Physics 417: Intermediate Quantum Mechanics

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Spring Semester, 2026

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Web: See Canvas
Class Hours: M/Th 12:10-1:30pm
Class Room: SEC 205

Course Description

This course is a continuation of Physics 361 *Quantum Mechanics and Atomic Physics* and is an intermediate Undergraduate quantum mechanics class. This course focuses on applications of quantum mechanics to a wide variety of physically relevant problems, as well as modern applications of quantum mechanics.

Breakdown of grade contributions

- Homework 34%
- Midterm 33%
- Final 33%

Homework

It is expected you are reading the course material specified in the content below prior to class. We will have weekly homework assignments due at the end of the day to be turned into the grader, Aaditya Panigrahi, aadityapanigrahi@physics.rutgers.edu, through Canvas or his mail box. In working on the problems, you are encouraged to talk with others in the class, but you must write up your own solution. Always show your work. You will not receive full credit if you do not show your work. In general, I am not looking for a specific answer; rather, I am always looking for the reasoning behind the answer.

Homework will be **due by midnight on the day specified in the assignment**. Please submit them to the grader Nakul Aggarwal either via Canvas or to their mailbox. Homework not turned in by the specified time will be considered late. Reasonable requests for extensions can be provided in the appropriate circumstances. The solutions are posted online after the due date. As a result, late homework will receive at most 50% credit.

Grading Rubric: For full points you must show your work in a clear, readable, and logical fashion that someone other then your self can follow. Partial points are given if the answer is incorrect, steps are skipped or not presented, and if only part of the problem is completed. There are several ways to solve a problem, and creativity and ingenuity are praised, not graded negatively.

Rubric for grading homework, and exam questions: Each problem would be graded on a 0 to 10 scale:

- 10 – fully completed problem
- 9-8 fully completed problem with tiny deficiencies
- 7-4 – most of the conceptual steps done correctly, but some errors made
- 3-1 – some essential steps made
- 0 – nothing of value was done

Half points are allowed. The final score for that problem will be converted to the fractional weight of that assignment, where the total assignment would be 100

Grading Scheme

90-100 = A
85-90 = B+
80-85 = B
75-80 = C+
70-75 = C
60-70 = D
below 60 = F

Exams

One in-class midterm will be held on the date specified in the syllabus timeline. The final will be held on May 8th 8-11am in SEC 212. You should bring a scientific calculator for each exam. For the midterm, you are allowed one 8.5x11" formula sheet (both sides) and for the final you are allowed two formula sheets. Any grade changes to your exam have to take place a week within the grade being received by the student, no exceptions will be made.

Policies

The course schedule and guidelines are subject to change. I will communicate any changes promptly and clearly. Still, it is your responsibility to make yourself aware of any and all changes by attending class and maintaining communication with me.

Disability Accommodations

Rutgers University welcomes students with disabilities into all of the University's educational programs. In order to receive consideration for reasonable accommodations, a student with a disability must contact the appropriate disability services office at the campus where you are officially enrolled, participate in an intake interview, and provide documentation: https://ods.rutgers.edu/students/documentation-guidelines. If the documentation supports your request for reasonable accommodations, your campus's disability services office will provide you with a Letter of Accommodations. Please share this letter with your instructors and discuss the accommodations with them as early in your courses as possible. To begin this process, please complete the Registration form on the ODS web site at: https://ods.rutgers.edu/students/getting-registered

Absences

Students are expected to attend all classes; if you expect to miss one or two classes, please use the University absence reporting website to indicate the date and reason for your absence. An email is automatically sent to your instructors. If you have been told to quarantine, or are experiencing symptoms of any transmissable disease, please do not attend in-person class meetings. Contact me to make arrangements for handling such absences.

Books: required and suggested

- (Griffiths) *Introduction to Quantum Mechanics* by David Griffiths, ISBN:1107189632. This is the **required textbook** for the class.
- (Sakurai) *Modern Quantum Mechanics* by J. J. Sakurai and Jim Napolitino, ISBN:1108473229. Depending on how far we get, this book will also be covered in the later part of the class.
- (Feynman) *Feynman's Thesis: A New Approach to Quantum Theory* by Richard Feynman (Author), Laurie M. Brown (Editor), ISBN:9812563806. This is worth reading during this semester even if we dont get far enough to cover path integrals.

Prerequisites

Prerequisites: Physics 361 (Quantum Mechanics and Atomic Physics).

Learning Goals

This class builds upon previous training in foundations in what quantum mechanics is to take the next step to teach students how to "do" quantum mechanics. After reviewing quantum mechanics formalism and many-particle systems, the learning goals include:

- *the role of symmetry in quantum mechanics*: Students will be able to understand how continuous symmetries are related to conservation laws that dictate the structure of the quantum wavefunction.

- *Perturbation Theory and variational wavefunctions*: Students will be able to perform perturbative calculations to determine the energy levels and wavefunctions of the system. This includes non-degenerate and degenerate perturbation theory, as well as time dependent perturbation theory. They will also learn the variational principle and gain experience using "simple" variational wavefunctions.
- *WKB approximation and scattering theory*: Students will learn the how determine the wavefunction from a a Schrodinger equation with a slowly varying potential through a semi-classical limit. They will also understand the notion scattering and its connection to phase shifts.
- *Quantum dynamics*: Students will time dependent perturbation theory and understand the interaction of coherent light with a two level system.

Schedule

The schedule is tentative and subject to change. Reading is meant to supplement the course lectures and is a required component of the class.

Week 01, 01/19 - 01/23: QM Formalism (QMF)

- MLK Holiday on Monday
- Thursday: Formalism of Quantum Mechanics, Hilbert Space, Inner Products, interpretation of measurements.
- Reading: Chapter 3-3.3

Week 02, 01/26 - 01/30: QM Formalism (QMF); Many-particles (MP)

- Monday: QMF: Dirac Notation; MPs: bosons and fermions
- Reading: Chapter 3.4-3.6
- MPs: solids and band structure;
- Reading: Chapter 5

Week 03, 02/02 - 02/06: Symmetries and conservation laws (SCLs);

- Monday: SCLs: meaning of conservation laws, translation symmetry, parity symmetry.
- Reading: Chapter 6.1–6.4
- Thursday: SCLs: Rotations, degeneracy, time. "Pictures of QM" Heisenberg, and Schrödinger.
- Reading: Chapter 6.5–6.8

Week 04, 02/09 - 02/13: Time Independent Perturbation Theory (TIPT)

- Monday: TIPT: Nondegenerate Perturbation Theory.
- Reading: Chapter 7.1
- Thursday: Degenerate Perturbation Theory
- Reading: Chapter 7.2

Week 05, 02/16 - 02/20: Applications of Time Independent Perturbation Theory (TIPT)

- Monday: Fine structure of hydrogen, spin-orbit coupling
- Reading: Chapter 7.3
- Thursday: Zeeman effect, hyperfine splitting of hydrogen.
- Reading: Chapter 7.4-7.5

Week 06, 02/23 - 02/27: Variational Principle (VP)

- Monday: VP: Theory, examples
- Reading: Chapter 8.1-8.2
- Thursday: VP: helium, the interacting Bose gas
- Reading: Chapter 8.3

Week 07, 03/02 - 03/06: WKB approximation

- Monday Sc: WKB: Classical region, tunneling
- Reading: Chapter 9.1-9.2
- Thursday : WKB: Connection formulas, applications.
- Reading: Chapter 9.3

Week 08, 03/09 - 03/13: Review and Midterm

- Monday : Finish WKB; Exam Review
- Thursday: Midterm

Week 09, 03/16 - 03/20: Spring Break

Week 10, 03/23 - 03/27: Scattering (Sc)

- Monday: classical/quantum theory, start partial wave analysis
- Reading: Chapter 10.1-10.2
- Thursday: Sc: Finish partial wave analysis, Phase Shifts, start Born approximation
- Reading: Chapter 10.3-10.4

Week 11, 03/30 - 04/03: Scattering and Quantum Dynamics (QDs)

- Monday: Finish Born Approximation
- Reading: Chapter 11.1
- Thursday: QDs: Two-level systems, time dependent perturbation theory
- Reading: 11.2

Week 12, 04/06 - 04/10: Time dependent perturbation theory

- Monday: QDs: Sinusoidal perturbations, Emission and absorption of radiation
- Reading: Chapter 11.3
- Thursday: Spontaneous emission, Fermi's Golden Rule
- Reading: Chapter 11.4

Week 13, 04/13 - 04/17: Quantum Dynamics and Modern Topics

- Monday: Finish Fermi's Golden Rule. The adiabatic approximation, Berry's phase, Aharanov-Bohm effect.
- Thursday: Finish QDs; EPR paradox, Bell's Theorem
- Reading: Chapter 12.1-12.2

Week 14, 04/20 - 04/24:

- Monday: Mixed states and the density matrix.
- Reading: Chapter 12.3
- Thursday: The no-clone theorem and measurements in QM
- Reading: Chapter 12.4

Week 15, 04/27 - 05/01:

- Monday: Finsih measurement.
- Reading: Sakura 2.6.1-2.6.2, Feynmann's Thesis – preface and Chapter 1
- Thursday: Propagator in quantum mechanics
- Reading: Feynmann's Thesis – Chapter II and III

Week 16, 05/04 - 05/08: Last Class and Reading Week;

- Monday: Construction of the path integral and Lagranian description of quantum mechanics

Week 17, 05/11 - 05/15: Final Exam

- TBD.

Resources for Students

The faculty and staff at Rutgers are committed to your success. Students who are successful tend to seek out resources that enable them to excel academically, maintain their health and wellness, prepare for future careers, navigate college life and finances, and connect with the RU community. Helpful resources include the Rutgers Learning Centers and school-based advising (for SAS, SOE, SEBS, and RBS). Additional resources that can help you succeed and connect with the Rutgers community can be found at https://success.rutgers.edu.

Please visit the Rutgers Student Tech Guide for resources available to all students. If you do not have the appropriate technology for financial reasons, please email the Dean of Students (deanofstudents@echo.rutgers.edu) for assistance. If you are facing other financial hardships please visit the Office of Financial Aid.

Academic Integrity

Rutgers University takes academic dishonesty very seriously. By enrolling in this course, you assume responsibility for familiarizing yourself with the Academic Integrity Policy and the possible penalties (including suspension and expulsion) for violating the policy. Using ChatGPT or other AI to generate written work is also a violation of academic integrity, unless explicitly allowed by the instructor in a specific course. As per the policy, all suspected violations will be reported to the Office of Student Conduct. Academic dishonesty includes (but is not limited to):

1. Cheating
2. Plagiarism
3. Aiding others in committing a violation or allowing others to use your work

4. Failure to cite sources correctly
5. Fabrication
6. Using another person's ideas or words without attribution–re-using a previous assignment Unauthorized collaboration
7. Sabotaging another student's work

If in doubt, please contact me. Also review the Academic Integrity Policy and Academic Integrity Resources for Students. Use of external website resources (such as Chegg.com or others) to obtain solutions to homework assignments or exams is cheating and a violation of the University Academic Integrity policy. Cheating in the course may result in grade penalties, disciplinary sanctions or educational sanctions. Posting homework assignments or exams to external sites without the instructor's permission may be a violation of copyright and may constitute the facilitation of dishonesty, which may result in the same penalties as cheating.

The Rutgers honor pledge will be included on all major assignments for you to sign: *On my honor, I have neither received nor given any unauthorized assistance on this examination/assignment.*

Almost all original work is the intellectual property of its authors. This includes not just books and articles, but the syllabi, lectures, slides, recordings, course materials, presentations, homework problems, exams, and other materials used in this course, in either printed or electronic form. **You may not copy this work, post it online, or disseminate it in any way without the explicit permission of the instructor**. Respect for an author's efforts and intellectual property rights is an important value that members of the university community are expected to take seriously.

Student Wellness Services

Student Wellness Services

The university provides a number of resources to support your physical and mental well-being. Several valuable resources and listed here and you are encouraged to contact the Professor for more guidance about university resources.

- Student Success Essentials: https://success.rutgers.edu
- Student Support Services: https://www.rutgers.edu/academics/student-support
- The Learning Centers: https://rlc.rutgers.edu/
- Rutgers Libraries: https://www.libraries.rutgers.edu/
- Bias Incident Reporting: https://studentaffairs.rutgers.edu/bias-incident-reporting
- Dean of Students – Student Support Office: https://success.rutgers.edu/resource/dean-students-student-support-office
- Office of Veteran and Military Programs and Services: https://veterans.rutgers.edu

- Student Health Services: http://health.rutgers.edu/
- Counseling, Alcohol and Other Drug Assistance Program & Psychiatric Services (CAPS): http://health.rutgers.edu/medical-counseling-services/counseling/
- UWill: free immediate access to teletherapy; you can choose a therapist based on your preferences including issue, gender, language, ethnicity. http://health.rutgers.edu/uwill/
- Office for Violence Prevention and Victim Assistance: vpva.rutgers.edu/
- Office of Disability Services: https://ods.rutgers.edu/
- Basic Needs Assistance (food, housing, and other essentials): https://ruoffcampus.rutgers.edu/basic-needs
- Rutgers Student Food Pantry: https://ruoffcampus.rutgers.edu/food-pantry