SYLLABUS

OPTI 345 Quantum Mechanics and Optical Physics

Spring 2022
M/W/F: 9:00 – 9:50 AM
Meinel 422

Description of Course

This course will introduce students to the ideas and methods of quantum theory by building on their knowledge of waves from optics, and developing the tools needed for working with light and matter. After describing the underpinnings of quantum mechanics some key examples will be worked out in detail including the quantum harmonic oscillator. The quantum theory of atomic structure will next be developed in detail to expose the student to some key techniques and notions for understanding atoms. Next the interaction between light and matter is explored along with some basic paradigms for understanding optical physics, including Rabi oscillations, spontaneous emission, and the quantum theory of light. Finally, some topics in quantum information science will be explored by building on the basic notions of quantum theory introduced in the class. In particular, quantum cryptography will be developed along with the notion of quantum gates that underpin the operation of quantum computers.

Course Prerequisites or Co-requisites

Students must have advanced to at least their junior year and passed all Fall exams with at least B grades in 341 and 210.

Instructor and Contact Information

Prof. Ewan M. Wright

Meinel 636

621-2406

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Web information: The class information will be available through D2L

Course Format and Teaching Methods

Lecture only.

Course Objectives and Expected Learning Outcomes

Course objectives:

1. Provide students with a basic background in quantum mechanics
2. Apply quantum theory to atomic structure and its classification
3. Study quantum aspects of light-matter interactions
4. Explore some topics in quantum information science

Expected learning outcomes:

1. The student will become conversant with the notions of quantum mechanics as a wave theory of matter, and the postulates of quantum mechanics as a basis for applying quantum theory.
2. The student will be able to state and use the solutions of the infinite square well and quantum harmonic oscillator, problems that underpin many physical problems.
3. The student will become conversant with the quantum solutions for the hydrogen atom as a basis for describing and calculating atomic structure and the optical spectra of atoms.
4. The student will be able to use atomic structure to calculate the interaction between atoms and light as a basis for understanding optical physics phenomena such as Rabi oscillations, spontaneous and stimulated emission, and the quantized light field (photons).
5. The student will become familiarized with the basic notions involved in quantum cryptography, quantum information processing using quantum gates, and the idea of quantum algorithms and computers.

Absence and Class Participation Policy

The UA's policy concerning Class Attendance, Participation, and Administrative Drops is available at: http://catalog.arizona.edu/policy/class-attendance-participation-and-administrative-drop

The UA policy regarding absences for any sincerely held religious belief, observance or practice will be accommodated where reasonable, http://policy.arizona.edu/human-resources/religious-accommodation-policy.

Absences pre-approved by the UA Dean of Students (or Dean Designee) will be honored. See: https://deanofstudents.arizona.edu/absences

Participating in the course and attending lectures and other course events are vital to the learning process. As such, attendance is required at all lectures and discussion section meetings. Students who miss class due to illness or emergency are required to bring documentation from their health-care provider or other relevant, professional third parties. Failure to submit third-party documentation will result in unexcused absences.

Required Texts or Readings

There are no required texts for the class, and class notes will be made available through the webpage. Alternative reading sources will be referred to throughout the class and made available in the reading room and Science Library.

Required or Special Materials

Students should have access to MATLAB and the capability to perform numerical calculations.

Assignments and Examinations: Schedule/Due Dates

The class shall include weekly homework, two midterm exams, and a final exam.

Final Examination or Project

The date and time of the final exam or project, along with links to the Final Exam Regulations, https://www.registrar.arizona.edu/courses/final-examination-regulations-and-information, and Final Exam Schedule, http://www.registrar.arizona.edu/schedules/finals.htm

Grading Scale and Policies

The final grade will be based on weekly homework, two midterm exams, and a final exam.

Homework	50%
Midterm exams	15%
Final exam	20%
Total	100%

The grade will be determined according to the cumulative percentage earned such that 90-100% = A, 80-89% = B, 70-79% = C, 60-69% = D, below 60% = E.

Requests for incomplete (I) or withdrawal (W) must be made in accordance with University policies, which are available at http://catalog.arizona.edu/policy/grades-and-grading-system#incomplete and http://catalog.arizona.edu/policy/grades-and-grading-system#Withdrawal respectively.

Scheduled Topics/Activities

The intended topics to be included are as follows:

1. Review of linear algebra
2. Introduction to quantum mechanics, wave/particle duality, uncertainty principle
3. Quantum mechanics of free and bound particles, wave packets
4. Schrodinger equation, wave functions, eigenvalue equations
5. Postulates of quantum mechanics
6. Measurements in quantum mechanics, expectation values
7. Quantum harmonic oscillator
8. Hydrogen atom, quantum mechanics of the real hydrogen atom
9. Dirac notation, matrix formulation of quantum mechanics
10. Spin angular momentum, Pauli exclusion principle
11. Optical physics, Hamiltonian for light/matter interaction
12. Electric dipole and rotating wave approximations
13. Two-level atom approximation, Rabi oscillations
14. Collisional decay and spontaneous emission, rate equations
15. Blackbody radiation, Einstein A and B coefficients
16. Steady-state absorption coefficient, saturation, optical properties of gases
17. Quantization of the electromagnetic field, number states, and vacuum field fluctuations
18. Jaynes-Cummings model for the interaction between a single-mode and a two-level atom
19. Photon number distributions, quantum collapses and revivals
20. Multi-mode quantum fields, Jones calculus, beam splitter, random number generator
21. Topics in quantum information, classical and quantum cryptography
22. Quantum key distribution using single photons or qubits
23. BB84 protocol, quantum security, quantum uncertainty as a resource
24. Quantum information processing, universal sets of classical and quantum gates
25. Quantum gates and their realization using polarization optics
26. Universal quantum computers, survey of quantum algorithms
27. Quantum primacy and the challenges of realizing quantum computers

The final exam date will be on the date set by the UA, and the midterms will approximately follow topics 10 and 18 above.

Classroom Behavior Policy

To foster a positive learning environment, students and instructors have a shared responsibility. We want a safe, welcoming, and inclusive environment where all of us feel comfortable with each other and where we can challenge ourselves to succeed. To that end, our focus is on the tasks at hand and not on extraneous activities (e.g., texting, chatting, reading a newspaper, making phone calls, web surfing, etc.).

Threatening Behavior Policy

The UA Threatening Behavior by Students Policy prohibits threats of physical harm to any member of the University community, including to oneself. See http://policy.arizona.edu/education-and-student-affairs/threatening-behavior-students.

Accessibility and Accommodations

At the University of Arizona we strive to make learning experiences as accessible as possible. If you anticipate or experience physical or academic barriers based on disability or pregnancy, you are welcome to let me know so that we can discuss options. You are also encouraged to contact Disability Resources (520-621-3268) to explore reasonable accommodation.

If our class meets at a campus location: Please be aware that the accessible table and chairs in this room should remain available for students who find that standard classroom seating is not usable.

Code of Academic Integrity

Students are encouraged to share intellectual views and discuss freely the principles and applications of course materials. However, graded work/exercises must be the product of independent effort unless otherwise instructed. Students are expected to adhere to the UA Code of Academic Integrity as described in the UA General Catalog. See: http://deanofstudents.arizona.edu/academic-integrity/students/academic-integrity.

The University Libraries have some excellent tips for avoiding plagiarism, available at http://new.library.arizona.edu/research/citing/plagiarism.

Selling class notes and/or other course materials to other students or to a third party for resale is not permitted without the instructor's express written consent. Violations to this and other course rules are subject to the Code of Academic Integrity and may result in course sanctions. Additionally, students who use D2L or UA e-mail to sell or buy these copyrighted materials are subject to Code of Conduct Violations for misuse of student e-mail addresses. This conduct may also constitute copyright infringement.

UA Nondiscrimination and Anti-harassment Policy

The University is committed to creating and maintaining an environment free of discrimination; see http://policy.arizona.edu/human-resources/nondiscrimination-and-anti-harassment-policy

Our classroom is a place where everyone is encouraged to express well-formed opinions and their reasons for those opinions. We also want to create a tolerant and open environment where such opinions can be expressed without resorting to bullying or discrimination of others.

Additional Resources for Students

UA Academic policies and procedures are available at http://catalog.arizona.edu/policies

Student Assistance and Advocacy information is available at http://deanofstudents.arizona.edu/student-assistance/students/student-assistance

Confidentiality of Student Records

http://www.registrar.arizona.edu/personal-information/family-educational-rights-and-privacy-act-1974-ferpa?topic=ferpa

Subject to Change Statement

Information contained in the course syllabus, other than the grade and absence policy, may be subject to change with advance notice, as deemed appropriate by the instructor.