PHYS 323 – Quantum Mechanics I
Course Outline: May 2023 – Aug 2023

Instructor:	Dr. M. Laidlaw
Office:	Elliott 106
Phone:	721-7701
Email:	laidlaw@uvic.ca

Lectures:	TWF 9:30-10:20 in CLEA330
Office Hours:	CLEA 330 after lecture.

Unless there is a material change in health guidelines all course activities will be exclusively face-to-face; there will not be an opportunity to do exams or labs remotely.

Prerequisite: PHYS 215 and MATH 204.
Concurrent enrolment or prior completion of either MATH 342 or 346.

Strongly Recommended Texts:
Griffiths, *Introduction to Quantum Mechanics,* and/or
McIntyre, *Quantum Mechanics*

Calendar Description:
Introduction to quantum mechanics, historical review, postulates, development of the theory and applications.

Course Content and tentative schedule.

1. Math Background (Early to Mid May; 1-2 weeks)
    a. Algebra with complex numbers: Addition, multiplication, division, complex conjugation, modulus
    b. Vector spaces over the reals or complex numbers, bases.
    c. Inner products, inner product spaces, orthonormality.
    d. Change of basis, projection, linear operators.
    e. Matrices: addition and multiplication, eigenvalues and eigenvectors, linear operators as matrices.
    f. Sturm-Liouville theorem: expansion in orthogonal functions, inner products on function space.
    g. Descriptive statistics: mean, variance, standard deviation.
2. 2-state and N-state systems (Mid May to Early June; 3 weeks)
    a. Spin-1/2 and the Stern-Gerlach experiment
    b. Operators, observables, commutators
    c. Schroedinger's equation
    d. Time evolution
    e. Spin-1
    f. Addition of angular momentum.
3. Quantum mechanics in one dimension (Early June to Late June; 3 weeks)
    a. Infinite square well
    b. Harmonic Oscillator

    c. Free particle
    d. Finite square well
    e. Delta function potential
    f. Scattering and tunnelling
4. Quantum mechanics in 2 or 3 dimensions (Late June to Mid July; 3 weeks)
    a. Square well revisited
    b. Harmonic oscillator in 2 dimensions
    c. Hydrogen atom
        i. Separation of variables
        ii. Angular equation
        iii. Radial equation
        iv. Spectrum and wavefunction
5. Synthesis (Mid to Late July; 1-2 weeks)
    a. Spin-orbit coupling in Hydrogen
    b. Harmonic oscillator; raising and lowering operators.

Note that precise content and timings are subject to change at my discretion. If I have overestimated the time to cover some material I will edit the topics list; if I have underestimated I will add more.

Organizational Details:

Midterm Exam:

There will be two in-person midterm exams on June 16 and July 14.

Final Exam:

There will an in-person final exam during the August exam period.

Course Material:

All posted material will be available via the UVic LMS Brightspace.

Assignments:

There will be regular assignments. I anticipate that most weeks there will be 2-3 written questions for you to respond to.

Computational Assignments:

There will be regular computational assignments which will require programming in a language such as Python to produce output relevant to our course material. The purpose of these questions is not to practice programming, but rather to use it as a tool to check claims and to develop intuition for complicated cases. I anticipate that most weeks there will be 1-2 computational questions.

Accommodations:

I am willing to arrange reasonable arrangement for customarily accommodated issues, however this is contingent on your active participation in the course and the accommodation process. If you miss a course requirement, I expect you to contact me as soon as reasonably possible, and I expect you to give me advance warning of issues that you could have reasonably foreseen. I will only consider "last minute" requests due to sudden or exceptional circumstances, and I will not consider requests made an unreasonable amount of time after the issue or deadline.

Labs:

Labs will be in person.
There will be an introductory session during the week of May 8-12.
You must complete all labs and exhibit satisfactory performance in the labs to obtain credit for the course. You are expected to submit your lab work in a timely fashion, respecting the customary deadlines. If you do not submit your lab work in a timely manner I may contact you and impose a final deadline for that work. Students applying for permission to be exempt from the labs require both permission from the lab coordinator and also the instructor.

I take Academic Integrity in this course extremely seriously.
You can find UVic's Policy on Academic Integrity in the Calendar; here is a link.
You can also find the Faculty of Science's Student Code of Conduct here.
In overview, your responsibilities are:

- You must complete all work on exams on your own without help from another person or from outside sources.
- You must submit only your own original work for the labs. You may seek help or advice from me, your lab instructor, or from another student. You may not copy or paraphrase from another student. You may not permit your work to be copied or paraphrased by another student.
- You must undertake the work on assignments by yourself. You may seek advice or help from me, other students, or other people, but you are responsible for undertaking and understanding the work you submitted.
- You may not share or post course material that I have created without my express permission.
- You must engage respectfully with your peers and engage honestly and forthrightly with processes and procedures at the University.

Marking and Grades:

The skills you must demonstrate in this course include

1. Identify and/or calculate the energy eigenstates of a constrained system
2. Express a quantum state as a linear combination of appropriate basis states
3. Correctly calculate the time-evolution of a state
4. Calculate probability distributions and expectation values for the results of measurements on a state
5. Understand and apply how measurement changes a quantum system.
6. Apply both the wavefunction and Dirac formalisms as appropriate
7. Other applications of the material taught in class and outlined in the text.

Examinable material includes everything discussed in class, in the assigned readings, and topics I think you should be able to deduce from those.

Grades will be assigned in accordance with the narrative descriptions in the undergraduate calendar, found here.

You should note that the narrative descriptions of the grade ranges indicate:

> A-range grades are earned by technically superior work which shows mastery of the subject.
> B-range grades are earned by work which shows good comprehension, command of course skills, and full engagement with the course material.
> C or D-range grades are earned by work which show adequate or minimal comprehension of course material, or minimal acceptable participation.
> F indicates work that is inadequate and unworthy of credit.

My philosophy on grading is that the act of assigning a grade is an expression of judgement. To earn an A or B in the course you need to both demonstrate ongoing engagement with the course by submitting at least good quality attempts to (essentially) all in-class work and good-to-excellent work on exams. To pass the course you need to submit good quality attempts to most of the in-class work and have at least borderline work on the exams. You can fail the course by not participating in the assignments, failing the labs, or not showing adequate mastery of material on the final exam.

I will use a criterion-based grading system using ordinal marks. You will be assessed in the following categories: Final exam, Midterm exam, Assignments, Numerical Work, and Labs. For each category you will be assigned a grade from the ordered set {F, P, B, A, A*}; their meanings are on the following pages.

If your lowest grade in any category is A I will assign a grade in the A-range.
If your lowest grade in any category is B I will assign a grade in the B-range.
If your lowest grade in any category is P I will assign a grade in the C or D range.
If your lowest grade in any category is F I will assign an F.
If you do not complete the final exam I will assign an N.

Once I have determined the range of grade I will assign, I will look at your performance in all categories and make a judgement of which letter grade to assign. Once I have determined a letter grade to assign I will choose a numerical grade from within the range and assign that.

If a student's grades were "P, B, B, B, A" I likely assign a C and the grade 62%.
If a student's grades were "B, A, A*, A*, A" I likely assign a B+ and the grade 78%.
If a student's grades were "A, A*, A*, A, A" I would assign an A and the grade 87%

The meanings of the categories.

Individual questions on class work or exams. These definitions form the basis for the grades in the exam and assignment elements:

4 – Indicates that the question is answered clearly and that the answer is technically correct using techniques and concepts from class. There are no (exams: few) discernable problems with the mathematical exposition. The work has clear and appropriate written explanations and diagrams. The work is (exams: may be) comparable in quality to the solution set.
3 – Indicates that the work is broadly correct in addressing the question using techniques and concepts from class. The work competently attempts to address the posed question. There may be small mathematical errors or omissions. There may also be defects in the written exposition such as poor explanations or unclear diagrams. The errors, omissions, and defects do not undermine the marker's inference that the writer understands the solution of the problem.
2 – Indicates work that competently uses techniques or concepts from class to attempt to solve the question. The work does not reach the correct answer because of calculational errors, inappropriate approximations, or similar issues, but the work shows meaningful and appropriate effort to apply the reasoning methods taught in class.
1 – Indicates work which has significant conceptual or mathematical deficits in the attempt to solve the question. This category includes being unable to proceed past the mathematical formulation of a question.
0 – Indicates work which is not submitted, that is unable to formulate the posed problem mathematically, that does not use techniques and concepts from class, or that makes mathematical claims that are not appropriately supported by the work presented. This category includes all forms of question-begging including "mathematical miracles" which take incorrect work and transform it into the expected answer.

A note about negative signs, numerical prefactors, and notation: In mathematical derivations these are common places for errors to occur. Sometimes those errors are inconsequential, and sometimes those errors communicate a significant lack of understanding. It is my job in marking to determine which is which.

Final Exam:

A* – indicates work of at least the "2" level in all skills examined. A significant fraction of the work submitted will be of the "4" level, and the bulk of the work will be at the "3" level.
A – indicates work of at least the "2" level in essentially all skills examined. The bulk of the work will be at the "3" level.
B – indicates work of at least the "2" level in most of the skills examined. Some of the work must be at the "3" level.
P – indicates work of at least the "2" level in at least half of the skills examined. Some of the work must be at the "3" level.
F – indicates work that does not meet the criteria for P: work below the "2" level in at least half of the skills examined or work that does not attain the level "3" in anything.

Midterm Exams:
A* – indicates work of at least the "2" level in all skills examined. A significant fraction of the work submitted will be of the "4" level, and the bulk of the work will be at the "3" level.
A – indicates work of at least the "2" level in essentially all skills examined. The bulk of the work will be at the "3" level OR work on the final at level A or A*.
B – indicates work of at least the "2" level in most of the skills examined. Some of the work must be at the "3" level OR work on the final at level B.
P – indicates work of at least the "2" level in at least half of the skills examined. Some of the work must be at the "3" level OR work on the final at level P.
F – indicates work that does not meet the criteria for P: work below the "2" level in at least half of the skills examined or work that does not attain the level "3" in anything AND work on the final at level F.
Your midterm grade thus naturally accounts for absence because of illness.

Assignments and Computational Assignments:
A* – indicates work of at least the "2" level on essentially all assigned problems, with the vast majority of the "3" level or higher, with a significant fraction at the "4" level.
A – indicates work of at least the "2" level on essentially all assigned problems, with the vast majority of the "3" level or higher.
B – indicates work of at least the "2" level on essentially all assigned problems, with over half of the "3" level or higher.
P – indicates work of at least the "2" level on a significant majority of all assigned problems.
F – indicates work below the "2" level on approaching half the assigned problems.

Labs:
A* – all labs completed promptly and an average score over 90% assigned.
A – all labs completed promptly and an average score over 80% assigned.
B – all labs completed and an average score over 70% assigned.
P – all labs completed and an average score over 50% assigned.
F – at least one lab not completed and/or an average score under 50% assigned.