UNIVERSITY OF CALGARY
FACULTY OF SCIENCE

Department of Physics & Astronomy
Science B 605
403 220-5385
phasoffice@phas.ucalgary.ca

COURSE OUTLINE

1. **Course:** PHYS 443, Quantum Mechanics I - Winter 2022

   Lecture 01 : TR 12:30 - 13:45 in SB 142

Instructor	Email	Phone	Office	Hours
Dr Daniel Oblak	doblak@ucalgary.ca	403 220-7660	SB 313	Fri. 1:30-2:30 pm (may be adjusted to better fit student schedules)

To account for any necessary transition to remote learning in the winter 2022 semester, courses with in-person lectures, labs, or tutorials may be shifted to remote delivery for a certain period of time. In addition, adjustments may be made to the modality and format of assessments and deadlines, as well as to other course components and/or requirements, so that all coursework tasks are in line with the necessary and evolving health precautions for all involved (students and staff).

In Person Delivery Details:

There are two nominal class times per week for this course. These will predominantly be dedicated to lectures, which are delivered in-class. In addition recordings of the lectures and notes will be posted subsequently on the course D2L page. A number of classes will be set aside for review, problem solving practice, mid-term and presentation catch-up at the end of the term.

Re-Entry Protocol for Labs and Classrooms:

To limit the spread of COVID-19 on campus, the University of Calgary has implemented safety measures to ensure the campus is a safe and welcoming space for students, faculty and staff. The most current safety information for campus can be found here.

Course Site:

D2L: PHYS 443 L01-(Winter 2021)-Quantum Mechanics I

Note: Students must use their U of C account for all course correspondence.

Equity Diversity & Inclusion:

The University of Calgary is committed to creating an equitable, diverse and inclusive campus, and condemns harm and discrimination of any form. We value all persons regardless of their race, gender, ethnicity, age, LGBTQIA2S+ identity and expression, disability, religion, spirituality, and socioeconomic status. The Faculty of Science strives to extend these values in every aspect of our courses, research, and teachings to better promote academic excellence and foster belonging for all.

The Physics and Astronomy EDI Committee acknowledges there are persistent barriers that prevent such accessibility and hinder our progress towards EDI. Our representatives (faculty, postdocs, graduate and undergraduate students) are committed to addressing any concerns and work towards proactive solutions that enact necessary change within the department. To submit anonymous questions, comments or concerns regarding EDI related issues, please reach out to our Acting Associate Head EDI, Jo-Anne Brown (jocat@ucalgary.ca)

2. **Requisites:**

   See section 3.5.C in the Faculty of Science section of the online Calendar.

   Prerequisite(s):
   Physics 343; and 229 or 325; Mathematics 311 or 313; and Mathematics 375 or 376; and Mathematics 367 or 377; and Physics 435 or Mathematics 433.

3. **Grading:**

   The University policy on grading and related matters is described in F.1 and F.2 of the online University Calendar.

   In determining the overall grade in the course the following weights will be used:

Course Component	Weight	Due Date (duration for exams)	Modality for exams	Location for exams
Homework assignments (5-6)[1]	30%	Ongoing		
Presentation[2]	10%	Ongoing		
Term project[3]	15%	Ongoing		
Midterm exam	15%	Mar 01 2022 at 12:30 pm (75 Minutes)	in-person	SB142
Registrar Scheduled Final Exam	30%	Will be available when the final exam schedule is released by the Registrar	in person	Will be available when the final exam schedule is released by the Registrar

[1] Spread out over the term. Submission dates will be posted at least two weeks prior in D2L.

[2] Students will present at various time throughout the term. More info about when a student presents will be in D2L and through consultation with the professor.

[3] Final week of term

Each piece of work (reports, assignments, quizzes, midterm exam(s) or final examination) submitted by the student will be assigned a grade. The student's grade for each component listed above will be combined with the indicated weights to produce an overall percentage for the course, which will be used to determine the course letter grade.

The conversion between a percentage grade and letter grade is as follows.

	A+	A	A-	B+	B	B-	C+	C	C-	D+	D
Minimum % Required	95 %	90 %	85 %	80%	75%	70 %	65 %	60%	55%	50 %	45 %

Homework

The lowest graded homework assignment score will not be counted towards your final grade.
Homework is to be handed in according to the schedule (approximately every 2nd week), which will be announced on the course website with at least one week notice for any changes to the schedule. Homework must be submitted via the course website (dropbox) on D2L. There are no homework-assignments during the first week of classes, reading-week, midterm week, and final exam week.

Presentations

Each student must make one presentation, which covers an application or real-world example of the theoretical topics covered in class. A list of topics will be provided on the course D2L site. Each presentation should last about 5 minutes. Presentations will be held at the beginning of each class following the drop-date for the course, i.e., January 20th. There will be one or two presentations each class depending on the number of students. Slots for the presentations will be randomly assigned within the first two weeks classes and posted on D2L.
The presentations will be delivered in class and recorded for grading purposes. Slides will be sent to the course instructor who will share the slide on his screen to all participants during class. Presenter will also be available to answer questions from the class. The presentations will be evaluated by the instructor and a small number of peers according to a rubric.

Term Project

Summary:
For the term project students will work individually or in teams of two members. The teams will be formed close to the reading week. The term project will be focused on a critical review of online (popular) educational material on quantum mechanics, e.g., tutorials on video-sharing platforms. Each team will review a 10-15 min video (or section of a video) with the aim to describe what are the important aspects of this concept as compared to what was covered in the content and why? The team will also be asked to assess if any information was misleading or a common misconception, if it contained good examples of how to physically/intuitively think about that concept presented in the video, or if anything was under-emphasized. More details about the format for the assessment will be provided when the groups are formed.

Team composition:
The project can be completed individually or in a group of two (all referred to as "teams" in the following). The team information, including the topic and format explained below, will be entered in an online spreadsheet. Teams can fill in just the names of the member(s) as soon as they are formed and then add the video link and format at a later time.

Topic choice:
The term project is a critical review of online (popular) educational material on quantum mechanics, e.g., tutorials on video-sharing platforms. The chosen videos should be between 10-15 mins and must be approved by the instructor. To that end, the video title and link is entered in the online spreadsheet and instructor will indicate if it is approved. The videos must be chosen by the end of the term break.

Review format:
The critical review can be presented as a reaction video, podcast, webpage/blog entry, newsletter, written report, poster, performance art, interview, quiz, or another format conditioned on approval from the instructor. Again, the review format must be stated and approval will be indicated in the online spreadsheet. The two key requirements for the format are: 1) It must be able to be accessed via a link in the D2L discussion board (this will be set once teams start to be formed). 2) It should not take longer than about 10 minutes to read/listen/see/etc the review.
Each student should explore five projects assigned to them and any other number they wish. The feedback will be in the form of scoring the projects they have explored. The score should be based on the subjective value of the information relayed through the project. Each student will be able to give the score of 5 to one project, 4 to another, and so on. A scoring system will be set up online. The due-date for submitting the scores in the online survey will be announced.

Grading and reward:
Teams who complete the project according to the stated guidelines, including the scoring of other projects, earn the 15 points towards the final grade in the course. As for the scoring, the project receiving the highest combined score - not surprisingly - wins! Along with this great honor and bragging rights come a number of perks, i.e., a carefully curated sciency/nerdy gift and 9 bonus points for final exam. Runners up will win: 6 bonus points for final exam. The third place: 3 bonus points for final exam. If the there is a tie for the winning spot, the stated allowance of time or points from first and runner up will be split evenly among the two tied winners and no runner up position will be awarded.
Note that the extra weights will be added as bonus such that the final course percentage exceeds 100% for the winners. As an example if the winner scores 22/30 -> 73.3% on the final exam the bonus will mean that the contribution of the final exam score to the final grade will be calculated as (0.30+0.09) x 73.3% instead of 0.30 x 73.3%.

This course will have a Registrar Scheduled Final exam that will be delivered in-person and on campus. The Final Examination Schedule will be published by the Registrar's Office approximately one month after the start of the term. The final exam for this course will be designed to be completed within 2 hours.

Final grades will not be rounded up or down.

The University of Calgary offers a flexible grade option, Credit Granted (CG) to support student's breadth of learning and student wellness. Faculty units may have additional requirements or restrictions for the use of the CG grade at the faculty, degree or program level. To see the full list of Faculty of Science courses where CG is not eligible, please visit the following website: https://science.ucalgary.ca/current-students/undergraduate/program-advising/flexible-grading-option-cg-grade

4. **Missed Components Of Term Work:**

The university has suspended the requirement for students to provide evidence for absences. Please do not attend medical clinics for medical notes or Commissioners for Oaths for statutory declarations.

In the event that a student legitimately fails to submit any online assessment on time (e.g. due to illness etc...), please contact the course coordinator, or the course instructor if this course does not have a coordinator to arrange for a re-adjustment of a submission date. Absences not reported within 48 hours will not be accommodated. If an excused absence is approved, one possible arrangement is that the percentage weight of the legitimately missed assignment could also be pro-rated among the components of the course. This option is at the discretion of the coordinator and may not be a viable option based on the design of this course.

Homework assignments handed in late without prior agreement with instructor will receive a score reduction of 25% if handed within 24 hours of the due date and a score reduction of 50% if handed in before the marked home-work has been returned.

5. **Scheduled Out-of-Class Activities:**

There are no scheduled out of class activities for this course.

6. **Course Materials:**

Required Textbook(s):

David J. Griffiths and Darrell F. Schroeter, *Introduction to Quantum Mechanics (3rd Edition)*: Cambridge University Press.

Notes on topics not covered by the textbook will be provided electronically after lectures.

In order to successfully engage in their learning experiences at the University of Calgary, students taking online, remote and blended courses are required to have reliable access to the following technology:

- A computer with a supported operating system, as well as the latest security, and malware updates;
- A current and updated web browser;
- Webcam/Camera (built-in or external);
- Microphone and speaker (built-in or external), or headset with microphone;
- Current antivirus and/or firewall software enabled;
- Stable internet connection.

For more information please refer to the UofC ELearning online website.

7. **Examination Policy:**

All exams are intended to be completed individually.

Midterm exam will be delivered during the regular class time on Mar. 1st. Any accommodations, e.g. extended time, will be calculated from the usual class duration.

The final exam will be scheduled by the registrar.

Students should also read the Calendar, Section G, on Examinations.

8. **Approved Mandatory And Optional Course Supplemental Fees:**

There are no mandatory or optional course supplemental fees for this course.

9. **Writing Across The Curriculum Statement:**

For all components of the course, in any written work, the quality of the student's writing (language, spelling, grammar, presentation etc.) can be a factor in the evaluation of the work. See also Section E.2 of the University Calendar.

10. **Human Studies Statement:**

Students will not participate as subjects or researchers in human studies.

See also Section E.5 of the University Calendar.

11. **Reappraisal Of Grades:**

A student wishing a reappraisal, should first attempt to review the graded work with the Course coordinator/instructor or department offering the course. Students with sufficient academic grounds may request a reappraisal. Non-academic grounds are not relevant for grade reappraisals. Students should be aware that the grade being reappraised may be raised, lowered or remain the same. See Section I.3 of the University Calendar.

a. **Term Work:** The student should present their rationale as effectively and as fully as possible to the Course coordinator/instructor within **ten business days** of either being notified about the mark, or of the item's return to the class. If the student is not satisfied with the outcome, the student shall submit the Reappraisal of Graded Term work form to the department in which the course is offered within 2 business days of receiving the decision from the instructor. The Department will arrange for a reappraisal of the work within the next ten business days. The reappraisal will only be considered if the student provides a detailed rationale that outlines where and for what reason an error is suspected. See sections I.1 and I.2 of the University Calendar

b. **Final Exam:** The student shall submit the request to Enrolment Services. See Section I.3 of the University Calendar.

12. **Other Important Information For Students:**

a. **Mental Health** The University of Calgary recognizes the pivotal role that student mental health plays in physical health, social connectedness and academic success, and aspires to create a caring and supportive campus community where individuals can freely talk about mental health and receive supports when needed. We encourage you to explore the mental health resources available throughout the university community, such as counselling, self-help resources, peer support or skills-building available through the SU Wellness Centre (Room 370, MacEwan Student Centre, Mental Health Services Website) and the Campus Mental Health Strategy website (Mental Health).

b. **SU Wellness Services:** For more information, see www.ucalgary.ca/wellnesscentre or call 403-210-9355.

c. **Sexual Violence:** The Sexual Violence Support Advocate, Carla Bertsch, can provide confidential support and information regarding sexual violence to all members of the university community. Carla can be reached by email (svsa@ucalgary.ca) or phone at 403-220-2208. The complete University of Calgary policy on sexual violence can be viewed at (https://www.ucalgary.ca/legal-services/sites/default/files/teams/1/Policies-Sexual-and-Gender-Based-Violence-Policy.pdf)

d. **Misconduct:** Academic integrity is the foundation of the development and acquisition of knowledge and is based on values of honesty, trust, responsibility, and respect. We expect members of our community to act with integrity. Research integrity, ethics, and principles of conduct are key to academic integrity. Members of our campus community are required to abide by our institutional Code of Conduct and promote academic integrity in upholding the University of Calgary's reputation of excellence. Some examples of academic misconduct include but are not limited to: posting course material to online platforms or file sharing without the course instructor's consent; submitting or presenting work as if it were the student's own work; submitting or presenting work in one course which has also been submitted in another course without the instructor's permission; borrowing experimental values from others without the instructor's approval; falsification/fabrication of experimental values in a report. Please read the following to inform yourself more on academic integrity:

   Student Handbook on Academic Integrity
   Student Academic Misconduct Policy and Procedure
   Research Integrity Policy

   Additional information is available on the Student Success Centre Academic Integrity page

e. **Academic Accommodation Policy:**

   It is the student's responsibility to request academic accommodations according to the University policies and procedures listed below. The student accommodation policy can be found at: https://www.ucalgary.ca/legal-services/sites/default/files/teams/1/Policies-Student-Accommodation-Policy.pdf

   Students needing an accommodation because of a disability or medical condition should communicate this need to Student Accessibility Services in accordance with the Procedure for Accommodations for Students with Disabilities: https://www.ucalgary.ca/legal-services/sites/default/files/teams/1/Policies-Accommodation-for-Students-with-Disabilities-Procedure.pdf.

   Students needing an accommodation in relation to their coursework or to fulfil requirements for a graduate degree, based on a Protected Ground other than Disability, should communicate this need, by filling out the Request for Academic Accommodation Form and sending it to Dr. David Feder by email phas.ahugrd@ucalgary.ca preferably 10 business days before the due date of an assessment or scheduled absence.

f. **Freedom of Information and Privacy:** This course is conducted in accordance with the Freedom of Information and Protection of Privacy Act (FOIPP). Students should identify themselves on all written work by placing their name on the front page and their ID number on each subsequent page. For more information, see Legal Services website.

g. **Student Union Information:** VP Academic, Phone: 403-220-3911 Email: suvpaca@ucalgary.ca. SU Faculty Rep., Phone: 403-220-3913 Email: sciencerep@su.ucalgary.ca. Student Ombudsman, Email: ombuds@ucalgary.ca.

h. **Surveys:** At the University of Calgary, feedback through the Universal Student Ratings of Instruction (USRI) survey and the Faculty of Science Teaching Feedback form provides valuable information to help with evaluating instruction, enhancing learning and teaching, and selecting courses. Your responses make a difference - please participate in these surveys.

i. **Copyright of Course Materials:** All course materials (including those posted on the course D2L site, a

course website, or used in any teaching activity such as (but not limited to) examinations, quizzes, assignments, laboratory manuals, lecture slides or lecture materials and other course notes) are protected by law. These materials are for the sole use of students registered in this course and must not be redistributed. Sharing these materials with anyone else would be a breach of the terms and conditions governing student access to D2L, as well as a violation of the copyright in these materials, and may be pursued as a case of student academic or non-academic misconduct, in addition to any other remedies available at law.

Schedule of topics

Schedule is approximate and may be adjusted depending on progress and feedback.

Week 1: Lecture 0 – 1 (January 11/13)
Introduction and review of syllabus
Origin of quantum mechanics, blackbody radiation
Intro to the Schrödinger equation

Week 2: Lectures 2 – 3, (January 18/20)
Wavefunctions and probability - Chapter 1.2 – 1.4
Separation of variables, solutions to the Schrödinger equation (Infinite square well)

Week 3: Lectures 4 – 5, (January 25/27)
Solutions to the Schrödinger equation (harmonic oscillator)

Week 4: Lectures 6 – 7, (February 1/3)
Solutions to the Schrödinger equation (free particle and delta function and finite square well)

Week 5: Lectures 8 – 9, (February 8/10)
Solutions to the Schrödinger equation (finite square well)
Hilbert space, matrix notation, observables, eigenfunctions

Week 6: Lectures 10 – 11 (February 15/17)
Generalized statistical interpretation
bra/ket (Dirac) notation

Week 7: No lectures, (Reading week)

Week 6: midterm & Lecture 12, (March 1/3)
Midterm on February Mar 1
The uncertainty principle and operators

Week 9: Lectures 13 – 14 (March 8/10)
Schrödinger equation in 3D
Hydrogen atom

Week 10: Lectures 15 – 16 (March 15/17)
Angular momentum, generators
Identical particles, Bosons and Fermions

Week 11: Lectures 17 – 18 (March 22/24)
Addition of spins
Symmetries of wavefunctions, exchange interaction

Week 12: Lectures 19 – 20 (March 29/31)
Structure of atoms
Conservation laws

Week 13: Lectures 21 – 22 (April 5/7)
Symmetries and selection rules
Heisenberg picture

Week 14: Lecture 23 (April 12)
Term project delivery and review

Course Incomes:

Ability to solve differential equations, perform basic matrix/vector operations, understanding of eigenvectors and eigenvalues, and working with complex numbers (including complex exponentials).

Familiarity with basics of modern physics – atoms, photons and electrons, linear and angular momentum,

potential and kinetic energy, and other concepts from classical mechanics, Coulombs Law, electric potential and other concepts from electromagnetism.

Course Outcomes:

- Know the background and experiments which led to the development of quantum mechanics.
- Explain, qualitatively and quantitatively, the role of photons, electrons and Bohr’s model in explaining these experiments
- Be able to discuss and interpret experiments displaying wavelike behaviour of matter, and how this motivates the need to replace classical mechanics by the Schrödinger equation
- Understand the postulates of quantum mechanics: the Schrödinger equation, the wave function and its physical interpretation, stationary and non-stationary states, time evolution
- Be able to solve the Schrödinger equation for simple one-dimensional systems -- the ones explicitly taught (e.g. square well, harmonic oscillator, potential barrier), as well as similar, new ones
- Gain a basic understanding of the formalism and 'language' of quantum mechanics and how it relates to linear algebra (Dirac’s notation).
- Use solutions of the Schrödinger equation to compute probabilities, expectation values, uncertainties and time evolution.
- Understand the background and implications of the uncertainty relation and it’s relation to physical phenomena.
- Explain the quantum mechanical derivation of the structure of (mainly Hydrogen-like) atoms and know how to apply selection rules.
- Understand qualitatively and quantitatively how quantum mechanics relates to a number of common technologies and phenomena.

Electronically Approved - Jan 06 2022 16:27

Department Approval

Electronically Approved - Jan 10 2022 14:47

Associate Dean's Approval