

Quantum Transport: Atom to Transistor
ECE 659, Spring'09 EE 115, MWF 930A-1020P

Course objective: To convey the basic concepts of quantum mechanics and statistical mechanics with special emphasis on non-equilibrium problems involving nanoscale current flow to graduate students with little or no background in these subjects.

Brief course description: Traditionally atomistic approaches have been used to model materials in terms of average parameters like the mobility or the diffusion coefficient which are then used as inputs to macroscopic device models. This approach is still widely used but it is not adequate to meet the challenges and opportunities afforded by the development of nanotechnology that makes it possible to engineer materials and devices on a length scale as small as several nanometers (atomic distances are ~ 0.2 nm). An integrated approach is needed that embeds modern atomistic thinking directly into the models used for non-equilibrium systems like nanoscale transistors, energy conversion devices and bio-sensors. This requires not just quantum mechanics, but also an appreciation of some of the most advanced concepts of non-equilibrium statistical mechanics, together with the valuable insights obtained from recent developments in mesoscopic physics. Our aim is to condense the central concepts into a one semester course, assuming no prior background other than linear algebra.

Prerequisite Matrix algebra, Familiarity with MATLAB (or equivalent) necessary for some homeworks and for take-home exam.

Instructor Supriyo Datta, EE325 email: datta@purdue.edu
Questions by email encouraged, or email for appointment to discuss personally.
Walk-ins welcome, if I am free.

TA Seokmin Hong, EE350 email: hong37@purdue.edu

Home Work/Grades: You are welcome to discuss your homework with the instructor and with others, but what you turn in must be your own work. **Overall grades** will be based on

8 HOME WORKS	20%
MIDTERM EXAM (Monday, 3/9)	30%
TAKE-HOME EXAM (MATLAB-based, due Friday 4/17)	20%
FINAL EXAM (Week of 5/4)	30%

Approximate guideline for grades: A: 85-100, B:70-84.

References: **1.** S.Datta, Quantum Transport: Atom to Transistor, Cambridge (2005), ISBN 0-521-63145-9 (referred to below as QTAT).

2. (a) Nanoelectronic Devices: A Unified View, <http://arxiv.org/abs/0809.4460v2>. (b) Nanodevices and Maxwell's Demon. <http://arxiv.org/pdf/0704.1623>. (c) Influence of Dimensionality on Thermoelectric Device Performance, <http://arxiv.org/pdf/0811.3632>.

3. Video lectures: <http://www.nanohub.org/resources/5279>, [6041](http://www.nanohub.org/resources/6041), [6063](http://www.nanohub.org/resources/6063)

4. Classroom lectures are important in supplementing and organizing material from the above references. Please try not to miss any.

Related course: Lectures, exams, homeworks, solutions for a related undergraduate course focusing on Chapters 1-6, QTAT are available at <http://www.nanohub.org/resources/5346>. In this course I will not assume prior familiarity with this material and review concepts as needed. This course will be focused on Chapters 7-11, QTAT along with other supplementary material.

ECE 659, Spring 2009: Course Outline

Weeks 1-3: Semiclassical Transport

References: 1. Chapter 1, QTAT
2. Lectures 1A,B: <http://www.nanohub.org/resources/5279>.
HW# 1, 2: Due Friday 1/23, 2/6 respectively

Week 4-6: Quantum Transport

References: 1. Chapter 7, 8, 9, QTAT
2. Nanoelectronic Devices: A Unified View, <http://arxiv.org/abs/0809.4460v2>
3. Lectures 2A,B: <http://www.nanohub.org/resources/5279>.
HW# 3, 4: Due Friday 2/20, 2/27 respectively

Week 7-9: Spin Transport

References: 1. Lectures 3A,B: <http://www.nanohub.org/resources/5279>.
2. <http://www.nanohub.org/resources/6041>
<https://www.nanohub.org/resources/6063>
HW# 5, 6: Due Friday 3/13, 3/27 respectively

Midterm exam (Closed book): Monday, 3/9 on Semiclassical and Quantum transport

Spring Break (Week of March 15)

Week 10-12: Energy Transport

References: 1. Chapter 10, 11, QTAT
2. Lectures 4A,B: <http://www.nanohub.org/resources/5279>.
3. Nanodevices and Maxwell's Demon. <http://arxiv.org/pdf/0704.1623>.
4. Dimensionality and Thermoelectric Devices, <http://arxiv.org/pdf/0811.3632>.
HW# 7: Due Friday 4/3

Take home Exam: Due Friday, 4/17 featuring MATLAB-based problems

Week 13-15: Correlated Transport

References: 1. Section 3.4, Appendix, QTAT
2. Lectures 5A, B: <http://www.nanohub.org/resources/5279>.
HW# 8: Due Wednesday 4/29

Final Exam (Closed book), Week of May 4, Cumulative