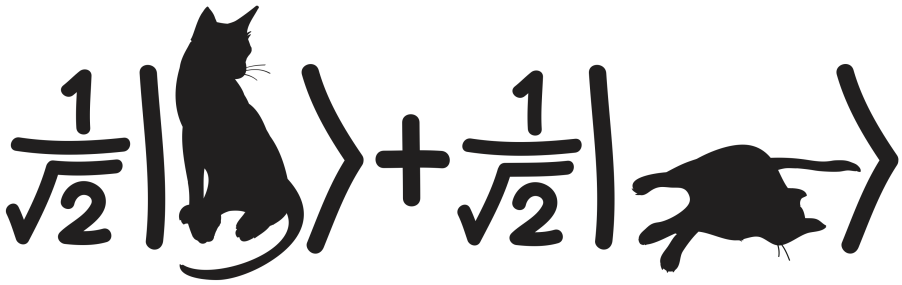
PHYS 4P51:

Quantum Mechanics

Brock University, Fall 2022

Prof. Barak Shoshany



About the Brock physics department

This course is part of the undergraduate physics curriculum at Brock University. For more information about physics at Brock, please visit the physics department website or the individual pages for people, research, programs, and courses. See also the Brock calendar entry for PHYS 4P51.

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Course overview ^

PHYS 4P51 is a quantum mechanics course at the 4th-year undergraduate level. It will be your last course in quantum mechanics before graduate school, and thus it should prepare you for graduate-level study and research.

My goal is that by the end of this course, you will gain a deep and intuitive understanding of the foundations of quantum theory, from the modern point of view of 21st-century theoretical physics – as it is currently understood by researchers in cutting-edge fields such as quantum foundations, quantum information, quantum computation, quantum field theory, and quantum gravity. Such an understanding will be absolutely crucial if you want to be a theorist, and will also be extremely useful if you want to be an experimentalist.

Before you begin this course, you should forget everything you learned about quantum mechanics before! We will re-learn quantum theory from scratch, developing it in an axiomatic and mathematically rigorous way from first principles. We will see that there is nothing particularly complex or mysterious about quantum mechanics (with the crucial exception of its philosophical interpretations), and obtain insight that will allow us to understand how it makes the universe works at the most fundamental level.

There is no textbook for this course. My lecture notes will contain everything you need to know. During the lectures I may sometimes teach bonus material (e.g. in reply to a student's question), but the exams will only cover the material that is in the notes. This will allow students who missed a lecture to make up the material by reading the notes without missing anything relevant to the exams.

About the professor ^

The professor for this course is Dr. Barak Shoshany (he/him). I did my BSc in mathematics and physics at Tel Aviv University in Israel and my MSc and PhD at Perimeter Institute for Theoretical Physics in Waterloo, Ontario. I then taught at the University of Toronto for a short time. I joined Brock University as Assistant Professor in September 2020, and I also teach scientific computing at McMaster University.

I am a theoretical, mathematical, and computational physicist. My research focuses on the nature of time and causality in general relativity and quantum mechanics, as well as symbolic and high-performance scientific computing.

I am particularly interested in time travel; I wrote a popular article about my research on The Conversation and was even interviewed about it on the TV show The Agenda. I'm always happy to talk about my research, and theoretical physics in general, so please feel free to ask me about it, both in and out of class!

When I'm not teaching or doing research, I love composing music (look for my album "Travel Music About Time" on all music streaming services), playing video games, board games, and tabletop role-playing games, and watching TV, especially science fiction and fantasy.

My office is located in room E219 in the Mackenzie Chown Complex (MC). I do not have fixed office hours. You are welcome to drop by my office unannounced whenever you want, but I'm not there too often. If you would like to meet, please email me, and I would be happy to schedule a meeting in my office.

Schedule and lectures ^

The course will take place during the Fall 2022 term, from September 7 to December 6, 2022. There will be two 1.5-hour lectures every week:

- Mondays 16:00-17:30,
- Thursdays 16:00-17:30.

There will be no lectures on Reading Week, October 10-14, 2022. Thus we will have 12 weeks of 2 lectures each, for a total of 24 lectures and 36 hours.

The course will be given **in person only**, in room TH241 in the Thistle Complex. **Important: Students must adhere to the COVID-19 guidelines listed below.**

The course will also have a Microsoft Teams site, where students can have discussions and ask the profes-

sor questions. The professor will also use Teams to make announcements, and it is crucial that you follow these announcements closely (I recommend enabling email notifications on Teams).

Lecture notes

The official course lecture notes are available here. They will be under constant revision throughout the term, so always make sure you have the latest version!

Download the lecture notes

(PDF file)

Last updated: September 8, 2022

These lecture notes will expand on lecture notes from a course I previously taught at the University of Toronto. Video lectures from that course are also available for those who are interested. However, in our course we will learn a larger amount of material, and at a more advanced level.

Possible advanced topics that I hope to cover, which are not currently in the lecture notes, include: applications of group theory and representation theory, a rigorous treatment of continuous states and operators, density matrices, measurements in quantum information, quantum cryptography, interpretations of quantum mechanics in depth, and more. We won't have time to learn all of these topics, so I will choose which ones to cover based on the students' interests. If there is any specific topic you would like to learn, whether or not it is in this list, please let me know!

Weekly progress

The following list will be populated as the course progresses, to indicate which sections of the lecture notes we learned each week:

- **Week 1 (Sep 05 - Sep 11):** TBA.
- **Week 2 (Sep 12 - Sep 18):** TBA.
- **Week 3 (Sep 19 - Sep 25):** TBA.
- **Week 4 (Sep 26 - Oct 02):** TBA.
- **Week 5 (Oct 03 - Oct 09):** TBA.
- **Reading week (Oct 10 - Oct 16):** TBA.
- **Week 6 (Oct 17 - Oct 23):** TBA.
- **Week 7 (Oct 24 - Oct 30):** TBA.
- **Week 8 (Oct 31 - Nov 06):** TBA.
- **Week 9 (Nov 07 - Nov 13):** TBA.
- **Week 10 (Nov 14 - Nov 20):** TBA.
- **Week 11 (Nov 21 - Nov 27):** TBA.
- **Week 12 (Nov 28 - Dec 04):** TBA.
- **Week 13 (Dec 05 - Dec 11):** TBA.

Homework problem sets

There will be a homework problem set every week, which will include problems related to the material

learned that week. Each problem set will be posted on Teams some time after the last lecture of the week. The homework problem sets will not be marked and will not contribute to your final grade directly, but solving them will be crucial for your success in the exams.

The problem sets can be solved either alone or together with other classmates, and discussion of the problem sets with other students, whether on Teams or in private, is strongly encouraged. I will provide solutions to each problem set two weeks after its release.

Each problem set will involve a subset of the exercises and problems in my lecture notes for the subsections we learned that week. If you want more practice, you should solve **all** the exercises and problems in the lecture notes. Detailed solutions to problems that are not in the homework sets will not be provided, but you can always ask about them on Teams if you are not sure if your solution is correct.

Exams and grading ^

There will be 3 exams during the term, roughly one per month. Each exam will test the students' understanding of the material learned up to the exam date. The exams will be scheduled for a time that works for all of the students; we will schedule them together during the lectures.

The exams will be given **in person only**, at a room which will be booked once the exams are scheduled. I will be present in the exam room for the duration of the exam in case clarification is needed for any of the exam questions. **Important: Students must adhere to the COVID-19 guidelines listed below.**

The exams will contain questions similar to the exercises and problems in the lecture notes. This means there will be both calculation and proof questions. The level will be the same as the questions in the notes - not harder, but also not any easier. Some questions may be taken directly from, or be variations of, questions from the lecture notes, while other questions will be completely new.

For allowed material, you may use my full lecture notes, and in addition, up to 42 normal-sized double-sided papers of any other material of your choice, handwritten or printed. Computers, phones, and other digital devices cannot be used, but you can use a calculator.

In your answers, you may make use of any results derived or stated explicitly in my lecture notes, and **only** them. If you wish to use any non-trivial result that is not in the lecture notes, you must prove it directly from the material in the lecture notes. If you make any assumptions beyond what's in the lecture notes, your question will be marked as incomplete.

Since notes are allowed, you do **not** need to memorize anything. The exam is not meant to test your memory. It will test your level of understanding of the physics and math concepts you learn in the course, and your ability to apply them correctly and efficiently to concrete problems.

Once the timer starts, you will have exactly 2 hours to solve the exam (unless you have extra time accommodations). If you are late to the exam, you will not get any extra time, so please make sure to be at the exam room at least 15 minutes before the beginning of the exam.

Each exam will be worth a third of the final grade. After the average is calculated, it will be rounded to the nearest integer, with .5 rounded up. A final grade of 50% or more is required to pass the course.

How to succeed in the exams ^

To succeed in the exams, please make sure to:

- Attend all the lectures and **actively participate** in them. If something is unclear, ask for a clarification. If a topic inspires you to ask a followup question, ask it. If I ask the class (or you personally) a question, do your best to answer it. In my experience, the students who participate the most in class are also the students who get the highest grades in the exams!
- Thoroughly read and understand my lecture notes in order to revise and get a better understanding of what I said in the lectures. This is especially important if you missed a lecture. Also, please note that anything in the lecture notes can appear in the exam, even if I did not cover it directly in the lectures, unless explicitly stated otherwise.
- Make an honest effort to solve the weekly problem sets in their entirety. Don't just wait for my solutions. If you do that, you will never learn how to solve problems on your own, and will not succeed in the exams! If you are stuck on a particular question, you should discuss it with your classmates.
- Read my solutions to the weekly problem sets very carefully. I try to make sure the solutions are as clear and detailed as possible. Your solutions to the exam questions should ideally look like my solutions to the weekly problem sets.
- Solve as many as possible of the exercises and problems from my lecture notes corresponding to the sections we learned each week - preferably **all of them!** The exams are designed such that any student who successfully solved all the problems and exercises in the notes should be able to get 100%.
- Make use of your greatest resource in this course: the professor. If you don't interact with me in any way, then you might as well just read a textbook or watch lectures on YouTube. I am available to you during the lectures, during my office hours, on Teams, and by email. You are always welcome to drop by my office. Don't be shy to ask for help if you need it - that's what I'm here for!

Missed exams and extra time accommodations ^

If you miss an exam, please email me within 7 days of the exam. Your email should explain why you missed the exam and include any necessary proof, such as a doctor's note. We will then schedule a day and time for you to take the exam in my office. Of course, you will be forbidden from asking other students about the contents of the exam; I trust you to be honest and comply with this rule.

If you have any extra time accommodations from Student Accessibility Services, please email me your Approved Accommodations Summary letter **before** the exam date. Please make sure you appear on the OASIS portal, and that you have a valid Approved Accommodations Summary letter, before emailing me. If you don't know what these things mean, please ask your case manager.

If you have extra time accommodations, you will take the exam in the same room with everyone else, but you will have more time to solve it. Do not attempt to take the exam at the SAS exam center - they will not have the exam in the first place, and being able to ask me questions directly during the exam is extremely important for your success.

COVID-19 guidelines ^

Your health and safety is very important to me! Since this course is delivered in person, all students must adhere to the following COVID-19 guidelines:

- **According to university policy, as of September 6, medical-grade masks are mandatory in all**

instructional spaces. This includes all lectures and exams for this course.
    - Fabric face coverings such as buffs, gaiters and bandanas do not satisfy the masking requirements; you must wear a medical mask (and I recommend an N95 mask).
    - Please note that if any student is not wearing a mask in the classroom, the lecture or exam will be canceled unless the student puts on a mask or leaves the class.
    - If you have a medical exemption from wearing a mask, please send me a doctor's note before coming to class.
    - **As the course instructor, I reserve the right to maintain the mask requirements in my classroom even if the university decides to lift it later in the term.**
- **Vaccine boosters are highly recommended for all students**. If you did not receive a booster in the last 6 months, you are encouraged to get one . While vaccines are not currently required by the university, they may become mandatory later in the term.
- **If you suspect that you are experiencing any COVID-19 symptoms, do not come to class.** If you miss a lecture, you can make up the missing material by reading the lecture notes (which will contain all the material needed for the exam), and if you miss an exam, you can take it another time.

For more information on university policies, please see the COVID-19 FAQ . If you have any questions, comments, or concerns, please do not hesitate to post them on Teams, send me a direct message on Teams, or email me .