Nanoelectronics

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I. COURSE STRUCTURE

- **WEEK 1**

  Lecture 1: Survival kit Lecturer: Sorin Paraoanu

  Review of key concepts from solid-state physics and quantum mechanics used in this course (second quantization, density of states, etc.) Overview of the systems studied in mesoscopic physics and nanoelectronics.

  Exercise set 1.1: Survival kit TA: Giacomo Catto

- **WEEK 2**

  Lecture 2: Semiclassical transport theory Lecturer: Ethan Minot

  Boltzmann equation. Ballistic and diffusive transport.

  Exercise set 1.2: Survival kit TA: Giacomo Catto

- **WEEK 3**

  Lecture 3: Quantum transport in metals Lecturer: Ethan Minot

  Single electron tunneling, Coulomb blockade, Landauer formalism, electron interference.

  Exercise set 2: Semiclassical transport theory TA: Giacomo Catto

- **WEEK 4**

  Lecture 4: Electronic transport in magnetic fields Lecturer: Ethan Minot

  Transport phenomena for 2D materials in magnetic fields.

  Exercise set 3: Quantum transport in metals TA: Hany Khalifa

- **WEEK 5**

  Lecture 5: Low-dimensional materials Lecturer: Ethan Minot

  Carbon nanotubes, graphene, and transition metal dichalcogenides: structure, properties and nanofabrication.

  Exercise set 4: Electronic transport in magnetic fields TA: Hany Khalifa

- **WEEK 6**

  Lecture 6: Superconductivity Lecturer: Sorin Paraoanu

  Phenomenology and BCS description, Josephson effect, SQUIDs, SINIS coolers.

  Exercise set 5: Low-dimensional materials TA: Hany Khalifa

- **WEEK 7**

  Lecture 7: Superconducting qubits Lecturer: Sorin Paraoanu

  Capacitive energy and Josephson energy. Lagrangeian formalism and quantization of circuits.

  Exercise set 6: Superconductivity TA: Giacomo Catto

- **WEEK 8**

  Lecture 8: Noise and correlations. Lecturer: Sorin Paraoanu

  Basic concepts in statistics: momenta, cumulants, etc. Types of noise: thermal, shot noise. Buttiker formalism, Fano factor.

  Exercise set 7: Superconducting qubits TA: Suman Kundu

- **WEEK 9**

  Lecture 9: Electromagnetic cavities and resonators Lecturer: Sorin Paraoanu

  Input-output theory, cavity response.

  Exercise set 8: Noise and correlations TA: Suman Kundu

- **WEEK 10**

  Lecture 10: Quantum amplifiers. Lecturer: Sorin Paraoanu

  Parametric amplification. Phase-sensitive versus phase-insensitive amplifiers.

  Exercise set 9: Electromagnetic cavities and resonators TA: Suman Kundu

- **WEEK 11**

  Lecture 11: Nanomechanical systems. Lecturer: Ethan Minot

Standard optomechanical Hamiltonian. Cooling and amplification. Resolved-sideband limit.

Exercise set 10: Quantum amplifiers TA: Suman Kundu

- **WEEK 12**

Lecture 12: Advanced topics in nanoelectronics Lecturer: Ethan Minot

Topological insulators and Majorana fermions.

Exercise set 11: Nanomechanical systems TA: Hany Khalifa

II. TEXTBOOKS

The main textbooks are Ref. [1–3]. Note also that there is a blog for Ref. [1] at http://thephysicsofnanoelectronics.info. You might want to consult as well [4, 5]. There will be also additional reading materials for some lectures.

III. GRADING SYSTEM

The course has 5 credits. The final grade will reflect your activity in the exercise session (60%) and the results from the final exam (40%). The final exam is mandatory. The exercises are due before the exercise session of the week after the corresponding lecture (if your lecture is on Tuesday, then the exercises are due the next week on Wednesday right before the session). They will be collected and graded by your T.A.'s.

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[1] Tero T. Heikkilä, The physics of nanoelectronics, Oxford University Press (2013).

[2] Yuli. V. Nazarov and Yaroslav M. Blanter, Quantum Transport - Introduction to Nanoscience, Cambridge University Press, Cambridge (2009).

[3] Thomas Ihn, Semiconductor Nanostructures - Quantum States and Electronic Transport, Oxford University Press, Oxford (2010).

[4] S. Datta, Electronic Transport in Mesoscopic Systems, Cambridge University Press (1995).

[5] A.M. Zagoskin, Quantum Engineering - Theory and Design of Quantum Coherent Structures, Cambridge University Press (2011).