**COURSE:** ECE730/QIC890-T33

**COURSE TITLE:** **Introduction to Noise Processes : Classical and Quantum Devices**

**INSTRUCTOR:** Prof. Na Young Kim
Office: RAC1 2101, x30481
Office hours: Thursdays 3-4 pm QNC4104 or by appointment via email
email: nayoung.kim@uwaterloo.ca
Note: Do not use LEARN email to reach the instructor

**LECTURES**: EIT 3141, Tuesdays 8:30am - 11:20 am (5/2/2016 - 7/19/2016)

## DESCRIPTION

The course will introduce fundamentals of various noise processes in classical and quantum devices. Review of mathematical methods in classical and quantum statistical mechanics is given, on which the theoretical framework of noise processes is developed. Thermal, shot, *1/f* and quantum noise processes are studied in macroscopic and mesoscopic electrical and optical devices. Measurement techniques of noise processes and the meanings of measurement accuracy are discussed in classical and quantum worlds. Introduction to coherence, decoherence and control theory is briefly given in closed and open systems.

## COURSE OBJECTIVE

The course is designed for students to

- Review classical and quantum statistical mechanics and learn mathematical framework to describe noise processes;
- Understand thermal, shot and *1/f* and quantum noise processes in electrical and optical devices;
- Study coherence and decoherence processes and control effects.

**Expected Background:** Basic understanding of statistical mechanics, quantum mechanics, solid-state electronics and photonics devices is recommended.

## SYLLABUS

I. **PART 1: Theoretical Foundations**

1. Classical Probability Theory
   - Time vs Ensemble Average
   - Statistically Stationary *vs* Non-stationary Processes
   - Wiener-Khintchine Theorem
   - Basic Stochastic Processes
2. Principles of Quantum Statistics
   - Symmetrization, Non-Commutability Postulates
   - Thermodynamic Partition Functions
   - Equipartition Theorem

II. **PART 2: Stochastic Processes in Electrical Devices**

3. Types of Noises
   - Thermal Noise
   - Shot Noise
   - *1/f* Noise
   - Quantum Noise
4. Classical and Quantum Circuit Theory
   - Two- and Four-terminal Networks
   - Noise Figures of linear circuits and cascaded circuits

5. Macroscopic Conductors
    - Fluctuation-Dissipation Theorem
    - Thermal Noise in a Transmission Line
6. Mesoscopic Conductors
    - Ballistic Transport in Mesoscopic Two-Dimensional Systems
    - Partition Noise and Johnson-Nyquist Noise
7. Case study: *p-n* Junction Devices and Amplifiers

III. **PART 3: Stochastic Processes in Optical Devices**

8. Noise of Lasers and Detectors
    - Amplitude and Phase Noise
    - Quantum Noise Theory of lasers
9. Noise of Parametric Amplifiers and Oscillators
    - Non-Degenerate and Degenerate Amplifiers
    - Quantum-limit of Linear Amplifiers
    - Quantum Correlations

IV. **PART 4: Measurements Decoherence and Open systems**

10. Coherence and decoherence processes
11. Open and Closed Systems
12. Introduction to Control Theory and Feedback Control

**TEXTBOOK**

None required. Article handouts provided and lecture notes will supplement course lectures.

**COURSE WEBSITE**

The course homepage is on LEARN, where course syllabus, lecture notes and problem sets are uploaded. Any important updates will be announced as well.

**GRADE DISTRIBUTION**

- **7-8 Problem Sets :** 50%

  Problem Set Late Policy

  $S(t) = S(0)*(10-t)*0.1$ if $t < t_s$ or $S(t) = 0$ if $t > t_s$,

  where $t = 0$ is the due date, $t$ is the turn-in date, and $t_s$ is the solution posting date.

  Exception to this policy can be made in special circumstances by contacting the instructor in advance. Note that any evidence violating Honor code (e.g. plagiarism, copying and etc.) will yield $S(t) = 0$ regardless of $t$.
- **Final Written Exam:** 50%

  The Final Exam will be in-class 150-minute long, held during UW regular final exam period. The exam will be open-book/open-notes. However, access to electronic devices will be prohibited.