Physics 661 – Quantum Mechanics II – Spring 2024

Instructor: Prof. S. Martin email: `spmartin@niu.edu`

Class Meetings: M,W,F 10:00 – 10:50, LaTourette 227.

Although I will try to avoid it, there is a possibility that some future classes will also be held on Zoom, as future events dictate. All classes that are held on Zoom will be recorded and uploaded to `youtube.com`. Classes held face-to-face will not be recorded. Recorded classes from 2021 can be found on youtube (search for "PHYS661 NIU Spring 2021").

Office Hours: M,W,F 11:00 – 1:00 (or any other time you can find me, but not in the hour before class) LaTourette 214. Office hours can also be by appointment on Zoom. Do not hesitate to send email at any time requesting an Office Hours meeting. If I am available, it can happen immediately, or we can schedule it. After class is usually a particularly good time. Before class is usually not good.

Course web page: `http://www.niu.edu/spmartin/phys661`
There is no "Blackboard" web page for this course. Everything relevant will be distributed to you in pdf form, either sent by email, or linked to on the web page above, or both.

Textbook: Typeset notes in pdf form, which will be sent to registered students (free!) by email on the first day of class. The notes have a clickable table of contents, index, and equation numbers. They cover more than we will be able to in this course. No other textbook is required.

Homework policies: Each homework should be turned in by email as a single pdf file. Please be neat and legible, and leave enough space for grading notes and corrections. Homework should be turned in by midnight on the due date. Late penalty: 10% off for each day late up to 4 days; 100% off for > 4 days. You are encouraged to consult with each other, and with me, on the homework. **However, each of you must turn in only your own work. Do not turn in anything that you have copied, or anything that you do not understand. Do not use Chegg or any similar service, or send any materials from this course to such services, or get homework solutions from students outside or inside of NIU who may have previously taken this course or equivalents. In particular, the notes, homework sets, and exams for this class should not be distributed to, or discussed with, anyone other than your peers in this class and your instructor.**

Exam policies: Exams will be closed book, but you may bring one page of notes in your own original handwriting, and when necessary you will be given a formula sheet. No electronic devices are allowed.

Midterm Exam: Friday, March 8, 2024, 9:00-10:59 AM.
Final Exam: Monday, May 6, 2024, 10:00-11:59 AM.

Extra Credit: For each substantive mistake (grammar, punctuation, and syntax corrections are appreciated, but usually won't count, unless I'm really impressed by your suggested revision) in the pdf class notes that you find and report, you will receive 2 extra percentage points on your final exam grade, up to a maximum of 6 points. The first student to report the mistake gets the point. If more than one of you finds the mistake in collaboration, you can choose to

each receive 1 point. Mistakes will be collected and posted on the course web page in real time.

Grading: Your numerical score in this class is weighted according to 40% homework, 25% midterm exam, 35% final exam. Grades will be assigned according to your numerical score as a percentage, with the low cutoff for each grade as follows:

A 89%,	A– 85%,	B+ 82%,
B 77%,	B– 73%,	C+ 66%,
C 55%,	D 45%.	

I reserve the right to amend the above grading scale to be more lenient, but it is guaranteed not be made more strict. To obtain a D or better, you **must also** score at least 50% on the homework portion alone, regardless of your overall score; this requirement will not be changed. No C– or D+ or D– grade will be assigned.

Accessibility Statement: If you need an accommodation for this class, please contact the Disability Resource Center as soon as possible. The DRC coordinates accommodations for students with disabilities. It is located on the 4th floor of the Health Services Building, and can be reached at 815-753-1303 or `drc@niu.edu`. Also, please contact me privately as soon as possible so we can discuss your accommodations. Please note that you will not be required to disclose your disability, only your accommodations. The sooner you let me know your needs, the sooner I can assist you in achieving your learning goals in this course.

Topics to be covered in PHYS 661:

- Brief review of PHYS 660
- Additional of angular momentum and Clebsch-Gordan coefficients
- Stationary state (time-independent) perturbation theory
  - Non-degenerate perturbation theory
  - Ground state of helium from first-order perturbation theory
  - Degenerate perturbation theory
  - Stark effect: hydrogen atom in an electric field
  - Almost-degenerate perturbation theory
- Variational method
  - Estimate and upper bound on the ground-state energy
  - Variational method for excited states
  - Ground state of helium from the variational method
- Fine and hyperfine structure of the hydrogen atom
  - Relativistic kinetic, spin-orbit coupling, and Darwin corrections
  - Hyperfine structure
  - Lamb shift
- Identical particles
  - Permutations and the spin-statistics principle
  - Bosons, fermions, Pauli exclusion
  - Excited states of helium

- Central field approximation and multi-electron atoms
- Periodic table of elements

- Representations (also known as "pictures") in quantum mechanics
  - Heisenberg picture
  - Interaction picture

- Time-dependent perturbation theory
  - Sudden approximations
  - Transition amplitudes and probabilities in perturbation theory
  - First-order time-dependent perturbation theory and Fermi's golden rule
  - Harmonic perturbations

- Absorption and emission of light
  - Absorption of electromagnetic waves
  - Induced and spontaneous emission of light
  - Electric dipole approximation and selection rules
  - Magnetic dipole and electric quadrupole transitions
  - Photo-electric effect for atoms

- Scattering theory
  - Probability density and current
  - Scattering problems in 1-d
  - Green functions
  - Differential and total cross-sections
  - Scattering matrix
  - Born approximation
  - Unitarity and the optical theorem
  - Eikonal approximation
  - Partial wave expansions and phase shifts
  - Coulomb scattering
  - Scattering of identical particles

- Feynman sum over histories and the path integral approach to quantum mechanics
- Relativistic quantum mechanics
- Interpretational issues
  - Einstein's locality principle and the Einstein-Podolosky-Rosen "paradox"
  - Bell's theorem and inequalities vs. hidden variables
  - Everett's "Many Worlds" interpretation