ECE 677/QIC 885, Applied Quantum Mechanics

University of Waterloo, Instructor: A. Hamed Majedi

Winter 2027

General Description

Quantum mechanics provides the conceptual and mathematical framework for understanding the behavior of matter and light, from individual electrons and photons to complex many-body systems. Its principles underpin modern electronic and photonic technologies and enable new approaches to sensing, computation, and communication. For engineering students and researchers, a solid grounding in quantum mechanics offers deeper insight into established technologies and a foundation for developing new devices and applications.

This course presents a systematic introduction to quantum mechanics, combining fundamental principles with applications across science and engineering. Designed for students from diverse backgrounds, it is particularly relevant to those interested in solid-state electronics, quantum photonics, and quantum information processing. The course emphasizes physical intuition, mathematical clarity, and analytical problem-solving. Carefully selected examples and structured exercises connect theoretical concepts to the behavior, operation, and design of electronic, optoelectronic, photonic, and superconducting devices.

No prior knowledge of quantum mechanics is required. The course assumes a working knowledge of classical physics and linear algebra and welcomes students with scientific curiosity and a commitment to developing a rigorous understanding of quantum phenomena and their applications.

General Course Contents

1- Brief History of Quantum Physics *Why, When and How?*

2- Schrödinger Wave Mechanics, *Electron Meows!*

3- Quantum Confined Structures (quantum well, wire, dot and superlattice), *Electrons' Ballroom Dance*

4- Periodic Structure & Transfer Matrix Method, *Electron in Hula Hoop!*

5- Axiomatic Structure of Quantum Mechanics, *Lets be Serious!*

6- Quantum Dynamics; *Time is Gold!*

7- Angular Momentum and Spin, *Irrotational Rotation!*

8- Many-Body Systems & Quantum Statistics, *Coin tossing with Mr. Fermi and Mr. Bose!*

9- Electromagnetic Field Quantization, *When Dirac Meets Maxwell.*

10- Quantum States of EM Field; Introductory Quantum Optics, *Photon starring in Face off!*

11- Electron/Photon & Atom-EM Field Interaction, *Electron-photon Cha Cha*

Text

1- Course notes and slides.

Some References

1- D.J. Griffiths, Introduction to Quantum Mechanics, 2nd Edition, Prentice Hall, 1995.

2- H. Kroemer, Quantum Mechanics for Engineering, Material Science and Applied Physics, Prentice Hall, 1994.

3- A.F.J. Levi, Applied Quantum Mechanics, 2nd ed., Cambridge, 2006.

4- Ph. Martin, F. Rothen, Many-Body Problems and Quantum Field Theory, 2nd ed., Springer, 2004.

5- H.A. Bacher, T.C. Ralph, A Guide to Experiments in Quantum Optics, 2nd Edition, Wiley-VCH, 2003.

6- J.C. Garrison, R.Y. Chiao, Quantum Optics, Oxford, 2008..

7- H. Bruus, K. Flensberg, Many-Body Quantum Theory in Condensed Matter Physics, Oxford, 2004.

Office hour: Friday 1:00-2:00 p.m. E5-4009.

Grading Policy: 50% Assignments, 50% Final Exam.