



UNIVERSITY OF CALGARY
FACULTY OF SCIENCE
DEPARTMENT OF PHYSICS & ASTRONOMY
COURSE OUTLINE

1. **Course:** PHYS 303, Quantum Mysteries & Paradoxes -- Fall 2018

| Instructor Name | Email | Phone | Office | Hours |
|--|-------------------|------------|--------|---------------|
| L01: (MWF 14:00 - 14:50 in EEEL 161) Christoph Simon | csimo@ucalgary.ca | 4032207007 | SB 315 | T 16:00-17:00 |

Course Site:

D2L: PHYS 303 L01-(Fall 2018)-Quantum Mysteries & Paradoxes

Department of Physics & Astronomy:

Office: Science B 605
Phone: 403 220-5385
Email: phasoffice@ucalgary.ca

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.

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 |
|-----------------------------|-------------|---------------------------|
| Assignments | 21 | |
| In-class exercises | 21 | |
| Midterm tests (2, in class) | 28 | Oct 5 and Nov 2, 14% each |
| Final Examination | 30 | |

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:**

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 himself/herself/themself with these regulations. See also [Section E.3](#) of the University Calendar.

5. **Scheduled out-of-class activities:**

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

6. **Course Materials:**

Recommended Textbook(s):

Valerio Scarani, *Quantum physics: a first encounter*: Oxford University Press .

Michael Raymer, *Quantum physics: what everyone needs to know*: Oxford University Press .

"Understanding quantum physics through simple experiments: from wave-particle duality to Bell's theorem", by Dhand et al., freely available at <https://arxiv.org/abs/1806.09958>

7. **Examination Policy:**

No aids are allowed on tests or examinations.

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.

1. **Term Work:** The student should present their rationale as effectively and as fully as possible to the Course coordinator/instructor within **15 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
2. **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](tel: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](tel: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](tel: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](tel:403-220-3911) Email: suvpaca@ucalgary.ca. SU Faculty Rep., Phone: [403-220-3913](tel:403-220-3913) Email: sciencerep@su.ucalgary.ca. Student Ombudsman, Email: suvpaca@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.

SYLLABUS

Introduction

Scientific method
Range of validity of quantum physics

Part I - Single-particle interference and wave-particle duality

Single particles - Principles and idealized experiments

Experiments with single photons
Behaviour of classical particles
Wave explanation
Quantum physics explanation

Local hidden variable explanation

Single particles - Applications

Bits
Degrees of freedom
Cryptography
Quantum key distribution
Qubits

Single particles - Real Experiments

Wave-particle duality of light
Wave-particle duality of matter
Indistinguishability and environment

Part II - Two-particle interference and entanglement

Entanglement - Principles and idealized experiments

Experiments with entangled photons
Rules of many-particle quantum physics
Signaling and correlations

Entanglement - Applications

Quantum teleportation
Entanglement swapping
Bell state measurements

Entanglement - Real Experiments

Basics of light-matter interaction
Generation of photon pairs
Creation of entanglement

Part III - Quantum nonlocality

Is quantum physics incomplete?

The EPR argument: What is real in two-photon experiments?
Local hidden variables

Local hidden variables cannot explain quantum physics

Hardy's version of Bell's theorem
Local hidden variable prediction
Quantum prediction
Non-local hidden variables - pilot wave theory
Realism and determinism
Locality and contextuality

Experiments related to Bell's theorem

Tests of Bell's theorem
Closing loopholes in Bell tests

Part IV - Quantum Information and Applications

Quantum cryptography with entangled particles

Entanglement-based quantum key distribution
Quantum hacking
Quantum key distribution based on Bell's theorem

Quantum computing

From classical to quantum computing
What is quantum computing good for?
How close are we to having useful quantum computers?
Where does the quantum speedup come from?

Building the quantum internet

Why is it difficult to send quantum states over long distances?
How to overcome the distance limitation: quantum repeaters
Quantum memories
How to connect quantum computers

Open questions

Quantum gravity?
Does quantum physics apply on macroscopic scales?
Do quantum effects play a role in biology?

Course Learning Incomes

This course will require a high-school level understanding of arithmetic, a very minimal amount of basic algebra, and an open mind.

Department Approval:

Electronically Approved

Date: 2018-08-29 15:41

Course Outcomes

- At the end of the course, students will have a clear mental picture of some of the ways in which quantum mechanical systems behave counterintuitively as compared to everyday experience, at a more advanced level than is presented in most popular books.
- Students will also be aware of some of the far-reaching consequences of this counterintuitive behaviour, and some of their applications.