2.S982 Quantum machines in a classical world

Prof. Vivishek Sudhir

This course is intended to address the need to describe and model state-of-the-art engineered (i.e., human-made) quantum systems. The central feature of these systems is that they are open to external intervention, either through their unavoidable contact with an undesirable (e.g., thermal) environment, or through their strong and desirable coupling to a measurement device. The imprint of the classical world on a quantum system is noise; the fingerprint of a quantum system is also noise, but of a different kind. This dichotomy between classical and quantum noise will be the leitmotif of our study.

Thus, breaking with traditional pedagogy in quantum physics, we will start from a study of classical stochastic processes, develop the mathematical tools to understand and manipulate them, and then generalize to noisy quantum systems. These concepts and tools are applicable to systems ranging in size from single trapped atoms to kilometer-scale gravitational-wave detectors, and relevant to applications ranging from the readout of quantum information processors to precision quantum sensing.

Engineers, conventionally familiar with noise, will learn to translate their understanding to quantum systems; the scientists will learn the oft-neglected and fundamental role of noise in the act of measurement.

<u>Pre-requisites</u>: 8.04 (or prior familiarity with basic quantum), and basic notions of statistical physics, or permission of instructor
<u>Units</u>: 3-0-9
<u>Coordinates</u>: Room 1-150, Tue/Thu 2-4pm

Tentative syllabus

Review of classical statistical physics: equipartition theorem, fluctuation-dissipation theorem, Langevin and Fokker-Planck description of classical statistical phenomena. Development of classical stochastic calculus: Wiener process, Ito and Stratonovich calculus. Description of open quantum systems: decoherence, and measurements. Continuous-time evolution of open quantum systems on average: quantum master equation, regression theorem, quantum Langevin equation, quantum fluctuation-dissipation theorem. Applications to quantum engineering problems (cavity/circuit QED, optomechanics). Evolution of open quantum systems in real-time: quantum trajectories, quantum stochastic calculus. Applications to continuous measurement, feedback, and quantum information processing devices. Quantum state filtering.