



# UNIVERSITY OF CALGARY

## DEPARTMENT OF PHYSICS AND ASTRONOMY COURSE OUTLINE

### 1. Course: Physics 615, Advanced Quantum Mechanics I

Lecture Sections: MWF 11:00-11:50, SS 117

Instructor: Dr. Alexander Lvovsky

Office: SB 319, 220-4124

Office Hours: by appointment

Email: [lvov@ucalgary.ca](mailto:lvov@ucalgary.ca)

Home page: <http://ucalgary.ca/~lvov/615/>

Departmental Office: SB 605, 403-220-5385, [phasugrd@ucalgary.ca](mailto:phasugrd@ucalgary.ca)

### 2. Prerequisites: undergraduate quantum mechanics

### 3. Grading: The University policy on grading and related matters is described sections F.1 and F.2 of the online University Calendar. In determining the overall grade in the course the following weights will be used:

Homework	30%
Midterm test	25%
Final Examination	45%

### 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 with these regulations. See also Section E.6 of the University Calendar

### 5. REGULARLY SCHEDULED CLASSES HAVE PRECEDENCE OVER ANY OUT-OF-CLASS-TIME-ACTIVITY. If you have a clash with this out-of-class-time-activity, please inform your instructor as soon as possible so that alternative arrangements may be made for you.

### 6. Course Materials: The primary resource is the lecture notes, to be distributed in the class. The last chapter (Theory of angular momenta) will be using *J. J. Sakurai, J. J. Napolitano, Modern Quantum Mechanics, Addison-Wesley 2011* or *J. J. Sakurai, Modern Quantum Mechanics, Addison-Wesley 1993*

### 7. Examination Policy: Students should also read the Calendar, Section G, on Examinations.

## 11. OTHER IMPORTANT INFORMATION FOR STUDENTS:

(a) **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

(b) **Assembly Points:** In case of emergency during class time, be sure to FAMILIARIZE YOURSELF with the information on [assembly points](#).

(c) **Academic Accommodation Policy:** Students with documentable disabilities are referred to the following links: [Calendar entry on students with disabilities](#) and [Student Accessibility Services](#).

(d) **Safewalk:** Campus Security will escort individuals day or night (<http://www.ucalgary.ca/security/safewalk/>). Call 220-5333 for assistance. Use any campus phone, emergency phone or the yellow phones located at most parking lot pay booths.

(e) **Freedom of Information and Privacy:** This course is conducted in accordance with the Freedom of Information and Protection of Privacy Act (FOIPP). As one consequence, 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 also

(f) <http://www.ucalgary.ca/secretariat/privacy>.

(g) **Student Union Information:** [VP Academic](#) Phone: 220-3911 Email: [suvpaca@ucalgary.ca](mailto:suvpaca@ucalgary.ca).  
SU Faculty Rep. Phone: 220-3913 Email: [sciencerep@su.ucalgary.ca](mailto:sciencerep@su.ucalgary.ca); [Student Ombudsman](#)

(h) **Internet and Electronic Device Information:** You can assume that in all classes that you attend, your cell phone should be turned off unless instructed otherwise. Also, communication with other individuals, via laptop computers, Blackberries or other devices connectable to the Internet is not allowed in class time unless specifically permitted by the instructor. If you violate this policy you may be asked to leave the classroom. Repeated abuse may result in a charge of misconduct.

(i) At the University of Calgary, feedback provided by students through the Universal Student Ratings of Instruction (USRI) survey provides valuable information to help with evaluating instruction, enhancing learning and teaching, and selecting courses ([www.ucalgary.ca/usri](http://www.ucalgary.ca/usri)). Your responses make a difference - please participate in USRI Surveys.

**The following signature lines should be added to the course outline as appropriate**

Department Approval \_\_\_\_\_ Date \_\_\_\_\_

## **SYLLABUS**

### ***Linear algebra and postulates of quantum mechanics***

- Linear spaces
- Basis, dimension
- Inner product. Hilbert space.
- Orthonormal basis.
- Projective measurements. Quantum tomography
- Adjoint spaces
- Linear operators
- Operator observables. Eigenvalues. Diagonalization. Pauli operators
- Hermitian and unitary operators
- Commutator. Simultaneous diagonalization.
- Heisenberg's uncertainty principle
- Functions of operators
- Schrödinger equation

### ***Entanglement***

- Tensor product of Hilbert spaces
- Entanglement. Partial measurements
- Quantum dense coding
- Remote state preparation
- Nonlocality. Einstein-Podolsky-Rosen paradox
- No-cloning theorem
- Quantum teleportation
- Schrödinger cats, nature of quantum measurements. Interpretations of quantum mechanics.

### ***Quantum mechanics of complex systems***

- The density operator
- Trace
- Positive operator-valued measures
- Partial measurements of multipartite systems
- Entanglement and decoherence
- Quantum tomography

### ***Quantum electromagnetic field***

- Quantization of the electromagnetic field
- Single-mode quantum states of light
- Phase-space probability densities
- Beam splitter
- Homodyne tomography
- Parametric down-conversion. Squeezing. Conditional preparation of photons

### ***Theory of angular momentum***

- Rotations and angular momentum commutation relations
- Spin  $\frac{1}{2}$  systems and finite rotations
- SO(3), SU(2), and Euler rotations
- Eigenvalues and eigenstates of angular momentum
- Orbital angular momentum
- Addition of angular momenta
- Schwinger's oscillator model of angular momentum
- Tensor operators. Wigner-Eckart theorem