QUANTUM MECHANICS FOR EVERYONE

A Course from GeorgetownX (PHYX-008)

COURSE SYLLABUS

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QUANTUM MECHANICS FOR EVERYONE

This course teaches the fundamental notions of quantum mechanics at a level that is accessible to everyone.

LEAD INSTRUCTOR

James Freericks
Professor and McDevitt Chair
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James Freericks is a Professor of Physics who works in theoretical and computational physics focused on quantum mechanical phenomena. He has published over 200 peer-reviewed articles, an award winning textbook, and has taught quantum mechanics to nonscientists since 1995. He is a Fellow of the American Physical Society and the Secretary/Treasurer of its Division of Computational Physics.

FACULTY SUPPORT TEAM

You can contact the faculty support team directly at gux@georgetown.edu.

WHAT IS THE COURSE ABOUT?

Quantum Mechanics for Everyone is a four-week long MOOC that teaches the basic ideas of quantum mechanics with a method that requires no complicated math beyond taking square roots (and you can use a calculator for that). The theory is taught without “dumbing down” any of the material, giving you the same version as experts use in current research. We will cover the quantum mystery of the two-slit experiment and advanced topics that include how to see something without shining light on it (quantum seeing in the dark) and bunching effects of photons (Hong-Ou-Mandel effect).

To get a flavor for the course, watch "Let's get small", which shows you how poorly you were taught what an atom looks like and "The fallacy of physics phobia" to see whether this course is right for you.

Please note: the four sections of this course will be released on a weekly basis from April 18, 2017 to May 23, 2017, when all the course material will be available and the course will become fully self-paced.

WHAT DOES THE COURSE INCLUDE?

Each week, you'll find **video lectures** and **activities,** including **simulations** and **practice questions,** related to the topics being discussed. For most topics, you'll find a sequence that includes one or more lecture videos, along with written contextual information, online simulations to experiment with, and problems to practice what you have learned.

Course Section Outline

1. Introduction to the Quantum World
In the first module, you will become aware of the truth that much of what you have learned about the quantum world is either incomplete or wrong. You'll learn about what happens to an effective magnet that moves through an inhomogeneous magnetic field, how to calculate the probabilities of occurrence of random events, and how to compute probabilities for quantum events with spin.

2. Advanced Quantum Mechanics with Spins
In the second module, we'll explore the phenomenon that quantum particles only remember the last thing that was measured about them. We'll look at quantum weirdness, magnetic resonance imaging, how one can erase which-way information, how quantum particles can be entangled, and how Einstein's hidden variable theory cannot be correct.

3. The Quantum Mechanics of Light
In the third module, we will explore the dual particle and wave nature of light, which we call a quantum particle. You will learn how light, while acting as a particle, manages to partially reflect off glass, how light travels employing the rules of quantum mechanics, and how quantum theory can be applied to mirrors, diffraction gratings, and lenses. We'll also explore what we call "the quantum mystery."

4. Advanced Quantum Ideas with Light
In the fourth module, we will look at how, using quantum interference, we can measure the presence of an object without interacting with it, also known as "quantum seeing in the dark." You'll learn about interferometers, infinity, limits, the polarization of light, interaction-free measurements, and what it means to be indistinguishable.

5. Epilogue
In the Epilogue, we'll conclude with resources for further study, and more.

6. Final Exam
The final exam will be available beginning May 16 and remain available for the entire run of the self-paced course.

WHAT WILL I LEARN IN THE COURSE?

The course is designed to support you in achieving several **learning goals**. By the end of the course, you will have:

- Come to understand what a quantum particle is in the world of the ultrasmall
- Learned the basics of probability theory
- Discovered what spin is and how it is manipulated by magnets

And, upon successfully completing the course, you will be able to:

- Explain what the quantum mystery is
- Apply quantum ideas to understand partial reflection of light, interaction-free measurements, and particle indistinguishability

WHAT SHOULD WE EXPECT FROM EACH OTHER?

What You Can Expect from Professor Freericks and the Course Team

Teaching Assistants will regularly participate in discussion boards to provide content clarification, guidance, and support.

You can also email us with important content-related questions at gux@georgetown.edu.

What You Can Expect from edX

In the event of a technical problem, you should click the "Help" tab located on the left border of the screen. This "Help" tab opens an instruction box that directs you to student Frequently Asked Questions (FAQs) for general edX questions. You can also:

- Report a problem
- Make a suggestion
- Ask a question

You may also contact technical@edx.org directly to report bugs.

What We Expect from You

You should expect to spend around seven to ten (7-10) hours per module to review the written content, watch lectures, and work through practice questions and other activities, including the discussion boards.

In each course section we have included activities to support you in reaching the specified learning objectives for that section. Some of the activities, such as experiments and simulations, are ungraded. There are also assessment questions called "practice questions" throughout. These low-stakes **graded** questions are worth 50% of your grade altogether. They include:

- Multiple choice questions;
- Checkbox questions;
- Number- or text-response questions; and
- Self-assessment questions.

Your **Final Exam** will comprise **50%** of your grade and will be made available beginning May 16. The final exam will be comprised of 11 randomized questions that target your learning throughout the course.

Your final exam must be completed by the end of the self-paced course, which is currently scheduled for April 18, 2019. This is your last chance for a course certificate, if you signed up for the Verified Track.

All activities included in the course are designed to help you gauge your learning as a result of your interaction with the course content. Instructions on how to complete the activities are included within each course section.

Timeline

This course will begin on an instructor-paced timeline and transition to a self-paced course on May 23, 2017. If you join us as part of the instructor-paced portion from April 18 to May 23, 2017, we ask you to follow along each week as we release new material. There is one official due date for this course, **April 18, 2019,** when your final exam must be completed should you be interested in receiving a score for this course (and a certificate if you signed up on the Verified Track). As a self-paced course, the course will be seen as a live resource; the course team will participate on the discussion boards occasionally, and we especially encourage learning interactions amongst students.

Netiquette Guidelines

Please be respectful
To promote the best educational experience possible, we ask each student to respect the opinions and thoughts of other students and be courteous in the way that you choose to express yourself. Informed debate should never give way to insult, rudeness, or anything that might detract from the learning process. PHYX-008 students should be respectful and considerate of all opinions.

In order for us to have meaningful discussions, we must learn to understand what others are saying and be open-minded about others' opinions. If you want to persuade someone to see things differently, it is much more effective to do so in a polite, non-threatening way rather than to do so antagonistically. Everyone has insights to offer based on his/her experiences, and we can all learn from each other. Civility is essential: our teaching assistants can and will remove students from the class who detract from the learning process with insulting comments on the course-wide discussion boards.

Look before you write
Prior to posting a question or comment on the discussion board, the GeorgetownX course team asks that you look to see if any of your classmates have the same question. Upvote questions that are similar to your own or that are also of interest to you, instead of starting a new thread. This will greatly help our TAs best monitor the discussions and bring important questions to the course team's attention.

Use the discussion board for course-related posts only
Although we encourage students to get to know each other, please use the discussion board for course content conversations only.

Properly and promptly notify us of technical issues
Although we do not predict technical issues, they can and may happen. To make sure these receive prompt attention, please use the "Help" tab to troubleshoot, and if you still need assistance, you can contact us at gux@georgetown.edu.

Academic Integrity

Observe the honor policy
Science is a collaborative venture, and you will find being able to discuss practice questions with peers will often help you to learn the material. This practice is encouraged on the discussion board, however, one is not allowed to post answers---instead, focus on asking help for what you do not understand and seek clarification. It is expected that all work that you submit for this course is your own. In particular, the final exam is not to be discussed on the discussion boards or elsewhere. Violations of the honor policy undermine the purpose of education and the academic integrity of the course. We expect that all work submitted will be a reflection of your own original work and thoughts, and that you will abide by the honor policy to allow others to also experience the course and learn from it.

GeorgetownX faculty and staff expect all members of the community to strive for excellence in scholarship and character.

APPENDIX A: DETAILED COURSE OUTLINE

1. Introduction to the Quantum World (released April 18, 2017)

In the first module, you will become aware of the truth that much of what you have learned about the quantum world is either incomplete or wrong. You'll learn about what happens to an effective magnet that moves through an inhomogeneous magnetic field, how to calculate the probabilities of occurrence of random events, and how to compute probabilities for quantum events with spin.

Learning Objectives

- Become aware of the truth that much of what you have learned about the quantum world is either incomplete or wrong
- Describe in detail what happens to an effective magnet that moves through an inhomogeneous magnetic field
- Describe the details of a classical Stern-Gerlach experiment run with magnetic needles or current loops
- Calculate the probabilities of occurrence of random events
- Calculate probability following its basic definition
- Translate words to equations for compound probabilities that use *or* and *and*
- Compute probabilities for quantum events with spin
- Compute the results of simple quantum experiments with spin

2. Advanced Quantum Mechanics with Spins (released April 25, 2017)

In the second module, we'll explore the phenomenon that quantum particles only remember the last thing that was measured about them. We'll look at quantum weirdness, magnetic resonance imaging, how one can erase which-way information, how quantum particles can be entangled, and how Einstein's hidden variable theory cannot be correct.

Learning Objectives

- Realize that quantum particles only remember the last thing that was measured about them
- Predict the results of repeated measurements on quantum particles and how to analyze experiments with analyzer-loops
- Have your first experience with quantum weirdness
- Identify how one can erase which-way information and restore interference
- Explain how two quantum particles can be entangled
- Describe how Einstein's hidden variable theory cannot be correct
- Describe how nuclear magnetic resonance is used in chemistry
- Explain what magnetic resonance imaging is and how it works

3. The Quantum Mechanics of Light (released May 2, 2017)

In the third module, we will explore the dual particle and wave nature of light, which we call a quantum particle. You will learn how light, while acting as a particle, manages to partially reflect off glass, how light travels employing the rules of quantum mechanics, and how quantum theory can be applied to mirrors, diffraction gratings, and lenses. We'll also explore what we call "the quantum mystery."

Learning Objectives

- Describe the dual particle and wave nature of light (and other quantum particles)
- Describe what a quantum particle is
- Use the quantum theory to describe partial reflection
- Develop Feynman's model for how light travels from one point to another employing the rules of quantum mechanics
- Describe how light appears to travel in straight lines, what happens when light is forced to travel through a narrow slit, and how this depends on the color of the light
- Articulate the bizarre results of the two slit experiment and be able to calculate them using our quantum rules
- Explain what the quantum mystery is
- Apply our quantum theory of light to mirrors, diffraction gratings and lenses
- Describe the subtle effects of normalization
- Use the quantum theory to describe how mirrors, diffraction gratings, and lenses all work

4. Advanced Quantum Ideas with Light (released May 9, 2017)

In the fourth module, we will look at how, using quantum interference, we can measure the presence of an object without interacting with it, also known as “quantum seeing in the dark.” You’ll learn about interferometers, infinity, limits, the polarization of light, interaction-free measurements, and what it means to be indistinguishable.

Learning Objectives

- Determine how quantum interference can allow one to measure the presence of an object without interacting with it (This is a phenomenon which is also called "quantum seeing in the dark”)
- Articulate how to see something without looking
- Explain how it is similar to a two-slit experiment, and propose useful experiments with it
- Explain how interferometry works, which is one of the most precise experimental tools in physics
- Summarize the concepts of infinity, limits, polarization of light, and how they are combined within an interaction-free measurement
- Explain how to control polarization, change polarization and use it in the quantum Zeno effect (where measuring the polarization stops the polarization from rotating)
- Describe how an efficient interaction-free measurement can be performed
- Explain how to measure something without interacting with it
- Identify what identical particle correlations are

5. Epilogue + Final Exam (released May 16, 2017)

In the Epilogue, we'll conclude with resources for further study, and more. Once released, the final exam will be available for the duration of the course.