# ECE 495N, Fall'08 ME 118, MWF 1130A – 1220P

## Fundamentals of Nanoelectronics

**Course objective:** To convey the basic concepts of nanoelectronics to electrical engineering students with no background in quantum mechanics and statistical mechanics.

**Brief course description:** The development of "nanotechnology" has made it possible to engineer materials and devices on a length scale as small as several nanometers (atomic distances are ~ 0.1 nm). The properties of such "nanostructures" cannot be described in terms of macroscopic parameters like mobility or diffusion coefficient and a microscopic or atomistic viewpoint is called for. The purpose of this course is to convey the conceptual framework that underlies this microscopic viewpoint using examples related to the emerging field of nanoelectronics.

**Prerequisites:** MA266 & MA265 or MA262
**Prerequisites by topic:** Familiarity with matrix algebra, MATLAB,
Elementary differential equations.
***Homeworks will often involve problems that require the use of MATLAB.***

**Corequisites:** ECE 305
**Corequisites by topic:** Basic semiconductor device physics
Authorized equivalent courses or consent of instructor may be used in satisfying course prerequisites. Co-requisites are recommended but not required.

**Recommended References** **1.** S. Datta, Quantum Transport: Atom to Transistor, Cambridge University Press (2005), ISBN 0-521-63145-9.

**2.** *MatLab: Student Version*, Current Edition, The MathWorks, Inc.

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***For homework-related questions, please discuss first with Mr. Hong***

**Course outcomes**
1. Ability to perform simple analysis of nanoelectronic devices (Exam I).
2. Ability to calculate density of states / modes in nanoelectronic devices (Exam II).
3. Ability to perform in-depth analysis of nanoelectronic devices (Exam III).

**Grades:** Home Work (20) + Exams I, II (2x25 = 50)
+ Cumulative Final Exam (30)

***You are welcome to discuss homeworks amongst yourselves, but what you turn in should be your own work.***

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## Fundamentals of Nanoelectronics: Lecture Outline

All page numbers refer to the recommended reference #1. Please note that this reference is a graduate level text (no comparable undergraduate texts are available yet) and the classroom lectures + class notes are very important in being able to understand the material.

| | ***Pages*** |
|---|---|
| 1 / An atomistic view of electrical resistance | 1-18, 21-27 |
| **See also [http://www.nanohub.org/courses/cqt](http://www.nanohub.org/courses/cqt), CQT Lecture 2 (80 mins)** | |
| 2 / Schrodinger equation | 33-49 |
| Hydrogen atom, Method of finite differences | |
| 3 / Self-consistent field / Coulomb blockade | 18-20, 51-78 |
| One-electron versus the many-electron picture | |
| **See also [http://www.nanohub.org/courses/cqt](http://www.nanohub.org/courses/cqt), CQT Lecture 4 (70 mins)** | |

**HW# 1, 2, 3: Due 9/3, 9/10, 9/24 respectively**
**Exam I (Oct.1)**

| | |
|---|---|
| 4 / Bandstructure | 81-93, 104-116 |
| Toy examples, general result, common semiconductors | |
| 5 / Subbands | 129-137 |
| Quantum wells, wires, dots and nanotubes | |
| 6 / Density of states and density of modes | 138-176 |
| minimum resistance, quantum versus electrostatic capacitance | |

**HW# 4, 5, 6 : Due 10/8, 10/22, 10/29 respectively**
**Exam II (Nov. 5)**

| | |
|---|---|
| 7/ Probabilities, wavefunctions and Green functions | 183-223, 232-248 |
| Local density of states, Lifetime, Golden rule, Transmission, Current-voltage characteristics for coherent devices. | |
| **See also [http://www.nanohub.org/courses/cqt](http://www.nanohub.org/courses/cqt), CQT Lecture 3 (90 mins)** | |
| 8 / Spins and magnets | |
| 9 / Incoherent processes, Atom to transistor, Nanoscale energy conversion | 285-318 |
| **See [http://www.nanohub.org/courses/cqt](http://www.nanohub.org/courses/cqt), CQT Lecture 1 (80 mins) and** S.Datta, Nanodevices and Maxwell's Demon, http://arxiv.org/abs/0704.1623 | |

**HW# 7, 8, 9: Due 11/19, 12/3, 12/10 respectively**
**Exam III (Cumulative, Week of Dec.15)**

**Office hours**: MWF 1230P-130P or anytime by appointment
(please send email to request an appointment). ***Questions by email are also encouraged.***