UNIVERSITY OF CALGARY
FACULTY OF SCIENCE

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

COURSE OUTLINE

1. **Course:** PHYS 543, Quantum Mechanics II - Fall 2019

   Lecture 01: MWF 10:00 - 10:50 in ENF 334

Instructor	Email	Phone	Office	Hours
Dr Paul Barclay	pbarclay@ucalgary.ca	403 220-8517	SB 135	Wednesday, 15:00 - 16:00, SB319

Course Site:

D2L: PHYS 543 L01-(Fall 2019)-Quantum Mechanics II

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

2. **Requisites:**

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

Prerequisite(s):
Physics 443 or Chemistry 373.

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:

Component(s)	Weighting %	Date
Homework	25	
Oral poster presentation	10	Final week of class
In class evaluations	10	
Midterm	15	October 28
Final exam	40	TBD

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 %

This course has a registrar scheduled final exam.

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

In the event that a student misses the midterm or any course work due to illness, supporting documentation, such as a medical note or a statutory declaration will be required (see Section M.1; for more information regarding the use of statuary declaration/medical notes, see FAQ). Absences must be reported within 48 hrs.

The regulations of the Faculty of Science pertaining to this matter are found in the Faculty of Science area of the Calendar in Section 3.6. It is the student's responsibility to familiarize themselves with these regulations. See also Section E.3 of the University Calendar.

Homework is to be handed in **in-class**.

Your worst homework score will not be counted towards your final grade.

No late homework will be accepted.

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

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

6. **Course Materials:**

   Required Textbook(s):

   Mark Fox, *Quantum Optics: An Introduction*: Oxford University University Press.

7. **Examination Policy:**

   Calculator and one page (double sided) formula sheet allowed.

   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 **10 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 immediately submit the Reappraisal of Graded Term work form to the department in which the course is offered. The department will arrange for a re-assessment of the work if, and only if, the student has sufficient academic grounds. 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 Center:** The Students Union Wellness Centre provides health and wellness support for students including information and counselling on physical health, mental health and nutrition. For more information, see www.ucalgary.ca/wellnesscentre or call 403-210-9355.

    c. **Sexual Violence:** The University of Calgary is committed to fostering a safe, productive learning environment. The Sexual Violence Policy (https://www.ucalgary.ca/policies/files/policies/sexual-violence-policy.pdf) is a fundamental element in creating and sustaining a safer campus environment for all community members. We understand that sexual violence can undermine students' academic success and we encourage students who have experienced some form of sexual misconduct to talk to someone about their experience, so they can get the support they need. 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 .

d. **Misconduct:** Academic misconduct (cheating, plagiarism, or any other form) is a very serious offence that will be dealt with rigorously in all cases. A single offence may lead to disciplinary probation or suspension or expulsion. The Faculty of Science follows a zero tolerance policy regarding dishonesty. Please read the sections of the University Calendar under Section K. Student Misconduct to inform yourself of definitions, processes and penalties. Examples of academic misconduct may include: submitting or presenting work as if it were the student's own work when it is not; submitting or presenting work in one course which has also been submitted in another course without the instructor's permission; collaborating in whole or in part without prior agreement of the instructor; borrowing experimental values from others without the instructor's approval; falsification/ fabrication of experimental values in a report. **These are only examples**.

e. **Assembly Points:** In case of emergency during class time, be sure to FAMILIARIZE YOURSELF with the information on assembly points.

f. **Academic Accommodation Policy:** Students needing an accommodation because of a disability or medical condition should contact Student Accessibility Services in accordance with the procedure for accommodations for students with disabilities available at procedure-for-accommodations-for-students-with-disabilities.pdf.

   Students needing an accommodation in relation to their coursework or to fulfill requirements for a graduate degree, based on a protected ground other than disability, should communicate this need, preferably in writing, to the Associate Head of the Department of Physics & Astronomy, Dr. David Feder by email phas.ahugrd@ucalgary.ca or phone 403-220-8127. Religious accommodation requests relating to class, test or exam scheduling or absences must be submitted no later than **14 days** prior to the date in question. See Section E.4 of the University Calendar.

g. **Safewalk:** Campus Security will escort individuals day or night (See the Campus Safewalk website). Call 403-220-5333 for assistance. Use any campus phone, emergency phone or the yellow phones located at most parking lot pay booths.

h. **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.

i. **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.

j. **Internet and Electronic Device Information:** Unless instructed otherwise, cell phones should be turned off during class. All communication with other individuals via laptop, tablet, smart phone or other device is prohibited during class unless specifically permitted by the instructor. Students that violate this policy may be asked to leave the classroom. Repeated violations may result in a charge of misconduct.

k. **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.

l. **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.

Expected knowledge and skills of students entering the course:

Ability to solve differential equations, perform basic matrix/vector operations. Understanding of eigenvectors and eigenvalues. Comfortable working with complex numbers (including complex exponentials). Familiarity with basics of modern physics – atoms, photons and electrons, Coulombs Law, electric potential and other concepts of electromagnetism. Understanding of wavefunctions, the Schrödinger equation, Dirac notation, and Hilbert space.

Oral poster presentation details:

Presentations will be given in class.

Individual or group presentation in “poster style” – single slide. Length to be determined, dependent on class size (10 minutes or less).

Evaluation criteria:

- Clarity of visual presentation: 30%
- Oral presentation: 30%
- Communication of scientific content: 30%
- Response to questions: 10%

In class work:

Weekly short questions related to either reading or recently completed homework.

Schedule of topics:

Week 0	September 6	
	Introduction and review of syllabus.	
Week 1	September 9 - 13	
	Review of wave optics, coherence. Intro to nonlinear optics.	Chapter 2
	Review of quantum mechanics formalism.	Chapter 3.1
Week 2	September 16 - 20	
	Quantum states of an atom, harmonic oscillator, solids.	Chapter 3.2 – 3.4
	Time independent perturbation theory (Zeeman effect).	
	Introduction to optical emission from atoms.	Chapter 4
Week 3	September 23 – 27	
	Photon statistics.	Chapter 5.1 – 5.7
	Photodetection and shot noise.	Chapter 5.8 – 5.10
Week 4	September 30 – October 4	
	Photon antibunching.	Chapter 6
Week 5	October 7 - 11	
	Coherent states and squeezed light.	Chapter 7
	Photon number states.	Chapter 8
Week 6	October 14 – 18	
	Two level system basics (time dependent perturbation theory).	Chapter 9.1 – 9.3
	Weak and strong (coherent) excitation of an atom.	Chapter 9.3 – 9.6
Week 7	October 21 – 25	
	Weak and strong (coherent) excitation of an atom continued.	Chapter 9.3 – 9.6
	Cavity QED and strong coupling.	Chapter 10
Week 8	October 28 – November 1	
	Midterm (October 28)	
	Laser cooling or QKD (class choice) or catch-up (if necessary)	Chapter 11
Week 9	November 4 – 8	
	Quantum bits, decoherence, and implementations.	Chapter 13
Week 10	November 11 - 15	
	Reading week (no class)	
Week 11	November 18 – 22	
	Quantum bits, decoherence, and implementations in 2019	Notes

	Entangled states and quantum teleportation.	Chapter 14
Week 12	November 25 – 29	
	Entangled states and quantum teleportation continued.	Chapter 14
Week 13	December 2 - 6	
	In class presentations, review.	

Course outcomes:

At the conclusion of this course you will understand the quantum mechanical description of the interaction between light and atoms. You will understand how to apply perturbation theory techniques to analyse light matter interactions, the implications of conservation laws such as conservation of angular momentum, and the importance of electronic wavefunctions in determining atom-photon coupling strength. You will understand the importance of these interactions in describing the operation of a laser. You will understand the statistical description of quantum optical phenomena, and the quantum behaviour of photons. You will be able to apply this understanding to describe technologies such as single photon sources and landmark experiments such as Hong-Ou-Mandel interference. You will understand the concept of strongly coupled quantum systems, and be familiar with physical implementations of such a systems. You will be familiar with concepts in quantum information such qubits, quantum key distribution, and Bell's Theorem.

Course Outcomes:

- Students will be able to solve for the ground and excited states of the time-independent Schrödinger equation for a single particle in a variety of potentials in one and three dimensions;
- Students will be exposed to approximation methods for solving the time-independent and time-dependent Schrödinger equation when analytical methods are not possible, including two-particle systems, time-dependent potentials, and perturbations;
- Students will be able to express the algebra associated with orbital and spin angular momentum, and will be able to apply this to many-particle systems.

Department Approval: Electronically Approved Date: 2019-09-08 13:47