SYLLABUS - PHYS 460 [PHYS 560] Quantum Mechanics (3 unit) Fall 2018

(Dated: version 1b for Fall 2018 semester [printed 26 August 2018])

Class meets - Mon Wed Fri at 10:00-10:50 am in Location TBD (Faraday 237 but we may change)
Professor C. Thompson (815-753-1772)- cthompson@niu.edu - LaTourette Hall 207
http://sites.google.com/site/profcthompson/home
Office hours - Monday 11:00 am-12:15 pm, but preferred arrangemnt is by appointment.

Textbook - *Quantum Mechanics for Scientists and Engineers*, David A. Miller, Cambridge University Press; 1st edition (April 21, 2008)
Otherreferences for the course - see section IV IV.A.

Three In-Class exams are scheduled. (They also may have take-home component).
Wednesday, October 3, 2018; Friday, November 2, 2018; and Friday December 7, 2018.
Final in-class exam is take-home, and will be due Wednesday, December 12, 2018 8:00 pm. (scanned pdf to my email)

This syllabus is a guide. Every attempt is made to provide an accurate overview of the course. However, circumstances and events may make it necessary for the instructor to modify the syllabus during the semester. Changes to the syllabus will be noted by announcements in class, by email to students NIU email address. *Students are responsible for any issues that occur if they are absent and miss an important in-class announcements*

I. FALL 2018 PHYS 460-PHYS 560 WEEKLY TOPICAL LIST

TABLE I. Topical List by week for PHYS 460 [PHYS 560] (Fall 2018)

Week	Topic	Readings	other
ONE (W, F)	I: Introduction; II: Waves and quantum mechanics;	Ch1 , Ch 2	Check Appendix A and B
TWO (W, F)	II: Waves and quantum mechanics; (M=NIU Holiday, F=Independent Recitation(?))	Ch 2	(Monday Labor Day Holiday) (Friday CT IAI Sciences Panel)
THREE (M, W, F)	III: The Time dependent Schrodinger equation;	Ch 2, Ch 3	
FOUR (M, W, F)	III: The Time dependent Schrodinger equation; IV: Functions and operators;	Ch 3, Ch 4	Check Appendix C, particularly divergence
FIVE (M, W, F)	IV: Functions and operators;	Ch 4	
SIX (M, W, F)	V: Operators and QM; (W=EXAM)	Ch 5	October 3 in-class exam Ch 1-4
SEVEN (M, W, F)	VI: Approximation Methods;	Ch 6	
EIGHT (M, W, F)	VI: Approximation Methods;	Ch 6	
NINE (M, W, F)	VII: Time Dependent Perturb;	Ch 7	
TEN (M, W, F)	VII: Time Dependent Perturb; IX: Angular Momentum; (F=EXAM)	Ch 7, Ch 9	(Fri CT IAI General Ed Panel) Nov 2 in-class exam Ch 4-6
ELEVEN (M, W, F)	IX: Angular Momentum; X: Hydrogen atom;	Ch 9, Ch 10	
TWELVE (M, W, F)	X: Hydrogen atom; XII: Spin;	Ch 9, Ch 12	(Fri CT IAI Physics Panel)
THIRTEEN (M)	XIII: Identical Particles; (W,F=Holiday)	Ch 12, Ch 13	(Wed/Fri Thanksgiving Holiday)
FOURTEEN (M, W, F)	XV: Harmonic oscillators and photons;	Ch 13, Ch 15	
FIFTEEN (M, W, F)	XV: Harmonic oscillators and photons; (F=EXAM)	Ch 15	(W/F CT Beamtime) Dec 7 in-class exam Ch 7,9,10,12
SIXTEEN (FINALS!)	FINAL EXAM WEEK (Take Home exam)	due Wed Dec 12, 2018, 8 pm	Final exam Ch 13, 15 (and prior topics)

The weekly topic list along with course meeting dates is given in Table I

II. GRADING AND GRADING POLICIES

II.A. Dates of Three in-class Exams and Take-home Final Exam

Three In-Class exams are scheduled. (They also may have take-home component).
In-class exams are on :

- Wednesday, October 3, 2018 (in-class 10-11:50am)
- Friday, November 2, 2018 (in-class 10-11:50am)
- Friday December 7, 2018 (in-class 10-11:50am)
- Final exam is take-home. I will accept the exam work turned in before Wednesday, December 12, 2018, 8:00 pm. (scanned pdf to my email in OK)

II.B. Final grade determination - Scoring of exams and homework and in class quizzes and exercises

The parts of the course used in grading are listed in Table II. Each part will receive its own letter grade, using the formulas also as noted in Table II. A Final Letter grade for this course is calculated similarly to calculating a 'gpa', using the letter grades parts weighted as noted in Table III. If Plus or Minus grades are given for the exams or final, an A- will count as a 3.66, B+ as 3.33, etc for purposes of calculating the 'gpa'. The conversion back from a 'gpa' to Final Letter Grade for the course is shown in Table IV.

TABLE II. Letter Grades assigned to the various assessments in the course. Each exam and the final will be assigned its own letter grade. Homework (plus any in class quizzes) and the PreClass/In class assignments are assigned a grade at end of the semester based on the percentage of the total number of points possible in the category.

Homework and In-class Quizzes:	85% A(4) 75% B(3) 65% C(3) 55% D(1)
Preclass and in class assignments:	85% A(4) 75% B(3) 65% C(3) 55% D(1)
Exams (in class and out of class):	80% A(4) 70% B(3) 60% C(3) 50% D(1)
FINAL Exam:	80% A(4) 70% B(3) 60% C(3) 50% D(1)

TABLE III. Final Course Grade Weighting. Each exam receives its own letter grade.

Homework/ Quizzes	PreClass/Inclass Exercises	Exams I + II + III	Final exam
25%	30%	10% + 10% + 10%	15%

TABLE IV. Calculated 'GPA' from weighted part grades to a Letter grade for the course. When using the weighting in Table III , a final 'GPA' is calculated and converted to the Course letter grade as follows.

A	A-	B+	B	B-	C+	C	D	F
≥ 3.83	≥ 3.49	≥ 3.16	≥ 2.83	≥ 2.49	≥ 2.16	≥ 1.7	≥ 0.82	< 0.82

II.C. Grading of exams, homework/quizzes and the new Preclass/inclass assignments(and credit!)

Due to the small class size, we will be trying to 'flip' this class, meaning that students will do readings (and be directed to check out either lectures that I've prepared or materials that I've curated from the web) prior to class. There will be an small in-class assignment due every class and work that we do together in class in a recitation style. Student's missing class will miss any credit for that assignment or for any credit for the class work.

II.C.1. Homework and Quizzes

Will be graded as is standard for homework. The due date for homework will usually be about a week to 1 1/2 weeks after it has been assigned. Points possible will be clearly marked. Credit is given for correct analysis and interesing or original thinking on the problem (that is correct). Study groups are encouraged, however, students should be transparent about when they could not have finished the problem without help from another student/web sources etc. Please see the guidelines at end of syllabus about group work and studying. Any pop-Quizzes scores will be treated similarly to the HW points and added onto the total Homework point tally possible. At the end of the semester, the HW/Quezz grade is determined from percentage from the total points possible

II.C.2. Exams

Will be graded as usual for exams. Credit is given for correct analysis. For take-home exames, students must work alone and should not be trying to 'solve' by web searches. Exams are typically closed book, closed notes, no calculator. A formula sheet will be provided and students generally get to see the formulat sheet format a few days before the exam. Each exam receives is own letter grade.

II.C.3. Inclass/Preclass assignments

These will typically be smaller assignments that both help prove the student is reading or checking the resources as well as be a springboard for the class discussions. Total points possible per session will be the sum of the points per problem. The due date for these assignments might be rather short, e.g., assigned one lecture for the next lecture). (I agree that would not be ideal - next time I do a flipped classroom we'll have everything we figured out!). Ideally there will be one for each class. **Students absent for an inclass session will receive zero points.** The in-class assigment will be graded holistically for

- (20%) credibly having prepared with effort (based on what is turned in at beginning of class and whether students can participate in the discussion and recitation on the material in class)
- (10%) correctly worked in advance based on what students hand in at beginning of class
- (70%) for participation (meaning that students will have to discuss their work, questions, and analysis in class.

III. CATALOG DESCRIPTIONS, PREREQUISITES, AND CONTEXT

Catalog descriptions:
PHYS 460 [**560**]**. Quantum Physics (3 credit)***: Schrodinger wave equation, eigenvalues and eigenfunctions, methods of approximation and applications to the square well, the harmonic oscillator, and hydrogen-like atoms. PRQ 460: PHYS 300 and PHYS 370 and PHYS 383. [PRQ 560: PHYS 300 and PHYS 370, or consent of department.]*

PHYS 461[**561**] **Modern Physics (3 credit)**. *Applications of quantum physics to atoms, molecules, solids, nuclei, and elementary particles. PRQ 461: PHYS 460 or consent of department. [PRQ 561: PHYS 560 or consent of department.]*

PHYS 460 is a one-semester course for the senior-level undergraduate course of quantum for physics majors. It is required for the professional physics emphasis, **strongly recommended** for the other emphases (applied physics and physics education). PHYS 460) meets simultaneously with PHYS 560 (grad credit).

Graduate level course PHYS 560 is designed to help provide a quantum physics background for students in interdisciplinary studies (math, chemistry, engineering). It also is suitable for physics graduate students coming from a refresher course before tackling the standard graduate 2 semester quantum mechanics course, PHYS 660/661 required for the MS and PhD physics degrees.

Lectures for PHYS 460 meet at same time as for PHYS 560. The expectation for the graduate credit course is that the student develops and demonstrates a deeper and more sophisticated mastery of the topics. To achieve this and to assess mastery, additional selected advanced problems on the homework are required for graduate credit, The tests and quizzes for PHYS 560 will incorporate subsets that include more advanced problems.

IV. TOPICS AND RESOURCES

IV.A. Suggestions for useful references

Due to the small class size, we will be trying to 'flip' this class, meaning that students will do readings (and be directed to check out either lectures that I've prepared or materials that I've curated from the web) prior to class.

IV.B. Miller Lectures on the Internet

Miller has a set of lectures on you-tube. They are numbered as lessons (lesson 01, 02, ...) Each lesson is typically split up into smaller portions). To see the set of audio-visual lessons (organized into chronological order) check out this link.

https://www.youtube.com/channel/UC4Zg2fA5HQ_gnTPR6a_fR7g/videos?flow=grid&sort=da&view=0

Several of the early lessons (01 to 03) are primarily background materials, and reviews of classical physics topics and concepts that are particularly relevant to working in quantum mechanics. Students who have had a course similar to Phys 383 at NIU will have seen most of this introductory materials. Lesson 04 starts with more material that really starts the quantum physics.

What also may be valuable are his large set of 'pre-lesson' background mathematics review videos. They are fairly well labeled so that if a student needs to review matrix multiplication, or vectors and coordinate systems, these might be a good first source to check.

IV.C. Other textbooks and resources

Books that are useful for Phys 460 (Phys 560) class can be found on ebay and Amazon and in used bookstores. Books titled Modern Physics tend to be for a slightly lower level class related to the 2 year intro sequence. If the title combines Modern Physics and Quantum Mechanics - it is likely for an advanced upper-level UG course as this one. A text that says Quantum Mechanics or Quantum Physics may be appropriate or may be rather more advanced. It is usually pretty clear from reading the preface whether the book is designed for an introductory (Freshman/Sophmore) semester sequence, for this advanced undergraduate (grad refresher course) or for a core MS/PhD graduate program course. Within a particular level, the fundamental topics covered will be similar but at different mathematical complexity - but how the topics are put together will be different depending on the pedagogical vision of the author.

The second semester of the course (PHYS 461/561) (e.g., applications of QM) sees important differences in level of treatment of some topics included in books published 20-30 years ago and now. Some 'applications' or examples go in and out of fashion. Also, as research has advanced in the various areas, authors will attempt to evolve the pedagogy so that students more quickly appreciate and work in new areas. Or, because it is newly fashionable topic, they may simply attempt to bring in a bit of enrichment to hook a student's interest.

A random selection of books that have material at the right level, (arranged by date of publication) - these happen to be ones I have. Some are designed for a year long course at level of Phys 460/560.

- *Introduction to Quantum Mechanics in Chemistry, Materials Science, and Biology*, S. M. Blinder (2011), Elsevier Press Complementary Science Series.
- *Quantum Mechanics - Foundations and Applications*, D. G. Swanson (2007), Taylor and Francis (CRC Press).
- *Quantum Physics*, S. Gasiorowicz (2003), 3rd edition, Wiley.
- *Introductory Quantum Mechanics*, R. L. Liboff (2003), 4th edition, Addison Wesley Press.
- *Quantum Physics of Atoms, Molecules, Solids, Nuclei, and Particles*, R. Eisberg and R. Resnick, 2nd edition, Wiley.
- *Modern Physics and Quantum Mechanics* E. E. Anderson (1971), 1st edition, W. B. Saunders Co.
- *Basic Quantum Mechanics*, R. L. White (1966), 1st edition, McGraw Hill Book Co.
- *Principles of Modern Physics*, R. B. Leighton (1959), 1st edition, McGraw Hill Book Co.

V. COURSE OUTCOMES

V.A. Topics

A successful student will have mastered areas in the following topics:

- momentum and position, operator notation
- Eigenstates, eigenfunctions, and how they apply
- Hermitian operators, hermiticity in operator and integral notation
- Schrodinger equation and its use in 1 D (and some 3D)
- Bound systems such as simple harmonic oscillator, square well (infinite and finite)
- solutions in transport systems
- 3D potentials - central force
- angular momentum (orbital) - operator and differential treatment
- spin
- Fermi and Bose particles - multiple particles
- Approximation methods for time independent QM
- Approximation methods for time-dependent QM

V.B. Outcomes in more dense prose

After completing this course, a successful student will have achieved these outcomes* :

Wave Properties Understanding: discuss and interpret experiments that reveal the wave properties of matter, as well as how this motivates replacing classical mechanics with a wave equation.

Central Concepts and Topics Coverage: understand the central concepts and principles in quantum mechanics, such as the Schrödinger equation, the wave function and its statistical interpretation, the uncertainty principle, stationary and non-stationary states, time evolution of solutions, as well as the relation between quantum mechanics and linear algebra. This includes an understanding of elementary concepts in statistics, such as expectation values and variance.

Schrödinger equation applications in QM: solve the Schrödinger equation for simple systems in one to three dimensions, both analytically and by using robust numerical methods; use these solutions to calculate their time evolution, associated probabilities, expectation values, and uncertainties, as well as give concise physical interpretations and reasoning underlying the mathematical results.

Angular Momentum and Spin Concepts in QM: mastered the concepts of angular momentum and spin, as well as the rules for quantisation and addition of these; account for the phenomena involved in the Zeeman effect and spin-orbit coupling, what is meant by identical particles and quantum statistics; perform calculations on systems of identical particles, for example to determine the symmetry properties of the wave function and total spin.

*: The prose for these outcomes above was adapted from the University of Oslo, https://www.uio.no/studier/emner/matnat/fys/FYS2140/index-eng.html#learning-outcomes

VI. STANDARD POLICIES AND PROCEDURES - THE FINE PRINT

1. If you need an disability 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. Your success as a student is important. Please contact me early in the semester to help me plan and coordinate my part.
2. Cheating will not be tolerated, and will be dealt with according to the NIU Student Code of Conduct.
3. Group Studying Policy - Homework studying may be done in groups and students are encouraged to seek help - but see the next item for being honest and transparent about help.
4. Group Work Policy - students should be comfortable acknowledging resouces used whether in writing a paper, developing research ideas, or getting significant help on answering or understanding answers on working problems. Be transparent and honest. Acknowledge (in writing) sources who helped significantly, in particular, if the homework would not have been done on time and correctly without that help.
5. EXAMS: If emergency medical crisis or family crisis interferes with an EXAM, contact Professor Thompson or the physics office by phone, mail, or email, when practical. Without compromising your privacy, give enough specific information to Professor Thompson to let her assess the situation and start developing plans for accommodation.

   Any realistic timeline is very helpful (i.e., is this a trauma requiring several weeks or more to overcome, or was this just a very scary event but with a quick recovery?) (Cramming the night before and oversleeping is not considered an scary emergency, nor is running out of gas).
6. For the non-emergency 'stupid' things, do not panic. If the exam has already started, please contact the Physics office as soon as possible at 815-753-1772. Leave contact information, short assessment of situation and the expected timeline for getting to the department as soon as possible. Reality check - students with many absences and/or many late and missing homeworks do not get much good-faith accommodation for non-emergency situations.
7. Incompletes and procrastination: Grades of Incompletes (I) may be given at the discretion of the instructor when serious unforseen circumstances arise causing several weeks *but temporary* disruptions of the student's ability to concentrate at his or her usual level of performance. This can happen to anyone. So please, be proactive, be professional and be realistic.

   Examples might be severe illness or chronic illness flare-up, or the normal coping response to a physical or emotional trauma such as an assault, the death or illness of a close family member, divorce, breakup. These can really throw off any human! Please be proactive and do not 'tough it out' when special situations arise.

   Note that an I (incomplete) is not used to accommodate 'chronic' procrastination or poor performance due to poor schedule planning, inability to develop good study habits, ignorance, or immaturity, or bad attitude.

   Important note: Grade of Incomplete turns automatically into an F if the work is not completed after a short specified period of time after the semester ends. This maximum time period limit is set via University policy, not the instructor although the instructure can specify a shorter time period to complete the work. If the disruption to the students abilities are long term (longer than a few weeks), it is in the student's best interests to do a medical withdrawal or a special withdrawal rather than an incomplete that will simply turn into an F later. See the college advisors (not the department) for withdrawals.
8. For medical withdrawals, (requests to college to be dropped from a class (after the deadline for withdraw has passed) - the Withdraw Pass (WP) or Withdraw Fail (WF) grade will usually be determined by the pro-rated grade that student had achieved by week eight in the semester.

This syllabus is a guide and every attempt is made to provide an accurate overview of the course. However, circumstances and events may make it necessary for the instructor to modify the syllabus during the semester and may depend, in part, on the progress, needs, and experiences of the students.