Course Title: **Quantum Hardware and Devices**

Credit Hrs: 3

Prerequisites: Linear Algebra, Quantum Mechanics

Course Overview

This course provides an advanced and comprehensive study of quantum hardware platforms and their physical operating principles. Students will explore the quantization of the electromagnetic field, photon statistics, and fundamental light–matter interaction models including the Jaynes–Cummings and Rabi models. A strong emphasis is placed on real quantum devices, including superconducting qubits, trapped ions, solid-state defects, semiconductor quantum dots, single-photon sources, detectors, entanglement modules, and interferometric systems.

Course Objectives

- Develop a solid understanding of the **quantization of the electromagnetic field**, photon statistics, and coherence fundamentals underlying quantum hardware.
- Build analytical skills to apply **Jaynes–Cummings, Rabi, and related light–matter interaction models** to real quantum devices.
- Provide technical insight into **superconducting qubits, trapped ions, solid-state spins, and semiconductor quantum systems**, focusing on their physical operation and control.
- Introduce the principles and practical implementation of **single-photon sources, detectors, and entanglement-generation modules** used in modern quantum technologies.
- Strengthen understanding of **quantum interferometry, nonlinear optics, and cavity QED**, emphasizing their roles in precision sensing and quantum information processing.

Course Learning Objectives (CLOs)

- Explain photon statistics, coherence, quantization of EM field, and light–matter interactions.
- Apply Jaynes–Cummings and Rabi models to analyze quantum hardware.
- Evaluate operation of superconducting qubits, trapped ions, and solid-state devices.
- Understanding of single-photon sources, detectors, and entanglement processes.

- Quantum interferometry, cavity QED, and nonlinear optics for sensing and computing.

Course Contents

Week	Contents
1	Quantization of EM field
2	Photon statistics
3	Jaynes–Cummings model
4	Rabi oscillations
5	Quantum coherence & interference
6	Hanbury Brown–Twiss experiment
7	Midterm exam
8	Linear and nonlinear optics
9	Cavity QED & Purcell effect
10	Superconducting qubits
11	Trapped ions & solid-state spins
12	Single-photon sources & detectors
13	Entanglement generation
14	Mach-Zehnder and Michelson setups for quantum metrology and Heisenberg-limited measurements.
15	Quantum interferometry in high-precision sensing, gravitational wave detection, Integrated quantum hardware
16	Final Exam

Textbooks / References:

- Walls & Milburn, Quantum Optics, Springer.
- Gerry & Knight, Introductory Quantum Optics, CUP.
- Loudon, The Quantum Theory of Light, OUP.

Assessments:

- Assignments: 10%
- Quizzes: 10%
- Midterm Exam: 30%
- Final Exam: 50%