Intermediate Quantum Physics (Phys 383)
Syllabus

Spring 2016

Monday and Friday, 10:00-11:15 am, Faraday 238

Instructor

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Office Hours:	Monday 11:15–noon and 1:00–2:45pm, Friday 11:15–noon and 1:00–2:00pm

Web Site

http://webcourses.niu.edu (Blackboard)

Course description

Development of quantum mechanics; applications of Schrödinger equation to simple systems, atoms, molecules, and solids; quantum statistics; relativistic kinematics; applications in particle and nuclear physics. *(Undergraduate Catalog)*

Intended Learning Outcomes

Students taking this course will become familiar with basic concepts of quantum mechanics. They will learn how to apply quantum mechanics towards simple systems including potential wells and atoms. They will also learn how to apply the principles of quantum mechanics to larger systems including molecules and solids and smaller systems in subatomic physics. Students will be able to combine basic concepts from quantum mechanics with basic concepts from the theory of relativity. Students will learn to combine multiple steps in order to develop the solution to problems.

Prerequisites

Phys 283 Fundamentals of Physics III: Quantum Physics

Credit Hours 3

Textbook

Taylor, Zafiratos and Dubson, *Modern Physics for Scientists and Engineers* (Second Edition), University Science Books, 2014 (previously published by Addison-Wesley, 2004)

Class participation

Full attendance at all class meetings is expected. Tardiness or leaving early must be avoided in order for the class to be productive for all. Students are strongly encouraged to participate in class discussion and ask questions during class.

In-class use of electronic devices

I ask that you do not take phone calls, text, email, update your status, or tweet during lectures. Also, do not take pictures in the classroom.

Reading assignments

To familiarize yourself with the material covered in class, reading assignments are given for each class one week in advance.

Homework

We are best learning by doing! There will be weekly graded homework assignments. Written assignments must be handed in at the beginning of class on the due date. If for some reason you cannot attend class on the due date, you may put your paper into my mailbox in the Physics Office *before it is due*. To avoid misunderstandings, ask one of the staff members in the Physics Office to time-stamp your paper when you turn it in.

Students may discuss homework concepts with each other. However, each student must submit his or her own work, i.e., he or she must formulate the results using his or her own words. The same rule applies when a book or other sources are used as a "source of inspiration". Do not turn in anything that you have copied, or anything that you do not truly understand. Note that in the exams you are on your own, and the homeworks should get you prepared for the exams.

Graded homework problems will be complemented by ungraded problems.

Exams

The exam date for the midterm exam is given in the course calendar listed below and will not be changed. Only material covered up to the exam date will be included. The final exam is comprehensive, but will be weighted towards the second half of the semester. Students may use in the exams one letter-size sheet of paper with notes in their own original handwriting. No photocopies or printed documents are allowed. Also, all students should have a calculator available for exams. No other materials are allowed.

Grading

Homeworks, midterm exam, and the final exam will each be given point values and the final course grade will be based on the total sum of points earned. The table below gives the weighting of points earned in homeworks and exams.

Homework:	30%	(weekly)
Midterm Exam:	30%	(Friday, Mar 25, 10:00–11:15am)
Comprehensive Final Exam:	40%	(Monday, May 9, 10:00–11:50am)

Final grades will be assigned as follows according to the total score as a percentage

A $\geq 86\%$	A− $\geq 80\%$	B+ $\geq 74\%$	B $\geq 68\%$	B− $\geq 62\%$
C+ $\geq 56\%$	C $\geq 50\%$	D $\geq 40\%$		

I may amend this grading scale to be more lenient, but it is guaranteed not to be made more strict.

To pass this course (grade C or above), you must also score at least 50% on the homework and at least 35% on the final exam. These requirements will not be changed.

Academic Integrity

Good academic work must be based on honesty. The attempt of any student to present as his or her own work that which he or she has not produced is regarded by the faculty and administration as a serious offense. Students are considered to have cheated if they copy the work of another during an examination or turn in a paper or an assignment written, in whole or in part, by someone else. Students are responsible for plagiarism, intentional or not, if they copy material from books, magazines, or other sources without identifying and acknowledging those sources or if they paraphrase ideas from such sources without acknowledging them. Students responsible for, or assisting others in, either cheating or plagiarism on an assignment, quiz, or examination may receive a grade of F for the course involved and may be suspended or dismissed from the university. *(Northern Illinois University Undergraduate Catalog)*

Incomplete grades

Incompletes will only be given under extraordinary circumstances such as extended illness or call-up to active military duty.

Receiving assistance

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 (V) or drc@niu.edu. See also http://niu.edu/disability.

Also, please contact me privately as soon as possible so we can discuss your accommodations. The sooner you let us know your needs, the sooner we can assist you in achieving your learning goals in this course.

Tentative Course Calendar

3.	Atoms
4.	Quantization of Light
5.	Quantization of Atomic Energy Levels
6.	Matter Waves
7.	The Schrödinger Equation in One Dimension
8.	The Three-Dimensional Schrödinger Equation
9.	Electron Spin
10.	Multielectron Atoms; the Pauli Principle and Periodic Table
	Spring Break, Mar 14 – 20
	Midterm Exam: Friday, Mar 25, 10:00-11:15am
11.	Atomic Transitions and Radiation
12.	Molecules
13.	Solids: Theory
14.	Solids: Applications
16.	The Structure of Atomic Nuclei
17.	Radioactivity and Nuclear Reactions
	Final Exam: Monday, May 9, 10:00-11:50am

General Problem Solving Strategies

1. Think Read the problem carefully. Ask yourself what quantities are known, what quantities might be useful but are unknown, and what quantities are asked for in the solution. Write down these quantities and represent them with their commonly used symbols. Convert into SI units, if necessary.

2. Sketch Make a sketch of the physical situation to help you visualize the problem. Often, this is also essential for defining the variables. Turn in your sketch with the homework solution.

3. Research Write down the physical principles or laws that apply to the problem. Use equations representing these principles to connect the known and unknown quantities to each other. In some cases, you will find an equation that has only the quantities that you know and the one unknown that you are supposed to calculate, and nothing else. More often you may have to combine two or more known equations to obtain the equation that you need.

4. Explain what you do It is not enough if the final answer is correct; it must always be clear how the anwser was obtained.

Explain symbols that you use in formulas. This is particularly important if a symbol characterizes a quantity that represents an aspect specific to the problem of interest, so that the meaning of this symbol cannot be inferred from the general discussion in the classroom.

It must be comprehensible how a solution was obtained!

5. Equations Do not plug numbers into your equation yet! First solve an equation symbolically for the unknown quantity. Also, at this stage it is often possible to simplify an expression. For example, if your result is expressed as a ratio, cancel out common factors in the numerator and the denominator. ***Inserting numeric values and evaluating the resulting expression should be the last step.***

For example, a particle moves with velocity $v = 4$ m/s, the traveled distance is $x = 2$ m, and we seek the elapsed time t.

We have $v = \dfrac{x}{t}$. So we solve for the unknown t, which gives us $t = \dfrac{x}{v}$.

Then we can insert the values for v and x to get the final answer $t = \dfrac{2 \text{ m}}{4 \text{ m/s}} = 0.5$ s

Note: If you give the intermediate steps of a calculation, it is possible to give partial credit if one of the steps turns out to be wrong. No partial credit can be given in such a case when the intermediate steps are missing!

6. Calculate Put the numbers with units into the equation and get to work with a calculator.

7. Round Determine the number of significant figures that you want to have in your result. As a rule of thumb, a result obtained by multiplying or dividing should be rounded to the same number of significant figures as in the input quantity that is given with the least number of significant figures. You should not round in intermediate steps, as rounding too early might give you a wrong solution.

8. Use of units ***Use the proper units*** throughout a calculation, both for the intermediate and the final results. *A number without proper units doesn't mean anything!*

This can help you to identify errors! – Example: We have $v = x/t$ with velocity v (unit [m/s]), traveled distance x (unit [m]), and elapsed time t (unit [s]). Therefore, the rearranged formula $t = v/x$ is certainly wrong because the left hand side t of this equation has the unit [s], but v/x has the unit $\frac{[\mathrm{m/s}]}{[\mathrm{m}]} = \frac{1}{[\mathrm{s}]}$.

Also, if we have $v = 4$ m/s, and the traveled distance given is $x = 2$ mm $(= 2 \times 10^{-3}$ m), we must keep track of the prefixes. If we seek the elapsed time t in seconds, and we just write $t = \frac{x}{v} = \frac{2}{4} = 0.5 = 0.5$ s, this is obviously wrong!

Similarly, we need to watch out if inconsistent units are used. For example, suppose the distance x is given in feet and inches, whereas the velocity v is given in miles per hour. These units must be converted into consistent units like meters for the distance x and meters per second for the velocity v before we can divide x by v to get t.

9. Double-Check Step back and look at the result. Judge for yourself if the answer (both the number and the units) seems realistic. You can often avoid handing in a wrong solution by making this final check.

Units Sometimes the units of your answer do not match what we need to have, and you know you must have made an error.

Typical values Sometimes the order of magnitude comes out wrong. Inserting numerical values for a quantity should give you a ***feeling for typical values*** that occur in certain areas of physics. – Are the numbers you got out of a calculation reasonable? If you find that the velocity of a car is 100 km/s, this result is most likely wrong!

10. Spelling and Grammar Though we talk here about physics, make sure that spelling and grammar of your writing are correct, too! If I cannot understand what you would like to say, I cannot give you credit for your work.

Please note

Full credit in homework assignments and exam problems requires that you follow the above rules. Only partial or no credit are given if these rules ignored.

More Problem-Solving Guidelines

1. Ratios

A common class of physics problems asks what happens to a quantity that depends on a certain parameter if that parameter changes by a given factor. These problems provide excellent insight into physical concepts and take almost no time to do.

Here is the trick: Write down the formula that connects the dependent quantity to the parameter that changes. Write it twice, once with the dependent quantity and the parameters indexed (or labeled) with 1 and once with them indexed with 2. Then form ratios of the indexed quantities by dividing the right-hand sides and the left-hand sides of the two equations. Next, insert the factor of change for the parameter (expressed as a ratio) and do the calculation to find the factor of change for the dependent quantity (also expressed as a ratio).

Example: A car travels with constant (but unknown) velocity v. Within time $t_1 = 1$ min $= 60$ s, the car travels the distance $x_1 = 1$ km $= 1 \times 10^3$ m. How far (distance x_2) does the car travel within the time $t_2 = 2$ s?

$$\begin{aligned} t_1 &= x_1/v \\ t_2 &= x_2/v \end{aligned} \qquad \Rightarrow \qquad \frac{t_1}{t_2} = \frac{x_1/v}{x_2/v} = \frac{x_1}{x_2} \qquad \Rightarrow \qquad x_2 = \frac{x_1\, t_2}{t_1} = \frac{(1 \times 10^3 \text{ m})(2 \text{ s})}{60 \text{ s}} = 33 \text{ m}$$

Note how the unknown velocity v canceled out.

2. Estimates

Sometimes you don't need to solve (or: we *cannot* solve) a physics problem exactly. When an estimate is all that is asked for, knowing the order of magnitude of some quantity is enough. For example, in astronomy an answer of 1.24×10^{20} km is for many purposes not much diferent from 1×10^{20} km. In such cases, you can round of all the numbers in a problem to the nearest power of 10 and carry out the necessary arithmetic.

The technique of gaining useful results through careful estimation was made famous by the 20th-century physicist Enrico Fermi (1901-1954), who estimated the energy released by the Trinity nuclear explosion on July 16, 1945, near Socorro, New Mexico, by observing how far a piece of paper was blown by the wind from the blast. There is a class of estimation problems called Fermi problems that can yield interesting results when reasonable assumptions are made about quantities that are not known exactly.

Estimates are useful to gain insight into a problem before turning to more complicated methods of calculating a precise answer. For example, one could estimate how many tacos people eat and how many taco stands there are in town before investing in a complete business plan to construct a taco stand.

3. Approximations (1)

Approximations (Taylor expansions) such as $\cos(x) \approx 1 - x^2/2$ (valid for $|x| \ll 1$) are a very powerful technique that can simplify *certain* calculations enormously and also make them more transparent. But if we use such an approximation, we must always ***check that the approximation is justified***, for example:

$$\text{If we have} \quad |x| \ll 1, \quad \text{then we can approximate} \quad \sin(x) \approx x.$$

We can easily convince ourselves that this approximation works pretty well for, e.g., $x = 0.1$ or $x = -0.03$. But for $|x| \not\ll 1$, for example $x = 2$, the above approximation fails completely.

4. Approximations (2)

When we use a Taylor expansion for an expression $f(x)$, we usually want to "keep the lowest nontrivial order" which is the lowest order of the Taylor expansion of $f(x)$ which still depends on x. For example, for $|x| \ll 1$ we get

$$\begin{aligned} &\sin x \approx x && \text{(Taylor expansion up to first order)} \\ \text{but} \quad &\cos x \approx 1 - \frac{x^2}{2} && \text{(Taylor expansion up to second order)} \end{aligned}$$

In that way, we can still see how the result *changes* when the small quantity x is varied.