thermal equilibrium, current flow mechanisms, drift current, diffusion current, mobility, generation and recombination, lifetime, internal electro-static fields and potentials, Poisson's equation, continuity equations, drift-diffusion equations.

2) **PN-Junction Diodes**: thermal equilibrium physics, energy band diagrams, space charge layers, internal electro-static fields and potentials, reverse biased diode physics, junction capacitance, breakdown, forward bias diode physics, wide and narrow diodes, transient behavior, transit time, diffusion capacitance, low forward bias, high forward bias, small and large signal models.

3) **Bipolar Transistors**: basic theory and operation, Ebers-Moll model, low forward bias, junction and diffusion capacitance, transit times, small-signal models, transition frequency, maximum oscillation frequency, large signal operation, Early effect, saturation and inverse operation, breakdown mechanisms, punch-through.

4) **MOSFET Transistors**: MOS capacitor, accumulation, depletion, strong inversion, threshold voltage, contact potential, body effect, drain current, saturation voltage, channel mobility, gate capacitance, MOSFET SPICE model levels 1.

***Laboratory**:*
The laboratory will consist of instrumentation involving measurement and extraction of parameters associated with (a) PN junctions, (b) BJTs and (c) MOSFETs and a very basic semiconductor device design exercise via a computer simulator (e.g. BiPOLE).

***Proposed course text**:*

1. Donald Neamen, *Semiconductor Physics and Devices: Basic Principles*, 3rd Ed, McGrawHill, 2003.

***Rationale for making ENSC 2xx-3 a prerequisite in Engineering Science (particularly for students taking Electronics or Engineering Physics options)**:*

1. Courses with content similar to the proposed ENSC 2xx-3 are part of the fundamental electrical engineering/engineering science core courses taught at those Canadian universities with a focus on electronics engineering. Below is a list of comparative engineering programs around Canada and the term in which the Electronic Devices course material is taught. Note in the table below how "Electronic Devices" is a separate course that is either taught concurrently with or prior to the ENSC 225 equivalent course.

University	Program	Semester "Electronic Devices" is taught	Semester "ENSC 225" taught
Toronto	Electrical Engineering	ECE 331 in 5/8	ECE 335 in 5/8
	Engineering Science	Same	same
Waterloo	Electrical Engineering	E&CE 231 in 4/8	E&CE 332 in 6/8
Alberta	Electrical Engineering	EE 340 in 5/8	EE 350 in 6/8
Queens	Electrical Engineering	ELEC 252 in 4/8	ELEC 353 in 5/8

2. Implementing this course at an earlier stage of undergraduate studies will provide the foundation to allow our graduates to stay competitive in Canada's rapidly expanding field of microelectronics.

3. It will also stimulate interest in undergraduates to possibly pursue graduate studies in microelectronics (particularly, in semiconductor device and circuit engineering) at SFU where, unlike most other Canadian universities focusing on microelectronics, we have access to separate silicon and III-V semiconductor processing cleanroom facilities at SFU that are ideal training grounds for microelectronics research.

***Potential Integration in current Engineering Science curriculum**:*

One manner of achieving ENSC 225 and ENSC 2xx in the same term is by moving ENSC 201-3 from its spot in Semester Four (Summer) to replace the Tech I-3 technical elective in Semester Seven (Spring) which will open up a spot for the proposed ENSC 2xx-3 Electronic Devices course.

Other alternatives for placing ENSC 225 and ENSC 2xx in the same term are also possible but require more schedule changes.