

## Physics 631 (Spring 2022): Quantum Mechanics I

(Course No. 26:755:631 and 26:160:561)

**Instructor:** Neepa Maitra

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(best way to reach me)

**Lecture times:** Th 6pm – 9pm

**Office Hours:** Th 5pm Smith 357, and by arrangement\*

**Location:** Smith Hall 241; first two classes online, via Zoom

\*For office hours by arrangement, we can meet in-person Smith 357, or on Zoom, whichever is more convenient. The Zoom coordinates are on the canvas page for the course.

**Course Description:** Graduate Quantum Mechanics covers fundamental concepts, techniques, and applications of quantum mechanics, including formalism, angular momentum, symmetries, semiclassical methods, and perturbation theory. The class covers the first 5 chapters of Sakurai and Napolitano's Modern Quantum Mechanics book and will review the mathematical tools needed to successfully tackle the subject. The course aims to help students learn how to use the more advanced concepts and techniques to solve the physical problems they will encounter in their future research. An undergraduate course in quantum mechanics, or physical chemistry 2 or equivalent, and a good background in undergraduate linear algebra, are strongly recommended as pre-requisite.

**Learning Outcomes:** This course is intended to provide an advanced, graduate level understanding of and facility with quantum mechanics. The specific topics to be included are outlined below. By the end of the course, the students should be able to: 1. Utilize the postulates and operator formalism of quantum mechanics to describe quantum systems and determine their properties, 2. Analyze the time dependence of quantum systems within both the Heisenberg and Schrödinger pictures, path integrals and propagators, 3. Use the properties of angular momentum to describe systems such as atoms in magnetic fields, 4. Use perturbation theory to find approximate solutions to complex quantum systems, and 5. Recognize the implications of symmetries in quantum mechanics.

**Text:** The lectures will be based on the textbook:

*Modern Quantum Mechanics, 2<sup>nd</sup> edition*, by J. J. Sakurai and J. Napolitano

**Grading:** There will be homework about every two weeks (20% of grade), in-class quizzes (10% of grade), one midterm (35% of grade, likely March 17), and a final exam (35% of grade). The grading schedule may then be adjusted, based on factors like class participation, to arrive at a final letter grade. You may work collaboratively with other students on the homework provided

you list the names of the students on the front page. The quizzes, midterm, and final are *not* collaborative 😊

**Topics/Chapters to be covered (likely):**

1. Fundamental Concepts: Ch.1 (Stern-Gerlach experiment, Dirac notation, operators, matrix representations, measurements, observables, uncertainty relations, change of basis, position, momentum, and translation, wavefunctions in position and momentum space)
2. Quantum Dynamics: Ch. 2 (time-evolution and the Schrödinger equation, Schrödinger versus Heisenberg pictures, simple harmonic oscillator, Schrödinger's wave equation, semiclassical WKB approximation, propagators and Feynman path integrals, potentials and gauge transformations).
3. Theory of Angular Momentum: Ch. 3 (mixed ensembles and density operators, rotations and angular momentum commutation relations, spin- $\frac{1}{2}$  and finite rotations,  $SO(3)$ ,  $SO(2)$  and Euler rotations, eigenvalues and eigenvectors of angular momentum, addition of angular momenta, tensor operators, central potentials)
4. Symmetry in QM: Ch. 4 (symmetries, conservation laws, degeneracies, discrete symmetries – parity, space inversion, lattice translation, time-reversal)
5. Time-Independent Perturbation Theory: Ch 5 (non-degenerate and degenerate time-independent perturbation theory, fine structure and Zeeman effect)
6. Time-Dependent Perturbation Theory: Ch 5 (interaction picture, emission and absorption of radiation, spontaneous emission, energy shift and decay width)
7. The Variational Principle: Ch. 5 (Rayleigh-Ritz minimization, helium atom)

**COVID-Safety Statement:**

In order to protect the health and well-being of all members of the Rutgers-Newark community, masks must be worn by all persons inside campus buildings (e.g., classrooms) when in the presence of others, and in buildings in non-private enclosed settings (e.g., common workspaces, workstations, meeting rooms, classrooms, etc.). Masks should securely cover the nose and mouth. Masks must be worn during class meetings. Each day before you arrive on campus or leave your residence hall, you must complete the brief survey on the My Campus Pass symptom checker self-screening app found at: myRutgers Portal. Violations will be reported immediately with the COVID Observation Reporting Form.

### **Accommodation and Support Statement**

Rutgers University Newark (RU-N) is committed to the creation of an inclusive and safe learning environment for all students and the University as a whole. RU-N has identified the following resources to further the mission of access and support:

**For Individuals with Disabilities:** The Office of Disability Services (ODS) is responsible for the determination of appropriate accommodations for students who encounter barriers due to disability. Once a student has completed the ODS process (registration, initial appointment, and submitted documentation) and reasonable accommodations are determined to be necessary and appropriate, a Letter of Accommodation (LOA) will be provided. The LOA must be given to each course instructor by the student and followed up with a discussion. This should be done as early in the semester as possible as accommodations are not retroactive. More information can be found at [ods.rutgers.edu](https://ods.rutgers.edu). Contact ODS at (973)353-5375 or via email at [ods@newark.rutgers.edu](mailto:ods@newark.rutgers.edu).

**For Individuals who are Pregnant:** The Office of Title IX and ADA Compliance is available to assist with any concerns or potential accommodations related to pregnancy. Students may contact the Office of Title IX and ADA Compliance at (973) 353-1906 or via email at [TitleIX@newark.rutgers.edu](mailto:TitleIX@newark.rutgers.edu).

**For Absence Verification:** The Office of the Dean of Students can provide assistance for absences related to religious observance, emergency or unavoidable conflict (e.g., illness, personal or family emergency, etc.). Students should refer to [University Policy 10.2.7](#) for information about expectations and responsibilities. The Office of the Dean of Students can be contacted by calling (973) 353-5063 or emailing [deanofstudents@newark.rutgers.edu](mailto:deanofstudents@newark.rutgers.edu).

**For Individuals with temporary conditions/injuries:** The Office of the Dean of Students can assist students who are experiencing a temporary condition or injury (e.g., broken or sprained limbs, concussions, or recovery from surgery). Students experiencing a temporary condition or injury should submit a request using the following link: <https://temporaryconditions.rutgers.edu>.

**For English as a Second Language (ESL):** The Program in American Language Studies (PALS) can support students experiencing difficulty in courses due to English as a Second Language (ESL) and can be reached by emailing [PALS@newark.rutgers.edu](mailto:PALS@newark.rutgers.edu) to discuss potential supports.

**For Gender or Sex-Based Discrimination or Harassment:** The Office of Title IX and ADA Compliance can assist students who are experiencing any form of gender or sex-based discrimination or harassment, including sexual assault, sexual harassment, relationship violence, or stalking. Students can report an incident to the Office of Title IX and ADA Compliance by calling (973) 353-1906 or emailing [TitleIX@newark.rutgers.edu](mailto:TitleIX@newark.rutgers.edu). Incidents may also be reported by using the following link: [tinyurl.com/RUNReportingForm](https://tinyurl.com/RUNReportingForm). For more information, students should refer to the University's Student Policy Prohibiting Sexual Harassment, Sexual Violence, Relationship

Violence, Stalking and Related Misconduct located at <http://compliance.rutgers.edu/title-ix/about-title-ix/title-ix-policies/>.

**For support related to interpersonal violence:** The Office for Violence Prevention and Victim Assistance can provide any student with confidential support. The office is a **confidential resource** and does *not* have an obligation to report information to the University's Title IX Coordinator. Students can contact the office by calling (973) 353-1918 or emailing [run.vpva@rutgers.edu](mailto:run.vpva@rutgers.edu). There is also a confidential text-based line available to students; students can text (973) 339-0734 for support.

**For Crisis and Concerns:** The Campus Awareness Response and Education (CARE) Team works with students in crisis to develop a support plan to address personal situations that might impact their academic performance. Students, faculty and staff may contact the CARE Team by using the following link: [tinyurl.com/RUNCARE](http://tinyurl.com/RUNCARE) or emailing [careteam@rutgers.edu](mailto:careteam@rutgers.edu).

**For Stress, Worry, or Concerns about Well-being:** The Counseling Center has confidential therapists available to support students. Students should reach out to the Counseling Center to schedule an appointment: [counseling@newark.rutgers.edu](mailto:counseling@newark.rutgers.edu) or (973) 353-5805. If you are not quite ready to make an appointment with a therapist but are interested in self-help, check out *TAO at Rutgers-Newark* for an easy, web-based approach to self-care and support: <https://tinyurl.com/RUN-TAO>.

**For emergencies,** call 911 or contact Rutgers University Police Department (RUPD) by calling (973) 353-5111.