Syllabus **QUANTUM MECHANICS I (PHYS 811)** Spring 2026

Instructor: Uwe Thumm, Cardwell Hall room 230
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Office hours: by appointment

Classes: Tuesdays and Thursdays 2:30 - 3:45, Cardwell Hall room 146

Textbook: Quantum Mechanics, Merzbacher, 3rd ed., Wiley & Sons (1998) or
Modern Quantum Mechanics, Sakurai & Napolitano, 2nd ed., Pearson (2010) **(**your choice)

Prerequisites: Working knowledge of Classical Mechanics (PHYS 522), Classical Electrodynamics (PHYS 532), Mathematical Methods of Physics (PHYS 801)

Supplementary resources (not required):

Undergraduate level
Introduction to Quantum Mechanics, Griffiths
Quantum Physics: Atoms, Molecules, Solids, Nuclei, and Particles, Eisberg and Resnick

Graduate level
Quantum Mechanics, Cohen-Tannoudji, Diu, Laloe
Principles of Quantum Mechanics, Shanker
Quantum Mechanics: Nonrelativistic Theory, Landau & Lifshitz
Feynman Lectures in Physics – Vol. III, Feynman
Quantum Mechanics: Fundamentals, Gottfried & Yan
Foundations of Quantum Mech.: From Photons to Quantum Computers, Blümel

Mathematical and computational
Mathematical Methods for Physicists, Arfken & Weber
Tables of Integrals, Series, and Products, Gradsheyn & Ryzhik
Handbook of Mathematical Functions, Abramowitz & Stegun
NIST Digital Library of Mathematical Functions: https://dlmf.nist.gov
Numerical Recipes: The Art of Scientific Computing, Press et al.
A first course in computational physics, 2. ed., DeVries & Hasbun

More advanced and specialized
Physics of Atoms and Molecules, Bransden & Joachain
The Theory of Atomic Structure & Spectra, Cowan
Theoretical Atomic Physics, Friedrich
Solid State Physics, Ashcroft & Mermin
Introductory Quantum Optics, Gerry & Knight
Quantum Optics, Walls & Milburn
Elements of Advanced Quantum Theory, Ziman
Advanced Quantum Mechanics: The Classical-Quantum Connection, Blümel
Chaos in Classical and Quantum Mechanics, Gutzwiller

Homework

1. To successfully complete this course, you need to practice what we discuss in class by carefully working through all assigned problems.

2. I encourage you to discuss homework assignments in small groups. However, I require that you write down all homework solutions on your own and return them to me in class at the assigned due dates. Only hand in what you understand and are able to reproduce and defend in case I contact you. You will receive no credit for solutions that you have copied and partial credit for incomplete solutions.

3. To obtain full credit, you must present correct answers in a professional, well-organized, and readable manner.

4. Clearly state which references, such as scientific papers, integral tables, books, online resources (including AI tools), etc., you have used to complete the assignments.

5. Once you have completed a problem, sit back, relax, and think about your result in every possible way. Does it make sense? Are there related phenomena? What happens if you change parameters? Does the problem simplify for certain limiting cases? Are the techniques used really new to you or have you already applied them to solve other problems (which ones)?

6. In addition to the "for credit" homework assignments, I will occasionally ask you in class to complete simple calculations that we cannot discuss in all detail. These assignments will not be graded, but it is important that you carefully "fill in" these gaps when reviewing your lecture notes. This is done most efficiently **before** the subsequent lecture.

Exams and grading

There will be two in-class and one final exam. You have to attend the final exam to pass this course. All exams will be held in CW 146 unless announced otherwise. Exam and homework problems may be related to appropriate recent physics colloquia.

	Points
Exam 1	200
Exam 2	200
Final exam	300
Homework	300
Total	1000

Grade	Points
A	> 849
B	700-849
C	550-699
D	450-549
F	< 450

K-State Course Syllabi Statements

1. **Academic Honesty:** Kansas State University has an Honor and Integrity System based on personal integrity, which is presumed to be sufficient assurance that, in academic matters, one's work is performed honestly and without unauthorized assistance. Undergraduate and graduate students, by registration, acknowledge the jurisdiction of the Honor and Integrity System. The policies and procedures of the Honor and Integrity System apply to all full and part-time students enrolled in undergraduate and graduate courses on-campus, off-campus, and via distance learning. A component vital to the Honor and Integrity System is the inclusion of the Honor Pledge which applies to all assignments, examinations, or other course work undertaken by students. The Honor Pledge is implied, whether or not it is stated: "On my honor, as a student, I have neither given nor received unauthorized aid on this academic work." A grade of XF can result from a breach of academic honesty. The F indicates failure in the course; the X indicates the reason is an Honor Pledge violation.

2. **Students with Disabilities:** At K-State it is important that every student has access to course content and the means to demonstrate course mastery. Students with disabilities may benefit from services including accommodations provided by the Student Access Center. Disabilities can include physical, learning, executive functions, and mental health. You may register at the Student Access Center (k-state.edu/accesscenter); to learn more contact: Manhattan/Olathe/Global Campus – Student Access Center [accesscenter@k-state.edu , 785-532-6441]. Students already registered with the Student Access Center please request your Letters of Accommodation early in the semester to provide adequate time to arrange your approved academic accommodations. Once SAC approves your Letter of Accommodation it will be e-mailed to you, and your instructor(s) for this course. Please follow up with your instructor to discuss how best to implement the approved accommodations.

3. **Expectations for Classroom Conduct:** All student activities in the University, including this course, are governed by the Student Judicial Conduct Code as outlined in the Student Governing Association By Laws, Article V, Section 3, number 2. Students who engage in behavior that disrupts the learning environment may be asked to leave the class.

4. **Mutual Respect and Inclusion in K-State Teaching and Learning Spaces:** At K-State, faculty and staff are committed to creating and maintaining an inclusive and supportive learning environment for students from diverse backgrounds and perspectives. K-State courses, labs, and other virtual and physical learning spaces promote equitable opportunity to learn, participate, contribute, and succeed, regardless of age, race, color, ethnicity, nationality, genetic information, ancestry, disability, socioeconomic status, military or veteran status, immigration status, Indigenous identity, gender identity, gender expression, sexuality, religion, culture, as well as other social identities.

Faculty and staff are committed to promoting equity and believe the success of an inclusive learning environment relies on the participation, support, and understanding of all students. Students are encouraged to share their views and lived experiences as they relate to the course or their course experience, while recognizing they are doing so in a learning environment in which all are expected to engage with respect to honor the rights, safety, and dignity of others in keeping with the K-State Principles of Community https://www.k-state.edu/about/values/community/.

If you feel uncomfortable because of comments or behavior encountered in this class, you may bring it to the attention of your instructor, advisors, and/or mentors. If you have questions about how to proceed with a confidential process to resolve concerns, please contact the Student Ombudsperson Office. Violations of the student code of conduct can be reported here: https://www.k-state.edu/sga/judicial/student-code-of-conduct.html.

5. **Discrimination, Harassment, and Sexual Harassment:** Kansas State University is committed to maintaining academic, housing, and work environments that are free of discrimination, harassment, and sexual harassment. Instructors support the University's commitment by creating a safe learning environment during this course, free of conduct that would interfere with your academic opportunities. Instructors also have a duty to report any behavior they become aware of that potentially violates the University's policy prohibiting discrimination, harassment, and sexual harassment (PPM 3010).

If a student is subjected to discrimination, harassment, or sexual harassment, they are encouraged to make a non-confidential report to the University's Office of Civil Rights and Title IX (OCR & TIX) using the online reporting form. Incident disclosure is not required to receive resources at K-State. Reports that include domestic and dating violence, sexual assault, or stalking, should be considered for reporting by the complainant to the Kansas State University Police Department or the Riley County Police Department. Reports made to law enforcement are separate from reports made to OCR & TIX. A complainant can choose to report to one or both entities. Confidential support and advocacy can be found with the K-State Center for Advocacy, Response, and Education (CARE). Confidential mental health services can be found with Lafene Counseling and Psychological Services (CAPS). Academic support can be found with the Student Support and Accountability (SSA). SSA is a non-confidential resource. OCR & TIX also provides a comprehensive list of resources on their website. If you have questions about non-confidential and confidential resources, please contact OCR & TIX at civilrights@k-state.edu or (785) 532-6220.

7. **Academic Freedom:** Kansas State University is a community of students, faculty, and staff who work together to discover new knowledge, create new ideas, and share the results of their scholarly inquiry with the wider public. Although new ideas or research results may be controversial or challenge established views, the health and growth of any society requires frank intellectual exchange. Academic freedom protects this type of free exchange and is thus essential to any university's mission.

8. **Artificial Intelligence (AI):** You may use AI tools to assist your learning in this course, including idea generation and grammar assessments for written assignments. However, you are prohibited from using generative AI tools to manufacture homework solutions without dominant personal intellectual effort or without being able to understand and defend in every detail solutions you submit. If you choose to use AI, you are expected to provide a citation for it using the following format: "Title of AI Tool. Brief description of the search topic." Using an AI tool to generate assignment content without proper attribution would be a violation of the K-State Honor Pledge.

Uwe Thumm Spring semester

Quantum Mechanics 1 – Topics covered in class

1. Introduction
a. Experiments that reveal the particle character of light (Photo-, Compton-effect, black-body radiation)
b. Experiments that reveal the non-classical character of (quasi) particles (Franck-Hertz, H spectrum, Josephson effect)
c. Diffraction of particle beams (single-, double-slit, coherence)

2. Schrödinger Equation for Free Particles
a. Wave function (time independent) and Fourier transforms
b. Time-dependent wave functions, (Gaussian) wave packets

3. Schrödinger Equation for a Particle in a Conservative Force Field
a. Consistency with 2a) for V(x, t) = const
b. Relation to classical mechanics and geometrical optics (Maxwell, Hamilton-Jakobi, eikonal equations)
c. Continuity equation
d. Schrödinger equation in momentum space

4. Linear Operators and Expectation Values
a. Definitions (linear, Hermitian operators, scalar product, algebra, Hilbert space, square integrability)
b. Momentum operator in coordinate representation
c. Classical and quantum observables, their (not unique) correspondence and time evolution. Ehrenfest theorem, uncertainty relation. Virial theorem. Time inversion
d. Stationary states. Degeneracy
e. Expansions in terms of stationary states. Analytic functions of operators. Completeness
f. Normalization of continuum wave functions
g. Unitary operators (examples: displacement, time-evolution, ...)
h. Charged particles in electro-magnetic fields
i (active and passive) Galilei transformations

5. Linear Harmonic Oscillator
a. Stationary states and energies
b. Time-dependent solutions. Expectation values and comparison with classical solution (in phase space)

6. Simple Model Potentials (1 D)
a. Quantum phenomena at step potentials (transmission, reflection, penetration)
b. Quantitative solutions (step, well, barrier)
c. Scattering: M and S matrices in relation to incident, transmitted, reflected flux. Resonances

7. Spherically Symmetric Potentials
a. Orbital angular momentum operator. Commutation relations. Relation to rotations. Ladder operators
b. Eigenvalues and vectors of L^2 and L_z. Properties of (associated) Legendre polynomials and spherical harmonics
c. Radial Schrödinger equation for a free particle. (Spherical) Bessel and Neumann functions
d. Examples: Coulomb potential. Hydrogen: spectrum and eigenfunctions. Expectation values. Properties of Laguerre polynomials. Momentum-space representation

8. Perturbation Theory with Applications
a. Time-independent (degenerate) perturbation theory
b. Valence spectra of alkali atoms
c. He atom
d. Stark effect (linear and quadratic) and polarizability for H. Metastable quenching in weak el. field
e. Time-dependent perturbation theory. Transition rates. Continuum transitions. Fermi's golden rule
f. Absorption and induced emission of electro -magnetic radiation. Detailed balancing. Application to hydrogen atoms: Dipole selection rules. Cross sections
g. Photoelectric effect

9. Scattering at a Central Potential
a. Scattering amplitude and (angle-differential) cross section. Classical versus quantum interpretation
b. Green's functions (inclusion of boundary conditions, contour integration technique)
c. Born series. First Born approximation cross section for Yukawa and Coulomb potentials
d. Partial wave expansion of scattering wavefunction, amplitude, and cross section
e. Scattering phase shifts and resonances. Example: scattering off radial square-well potential

(over)

Uwe Thumm Fall semester

Quantum Mechanics 2 – Topics covered in class

1. **Formal Foundation of QM**
   a. Hilbert space. Definition, examples. Dirac (bra-ket) notation
   b. Linear operators and their representation. Normal, Hermitian, unitary, adjoint operators
   c. Operators with continuous spectra. Completeness, closure relation. Functions of operators. Fourier transformation
   d. Solving eigenvalue problems by i) matrix diagonalization and ii) variation. Example: He atom
   e. Observables and measurement. Single & simultaneous measurements, complete sets of commuting observables

2. **Application of Algebraic Operator Techniques**
   a. Harmonic oscillator. Quantization of classical fields. Quasi particles
   b. Coherent and squeezed states
   c. Angular momentum algebra

3. **Quantum Dynamics**
   a. Time-evolution operator
   b. Schrödinger, Heisenberg, and interaction picture
   c. Correspondence principle, quantization
   d. Canonical quantization
   e. Forced harmonic oscillator: advanced & retarded Green's functions, time ordering, relation to scattering theory
   f. Coordinate representation of the time-evolution operator. Examples: free particle, harmonic oscillator
   g. Path integrals. Classical limit. Semi-classical approximations
   h. Statistical mixtures of quantum states. Density operator. Shannon and von Neumann entropy

4. **Spin**
   a. Experimental evidence. Stern-Gerlach, Einstein-de Haas experiments. Zeeman effect
   b. Mathematical description: Two component spinors. Remarks on Dirac equation
   c. Spin rotations: Pauli matrices
   d. Spin dynamics. Spin-orbit coupling. Paramagnetic resonances. Remarks on NMR
   e. Spin-dependent scattering: angle-differential cross section, spin-polarization of scattered particles
   f. Information content in spin ensembles: von Neumann and outcome entropy
   g. Measurement and reduction of quantum states. Multiple Stern-Gerlach experiments

5. **Addition of Angular Momenta**
   a. Two spin-1/2 particles: product and total spin basis; hyperfine interaction in H (21cm line)
   b. Addition of two arbitrary angular momenta: Clebsch-Gordon coefficients, spectroscopic notation
   c. (Irreducible) representations of rotations and tensor operators. Wigner-Eckart theorem
   d. Applications of Wigner-Eckart theorem: normal & anomalous Zeeman effect, Paschen-Back effect
   e. Other symmetry operations: parity, time reversal, translation, iso-spin (example: nuclear spectra)

6. **Many-Particle Systems**
   a. Identical particles, Fock space, symmetrization postulate, bosons, fermions, spin-statistics theorem
   b. System of N independent indistinguishable particles (bosons or fermions)
   c. System of N interacting indistinguishable particles (bosons or fermions), "second quantization"
   d. Direct and exchange interactions. Examples: He atom, scattering
   e. Hartree-Fock method, Brillouin and Koopman theorem
   f. Molecules (mainly $H_2^{(+)}$)

7. **Relativistic Quantum Mechanics**
   a. Klein-Gordon equation for spinless particles
   b. Dirac equation for spin-½ particles
   c. Electromagnetic interactions of Dirac particles. Pauli equation for small $\langle v \rangle /c$. Gyromagnetic factors
   d. Approximate solution of Dirac equation for H atom
   e. Outline of exact solution of Dirac equation for H atom and QED corrections