QUANTUM PHYSICS 3 FALL 2023

PHYS 434

Published Aug 31, 2023

CLASS SCHEDULE

Section	Location	Time	Instructor(s)
PHYS 434 001 *[LEC]*	EIT 1015	Tuesdays & Thursdays 11:30 a.m. - 12:50 p.m.	Christine Muschik christine.muschik@uwaterloo.ca
			This table is generated automatically

INSTRUCTOR / TA INFORMATION

Instructor: Christine Muschik

Office Hours: Fridays, 4 p.m. to 5 p.m. (Office QNC 4122 or arranged through Teams)

Teaching Assistant:

Estevao DeOliveira: evbdeoli@uwaterloo.ca

TA Office Hours: Wednesdays, 4 p.m. to 5 p.m. (In Office PHYS 2014 or arranged time)

COURSE DESCRIPTION

> *Calendar Description for PHYS 434*
>
> Symmetries and conservation laws. Review of time-independent perturbation theory (degenerate and non-degenerate, Rayleigh-Schrodinger, Brillouin-Wigner and canonical perturbation theory; effective Hamiltonian derivation). Time-dependent perturbation theory (1st and 2nd order, adiabatic perturbation, Aharonov-Bohm effect). Fermi's golden rule. Two-level systems. Emission and absorption of radiation (applications). Second quantization of electromagnetic field in free space; photons. Spontaneous emission and natural lifetime; Lamb shift. Elements of scattering theory. Introduction to the Dirac equation. [Offered: F]
>
> Prereq: PHYS 334 or AMATH 373; PHYS 364 or (AMATH 351 and 353)

This course will start with a review of the most important concepts from the two previous quantum mechanics courses. We will then cover continuous quantum variables (i.e. wave functions in position x and momentum p). We will study quantum time evolutions in different pictures (the Schrödinger picture, the Heisenberg picture, and the interaction picture), and apply these formalisms to different examples. In the next part, we will have an in-depth look at rotationsand quantum spin systems. We will also cover symmetries in quantum mechanics. In this context, we will for example see how the momentum operator p acts as generator for translations in space, and how angular momentum

operators act as generators for rotations. These are examples of continuous symmetries. We will also study discrete symmetries such as the parity symmetry, which leads us to the concept of identical particles, the distinction between Fermions and Bosons, and the puzzling consequences of quantum statistics. If time allows, we will cover modern topics in our last week (quantum teleportation, quantum computing).

LEARNING OUTCOMES

By the end of this course students should be able to:

Understanding of the principles of quantum mechanics. Ability to apply quantum mechanical concepts in a variety of different settings.
Ability to do calculations with wave functions in x and p with ease.
Ability to do calculations involving time evolutions. Ability to use and change between different formalisms (Schrödinger, Heisenberg, Interaction picture).
Understanding of quantum spin systems and application of the concepts involved (e.g. addition of angular momentum).
Ability to do calculations for spin 1/2 systems and spin 1 systems with ease.
Understanding of continuous & discrete symmetries in quantum mechanics and understanding of the connection between symmetries and conserved quantities.
Understanding of symmetries wave functions and application in different settings.

TENTATIVE COURSE SCHEDULE

Week	Date	Things happening	Topics	Textbook Chapter
1	Sep 7 (Thu)	• Lecture 1 • HW1 released	Course Intro Review and notation	1.1, 1.2, 1.3, 1.4 and 1.5
2	Sep 12 (Tue)	• Lecture 2	Position and Momentum	1.6
	Sep 13 (Wed)	• TA office hours		
	Sep 14 (Thu)	• Lecture 3 • HW2 released	Wave functions in position and momentum	1.7
	Sep 15 (Fri)	• Prof. Muschik office hours • **HW1 due (11:59 p.m. EST)**		

3	Sep 19 (Tue)	• Lecture 4	Time evolution and Schrödinger equation	2.1 and 2.4
	Sep 20 (Wed)	• TA office hours		
	Sep 21 (Thu)	• Lecture 5 • HW3 released	Time evolution and Heisenberg equation	2.2
	Sep 22 (Fri)	• Prof. Muschik office hours • **HW2 due (11:59 p.m. EST)**		
4	Sep 26 (Tue)	• Lecture 6	Rotation and angular momentum	3.1
	Sep 27 (Wed)	• TA office hours		
	Sep 28 (Thu)	• Lecture 7 • HW4 released	Spin 1/2 systems	3.2
	Sep 29 (Fri)	• Prof. Muschik office hours • **HW3 due (11:59 p.m. EST)**		
5	Oct 3 (Tue)	• Lecture 8	Eigenstates of angular momentum (arbitrary spins)	3.5
	Oct 4 (Wed)	• TA office hours		
	Oct 5 (Thu)	• Lecture 9 • HW5 (Midterm Prep) released	Orbital angular momentum	3.6
	Oct 6 (Fri)	• Prof. Muschik office hours • **HW4 due (11:59 p.m. EST)**		
6	**Oct 9 to Oct 13**	**READING WEEK**		
7	Oct 17 (Tue)	• Lecture 10	Training Session: Midterm Prep	

	Oct 18 (Wed)	TA office hours		
	Oct 19 (Thu)	**Lecture 11: IN CLASS MIDTERM**		
8	Oct 24 (Tue)	• Lecture 12 • HW6 released	Addition of angular momentum	3.8
	Oct 25 (Wed)	TA office hours		
	Oct 26 (Thu)	• Lecture 13	Symmetries, Wave functions under parity and the Double Well	4.1 and 4.2
	Oct 27 (Fri)	• Prof. Muschik office hours		
9	Oct 31 (Tue)	• Lecture 14 • HW7 released	Lattice translations and Time reversal	4.3 and 4.4
	Nov 1 (Wed)	• TA office hours • **HW6 due (11:59 p.m. EST)**		
	Nov 2 (Thu)	• Lecture 15	Time-dependent potentials	5.5
	Nov 3 (Fri)	• Prof. Muschik office hours		
10	Nov 7 (Tue)	• Lecture 16 • HW8 released	Adiabatic approximation	5.6
	Nov 8 (Wed)	• TA office hours • **HW7 due (11:59 p.m. EST)**		
	Nov 9 (Thu)	• Lecture 17	Berry's phase	5.6
	Nov 10 (Fri)	• Prof. Muschik office hours		
11	Nov 14 (Tue)	• Lecture 18 • HW9 released	Time dependent perturbation theory	5.7

	Nov 15 (Wed)	• TA office hours • **HW8 due (11:59 p.m. EST)**		
	Nov 16 (Thu)	• Lecture 19	Identical particles	7.1 and 7.2
	Nov 17 (Fri)	• Prof. Muschik office hours		
12	Nov 21 (Tue)	• Lecture 20 • HW10 released • HW12 (Final Prep) released	Identical particles: multi-particle states	7.5
	Nov 22 (Wed)	• TA office hours • **HW9 due (11:59 p.m. EST)**		
	Nov 23 (Thu)	• Lecture 21	Quantization of the electromagnetic field	7.6
	Nov 24 (Fri)	• Prof. Muschik office hours		
13	Nov 28 (Tue)	• Lecture 22 • HW11 released	Path integrals	2.6
	Nov 29 (Wed)	• TA office hours • **HW10 due (11:59 p.m. EST)**		
	Nov 30 (Thu)	• Lecture 23	Bell's Theorem	Slides
	Dec 1 (Fri)	• Prof. Muschik office hours		
14	Dec 5 (Tue) (Classes End	• Lecture 24	Training Session: Final Exam Prep	
	Dec 6 (Wed)	• TA office hours • **HW11 due (11:59 p.m. EST)**		

	Dec 8 (Fri)	• Prof. Muschik office hours		
15	Dec 13 (Wed)	Last TA Office hours		
	Date TBA	**• FINAL EXAM**		

TEXTS / MATERIALS

Title / Name	Notes / Comments	Required
J. J. Sakurai and J. Napolitano, Modern Quantum Mechanics	Course Textbook	Yes

STUDENT ASSESSMENT

Component	Value
Homework	50%
Mid Term	20%
Final Exam	30%
Homework grades will be given based on the student's solutions to weekly assignments (or on a subset of thereof).	

ASSIGNMENT SCREENING

No assignment screening will be used in this course.

ADMINISTRATIVE POLICY

In this course, you should expect to be treated fairly and with respect by everyone on the instructional team and all your peers. You should expect equal opportunity to learn. You are also expected to behave fairly and respectfully toward everyone else and avoid behaviours that it harder for others to be comfortable. Everyone in the course has equally earned their place. Please help to create a welcoming and inclusive environement by, for example, refraining from discussing a person's appearance or making assumptions based on gender, race, ethnicity, sexual orientation, disability, or other personal characteristics. If you have a concern about how you are being treated, some of the people you can contact include (in order if escalating seriousness): your instructor, the current Chair of the Department of Physics and Astronomy, the University of Waterloo's Sexual Violence Prevention and Response Office at svpro@uwaterloo.ca or the police on - or offcampus.

Academic integrity: In order to maintain a culture of academic integrity, members of the University of Waterloo community are expected to promote honesty, trust, fairness, respect and responsibility. [Check the Office of Academic Integrity for more information.](https://uwaterloo.ca/academic-integrity/)

Grievance: A student who believes that a decision affecting some aspect of their university life has been unfair or unreasonable may have grounds for initiatinga grievance. Read Policy 70, Student Petitions and Grievances, Section 4 . When indoubt, please be certain to contact the department's administrative assistant who will provide further assistance.(https://uwaterloo.ca/secretariat/policies-procedures-guidelines/policy-70)

Discipline: A student is expected to know what constitutes academic integrity to avoid committing an academic offence, and to take responsibility for their actions. [Check the Office of Academic Integrity for more information.] A student who is unsure whether an action constitutes an offence, or who needs help in learning how to avoid offences (e.g., plagiarism, cheating) or about "rules" for group work/collaboration should seek guidance from the course instructor, academic advisor, or the undergraduate associate dean. For information on categories of offences and types of penalties,students should refer to Policy 71, Student Discipline . For typical penalties, check Guidelines for the Assessment of Penalties .(https://uwaterloo.ca/academic-integrity/) (https://uwaterloo.ca/secretariat/policies-procedures-guidelines/policy-71) (https://uwaterloo.ca/secretariat/guidelines/guidelines-assessment-penalties)

Appeals: A decision made or penalty imposed under Policy 70, Student Petitions and Grievances (other than a petition) or Policy 71, Student Discipline may be(https://uwaterloo.ca/secretariat/policies-proceduresguidelines/policy-70) (https://uwaterloo.ca/secretariat/policies-procedures-guidelines/policy-71) maybe appealed if there is a ground. A student who believes they have a ground for an appeal should refer to Policy 72, Student Appeals. (https://uwaterloo.ca/secretariat/policies-procedures-guidelines/policy-72)

Note for students with disabilities: AccessAbility Services (https://uwaterloo.ca/accessability-services/) , located in Needles Hall, Room 1401, collaborates with all academic departments to arrange appropriate accommodations for students with disabilities without compromising the academic integrity of the curriculum. If you require academic accommodations to lessen the impact of your disability, please register with AccessAbility Services at the beginning of each academic term. https://uwaterloo.ca/accessability-services/

Turnitin.com: Text matching software (Turnitin®) may be used to screen assignments in this course. Turnitin® is used to verify that all materials and sources in assignments are documented. Students' submissions are stored on a U.S. server, therefore students must be given an alternative (e.g., scaffolded assignment or annotated bibliography), if they are concerned about their privacy and/or security. Students will be given due notice, in the first week of the term and/or at the time assignment details are provided, about arrangements and alternatives for the use of Turnitin in this course.

It is the responsibility of the student to notify the instructor if they, in the first week of term or at the time assignment details are provided, wish to submit alternate assignment.

UNIVERSITY POLICY

Academic integrity: In order to maintain a culture of academic integrity, members of the University of Waterloo community are expected to promote honesty, trust, fairness, respect and responsibility. [Check the Office of Academic Integrity (https://uwaterloo.ca/academic-integrity/) for more information.]

Grievance: A student who believes that a decision affecting some aspect of their university life has been unfair or unreasonable may have grounds for initiating a grievance. Read Policy 70, Student Petitions and Grievances, Section 4 (https://uwaterloo.ca/secretariat/policies-procedures-guidelines/policy-70) . When in doubt, please be certain to contact the department's administrative assistant who will provide further assistance.

Discipline: A student is expected to know what constitutes academic integrity to avoid committing an academic offence, and to take responsibility for their actions. [Check the Office of Academic Integrity

(https://uwaterloo.ca/academic-integrity/) for more information.] A student who is unsure whether an action constitutes an offence, or who needs help in learning how to avoid offences (e.g., plagiarism, cheating) or about "rules" for group work/collaboration should seek guidance from the course instructor, academic advisor, or the undergraduate associate dean. For information on categories of offences and types of penalties, students should refer to Policy 71, Student Discipline (https://uwaterloo.ca/secretariat/policies-procedures-guidelines/policy-71) . For typical penalties, check Guidelines for the Assessment of Penalties (https://uwaterloo.ca/secretariat/guidelines/guidelines-assessment-penalties) .

Appeals: A decision made or penalty imposed under Policy 70, Student Petitions and Grievances (https://uwaterloo.ca/secretariat/policies-procedures-guidelines/policy-70) (other than a petition) or Policy 71, Student Discipline (https://uwaterloo.ca/secretariat/policies-procedures-guidelines/policy-71) may be appealed if there is a ground. A student who believes they have a ground for an appeal should refer to Policy 72, Student Appeals (https://uwaterloo.ca/secretariat/policies-procedures-guidelines/policy-72) .

Note for students with disabilities: AccessAbility Services (https://uwaterloo.ca/accessability-services/) , located in Needles Hall, Room 1401, collaborates with all academic departments to arrange appropriate accommodations for students with disabilities without compromising the academic integrity of the curriculum. If you require academic accommodations to lessen the impact of your disability, please register with AccessAbility Services at the beginning of each academic term.

Turnitin.com: Text matching software (Turnitin®) may be used to screen assignments in this course. Turnitin® is used to verify that all materials and sources in assignments are documented. Students' submissions are stored on a U.S. server, therefore students must be given an alternative (e.g., scaffolded assignment or annotated bibliography), if they are concerned about their privacy and/or security. Students will be given due notice, in the first week of the term and/or at the time assignment details are provided, about arrangements and alternatives for the use of Turnitin in this course.

It is the responsibility of the student to notify the instructor if they, in the first week of term or at the time assignment details are provided, wish to submit alternate assignment.