Physics 137B. A course covering quantum mechanics in its classical applications as well as quantum information. The tools needed to make quantum mechanics *work* – solving a broad range of problems by approximations, Bosons and Fermions, interactions of atoms with radiation, photons. We will round it off with an introduction to cutting-edge quantum information topics.

We welcome every student and will make every effort to make you feel welcome and respected. If your name or set of pronouns differ from those in official documents, let us know. Also let us know if your performance in the class is impacted by your experiences outside the class, or if something said in class (by anyone) made you feel uncomfortable. As a participant in this class, please help make other students feel included and respected.

Instructor	Lecture	Office hours
Holger Müller, Office 301C Physics South hm@berkeley.edu (**Start the subject line with "137B"** so I can find your email later)	Etcheverry 3106	Wednesdays

GSI	Sections	Office hours
Kevin Wang Office 421 Birge kwang98@berkeley.edu	**101** Wednesday 10-11AM Hearst Field Annex B5 **102** Thursday 5-6PM Evans 3	Thursdays 1-2PM in person or over Zoom: https://berkeley.zoom.us/j/2744663617

Course Website: Bcourses. General Information, reading assignments, problem sets and due dates, solutions to problem sets and exams, and special announcements will be posted.

EdDiscussion: Everyone should have received an invitation to edstem. Please let us know if you have any trouble accessing the site.

Course capture is being used

Homework: will be announced Fridays on Bcourses and will be due on the Monday ten days after the announcement, at 5 pm. Late homework will *not* be accepted. However, I will drop your two lowest-scoring assignments at the end of the semester. You are allowed and encouraged to collaborate on the homework and discuss the problems, but you must write your solution independently and hand in your own solution.

Textbook: D. H. McIntyre, Quantum Mechanics, Pearson, 2021. Also Schwabl, Quantum Mechanics and Advanced Quantum Mechanics. Berkeley students can access it free of charge online. The library has a reading list for this course.

Exams: There will be two in-class midterm examinations and a final exam. It is your responsibility to check for conflicts and notify me well in advance if you are planning to be absent.

Please self-isolate in case you get COVID. We will allow you to take the exam at home, on camera, at the same time as the others. Please let us know as early as possible. If you are sick and can't take the exam, let us know and we will find an arragement.

Grading: There will be two midterms, finals, and homework. The class grade will be determined as a weighted average of these, with the weights MT1/MT 2/HW/Finals: 20/20/30/30. If your final exam score is higher than the average of your two midterm scores, we will count the finals more. In this case, the weights are 15/15/30/40.

We will drop the two lowest-scoring homework problem sets from the grading without asking any questions. Further exceptions, however, will not be made.

A grade of "Incomplete" will only be given under dire circumstances beyond a student's control, and only when work already completed is of at least C quality.

If you are in trouble (behind in homework, doing worse than you would like, etc.) for whatever reason, please let us know. We'll try to help! Additional help may be available - Inquire in the Physics Department Undergraduate Student Services Office for further information.

Mental health: Please take care of yourself and prioritize your physical and mental health. The following links may be of use if you or a friend are in trouble:

- CAPS (Counceling and Psychological Services) Website: https://uhs.berkeley.edu/caps
- CAPS COVID-19 Website: https://uhs.berkeley.edu/coronavirus/student-mental-health
- Helping a Distressed Friend: https://uhs.berkeley.edu/sites/default/files/distressed_friend.pdf
- Student Advocates Office: https://advocate.berkeley.edu/
- Division of Student Affairs COVID-19 Toolkit: https://sa.berkeley.edu/covid19
- Student Technology Equity Program: https://technology.berkeley.edu/STEP

Disability Accommodation: UC Berkeley is committed to creating a learning environment that meets the needs of its diverse student body. If you anticipate or experience any barriers to learning in this course, please feel welcome to discuss your concerns with me. If you have a disability, or think you may have a disability, you can work with the Disabled Students' Program (DSP) to request an official accommodation. The Disabled Students' Program (DSP) is the campus office responsible for authorizing disability-related academic accommodations, in cooperation with the students themselves and their instructors. You can find more information about DSP, including contact information and the application process here: dsp.berkeley.edu. If you have already been approved for accommodations through DSP, please meet with me so we can develop an implementation plan together. Students who need academic accommodations or have questions about their accommodations should contact DSP, located at 260 César Chávez Student Center. Students may call 510-642-0518 (voice), 510-642-6376 (TTY), or email dsp@berkeley.edu.

Schedule: A detailed schedule is available below. It will be updated regularly. M *x* means McIntyre, Chapter x; S *x* means Schwabl, Quantum Mechanics, Ch. *X*. **The lecture will often cover material that goes beyond the book, so make sure to attend.**

8/22	M	No class	Reading
	W	Review: States, Operators, and Measurement; Schrödinger equation; Operators; Free particle and Gaussian wave packets; Square well; Harmonic Oscillator; Hydrogen; Spin; coherent states	
	F		M1-9
8/29	M	Time-independent perturbation theory, first order	10.1-10.3
	W	Second order, degenerate perturbation theory	10.4, 10.5, 10.6
	F	Stark effect	
9/5	M		
	W	Hyperfine structure and addition of angular momenta	M11.1-11.4
	F	Addition of angular momenta	11.5-11.7
9/12	M	Fine stucture	12.1-12.2
	W	Zeeman effect	M12.3
	F	Identical particles: exchange forces, Bosons and Fermions;	M13
9/19	M	Review session	
	W	Midterm 1	
	F	No class	
9/26	M	Variational Principle; Helium atom; Hydrogen molecule	M13.4-13.6
	W		
	F	WKB approximation, atom interferometers	
10/3	M	Tunneling, connection formulas, bound states	
	W	Quantum dynamics. Heisenberg picture, Two-level systems. Einstein A and B coefficients, selection rules	M14, Bcourses notes
	F	Bloch Sphere	
10/10	M	Atomic clocks	Bcourses notes
	W	Second quantization of the electromagnetic field.	S16.4
	F	Spontaneous emission	
10/17	M	Review Session	
	W	Midterm 2	
	F		
10/24	M	Adiabatic approximation, Berry Phase Aharonov-Bohm effect	BCourses

			notes
	W	Scattering Theory. Classical and Rutherford scattering, definition of terms	
	F	Green's function approach to the Schrödinger equation	
10/31	M		
	W	Born approximation, Rutherford scattering	
	F	Partial wave analysis	
11/7	M	Soft-sphere scattering, scattering in a van der Waals potential	
	W	Resonant scattering, optical theorem	
	F	Scattering wrap up	
11/21	M	Quantum information: key concepts	
	W	Thanksgiving	
	F	Thanksgiving	
11/28	M		
	W	Quantum logic spectroscopy	
	F	Quantum computing	
12/5			
12/12			

Mathematical background: Succeeding in this course requires being able to apply (not just being familiar with! The difference is practice) a number of mathematical concepts. Here is a list of them to help you revisit these topics, if needed. The list is incomplete, but courses covering the concepts are likely to give you a good preparation for 137B. If you took the undergraduate series in physics at Berkeley, it is likely that you are familiar with most required concepts, but it is your responsibility to catch up on any mathematical knowledge required for the course.

- **Probability**: Conditional probability, averages, standard deviation, standard error.
- **Simple functions:**
    - Polynomials, rational functions, exponentials (real and complex arguments), log, trigonometric functions.
    - Expressions for sums and multiples of trigonometric functions, trigonometric functions of products, etc. Inverse trigonometric functions. E.g., you should be able to calculate $\tan^2 x$ from $\sin^2 x$?
- **Series:** Convergence, divergence, geometric series, absolute convergence vs conditional convergence.
- **Differential equations:**
    - Existence theorems,
    - linear differential equations, linear differential equations with constant coefficients,

    - Frobenius' method of solving differential equations,
    - differential equation of a harmonic oscillator,
    - Separation of variables for partial differential equations.
- **Linear Algebra:**
    - Systems of linear equations, conditions for nontrivial solutions, methods to solve systems of equations.
    - Vector spaces, vector axioms. Examples for vector spaces: R^n and C^n, vector space of functions. Linear combinations, linear (in)dependence, base vectors, orthonormal bases. Scalar product, norm
    - Cauchy-Schwarz inequality
    - Gram-Schmidt orthogonalization
    - Matrices, linear forms, matrix multiplication, determinants (properties, how to calculate them), hermitian matrices, change of basis, transformation matrix, eigenvalues and eigenvectors, characteristic polynomial, diagonalization.
- **Multivariate calculus**
    - Scalar product and norm of infinite-dimensional vector spaces,
    - convergence in R^n, continuous functions,
    - differentiation in R^n, partial derivatives, Jacobian, chain rule, product rule, gradient, nabla operator, divergence, rotation,
    - Taylor series in multiple variables,
    - Integrals in R^n, integrals in cylindrical and polar coordinates, volume and surface integrals, Gauss', Stokes' and Green's theorems.
- **Complex analysis:** Residues and using residues to evaluate integrals.