Annexe A: New/Revised Course Content in OBTL+ Format

Course Overview

The sections shown on this interface are based on the templates UG OBTL+ or PG OBTL+
If you are revising/duplicating an existing course and do not see the pre-filled contents you expect in the subsequent sections e.g. Course Aims, Intended Learning Outcomes etc. please refer to Data Transformation Status for more information.

Expected Implementation in Academic Year	AY2025-2026
Semester/Trimester/Others (specify approx. Start/End date)	Semester 1
Course Author * Faculty proposing/revising the course	Qu Zhisong
Course Author Email	zhisong.qu@ntu.edu.sg
Course Title	Technological Applications of Quantum Mechanics
Course Code	PH3103
Academic Units	3
Contact Hours	38
Research Experience Components	Not Applicable

Course Requisites (if applicable)

Pre-requisites	PH2101 Quantum Mechanics 1
Co-requisites	
Pre-requisite to	
Mutually exclusive to	
Replacement course to	
Remarks (if any)	

Course Aims

Quantum Mechanics is the foundation of many areas of physics and countless modern technologies. This course serves as an introduction to three main areas built on modern quantum mechanics: (1) atomic and molecular physics, (2) condensed matter physics and (3) nuclear physics. You will be exposed to the basic concepts of each subject, supported by ample examples and applications. By the end of the course, you are expected to form a deeper understanding of both the theory of quantum mechanics and how it is connected to real life.

Course's Intended Learning Outcomes (ILOs)

Upon the successful completion of this course, you (student) would be able to:

ILO 1	Solve the time-independent Schrodinger equation for the barrier potential
ILO 2	Solve the time-independent Schrodinger equation for the square well potential
ILO 3	Solve the time-independent Schrodinger equation for the hydrogen atom
ILO 4	Explain the concept of electron spin and the spin-orbit interaction
ILO 5	Compute the split of atomic energy-level split in a magnetic field
ILO 6	Explain how electrons occupy their orbits in a many-electron atom
ILO 7	Illustrate the principle of lasers and their applications
ILO 8	Describe different types of molecular bonding and their properties
ILO 9	Identify different mechanisms of forming molecular energy levels
ILO 10	Discuss the applications of the molecular spectra
ILO 11	Write down the Maxwell-Boltzmann distribution; use it to derive the Maxwell distribution of molecular speeds, and use the Equipartition theorem to write down the average kinetic energy per molecule
ILO 12	Use the Fermi-Dirac, Bose-Einstein and Maxwell-Boltzmann distribution functions, together with the density of states, to calculate average values of quantities such as particle number and energy
ILO 13	Distinguish between ionic and covalent solids
ILO 14	Explain the classical theory of conduction
ILO 15	Using the free-electron gas in metals, explain the concept of Fermi energy and Fermi temperature, and the quantum theory of conduction
ILO 16	Use the Kronig-Penny model to derive the band theory of solids
ILO 17	Use the concept of band theory to distinguish between a metal, semiconductor and insulator

ILO 18	Explain impurity semiconductors
ILO 19	Explain the two properties of superconductors: (a) zero resistivity and (b) Meissner effect
ILO 20	Explain applications of quantum mechanics behind components present in smartphones. Also explain the quantum mechanical principles of (d) scanning tunnelling microscope, (e) semiconductor junction diodes, (f) photovoltaic effect, (g) light-emitting diodes, (h) liquid Helium, (i) superconducting magnets, etc. A subset of the abovementioned applications will be discussed.
ILO 21	Describe the composition of nucleus
ILO 22	Explain the concept and binding energy and nuclear stability
ILO 23	Discuss the different models of nucleus
ILO 24	Explain the principle of Nuclear Magnetic Resonance (NMR) and recognize its applications
ILO 25	Describe the concept of radioactivity and summarize different types of decays
ILO 26	Illustrate various applications of radioactivity
ILO 27	Explain nuclear fission and fusion, as well as the ways to use them as energy sources

Course Content

Basic quantum mechanics (B):

- Time-independent Schrodinger equation for the barrier potential
- Time-independent Schrodinger equation for the square well potential
- Time-independent Schrodinger equation for the hydrogen atom

Atomic and molecular physics (A):

- Electron spin, spin-orbit interaction, and Zeeman effects
- Exclusion principle
- Energy levels of many-electron atom
- Principle of lasers
- Ionic bonding and covalent bonding
- Molecular spectra and its applications

Condensed matter physics (C):

- Classical and quantum statistics
- Bose-Einstein condensation
- Photon gas
- Properties of a fermion gas
- Structure of solids
- Classical theory of conduction
- Free electron gas in metals
- Quantum theory of conduction
- Band theory of solids
- Impurity semiconductors
- Semiconductor junctions and devices
- Superconductivity

Nuclear physics (N):

- Composition of nucleus and their properties

- Binding energy, nuclear stability, and nuclear models
- Nuclear magnetic resonance and applications
- Radioactivity, nuclear reactions, and applications
- Nuclear fission and fusion, nuclear powerplant concept

Reading and References (if applicable)

1. Tipler, P.A. and Llewellyn, R.A., 2012. Modern physics. WH Freeman and Co., ISBN 9781429250788.
2. Blatt, F. J., 1992. Modern physics, McGraw-Hill, Inc., ISBN 9780070058774.
3. Eisberg, R. and Resnick, R., 1985. Quantum physics of atoms, molecules, solids, nuclei, and particles, ISBN 9780471873730.
4. Beiser, A., 2003. Concepts of modern physics, ISBN 9780072448481.
5. More readings on individual topics will be suggested during the lectures.

Planned Schedule

Week or Session	Topics or Themes	ILO	Readings	Delivery Mode	Activities
1	Solution to 1D Schrödinger equation and the Hydrogen atom	1-3	Book 3, Chapter 6-7	In-person	Wooclap
2	Electron spin, Zeeman effect	4-5	Book 1, Chapter 7 Book 2, Chapter 9	In-person	Woolclap, Tutorial, Mastering Physics Assignment 1
3	Lasers, many-electron atoms	6-7	Book 1, Chapter 7 and 9 Book 2, Chapter 9	In-person	Woolclap, Tutorial
4	Molecular structure	8-10	Book 1, Chapter 9 Book 2, Chapter 10	In-person	Woolclap, Tutorial, Mastering Physics Assignment 2
5	Classical and quantum statistics	11	Book 1, Chapter 8	In-person	Woolclap, Tutorial
6	Bose-Einstein condensation, photon gas, fermion gas	12	Book 1, Chapter 8	In-person	Woolclap, Tutorial, Mastering Physics Assignment 3, Mid-term Test 1
7	Structure of solids, classical theory of conduction, free-electron gas in metals	13-15	Book 1, Chapter 10	In-person	Woolclap, Tutorial
8	Quantum theory of conduction, band theory of solids	16-17	Book 1, Chapter 10	In-person	Woolclap, Tutorial

Week or Session	Topics or Themes	ILO	Readings	Delivery Mode	Activities
9	Impurity semiconductors, semiconductor devices, superconductivity	18-20	Book 1, Chapter 10 Web articles	In-person	Woolclap, Tutorial, Mastering Physics Assignment 4
10	Nuclear composition and properties, models of the nucleus	21-23	Book 1, Chapter 11 Book 2, Chapter 14	In-person	Wooclap, Tutorial
11	Nuclear spin, nuclear magnetic resonance	24	Book 1, Chapter 11 Book 2, Chapter 14	In-person	Wooclap, Tutorial, Mid-term Test 2
12	Radioactivity and decay	25-26	Book 1, Chapter 11 Book 2, Chapter 15	In-person	Wooclap, Tutorial, Mastering Physics Assignment 5
13	Nuclear reactions	27	Book 1, Chapter 12 Book 2, Chapter 15	In-person	Wooclap, Tutorial

Learning and Teaching Approach

Approach	How does this approach support you in achieving the learning outcomes?
Lectures	Applications will be introduced first to motivate the topic. The fundamental concepts and the theory will then be introduced and discussed. Finally, the concepts are utilized to further explain the application.
Tutorial	Carry out step-by-step derivations of the equations introduced during the lectures. Review and discussion of key concepts from lectures with TAs, by working through problems. The TAs will monitor and provide timely feedback.
Mastering Physics Assignments	The Mastering Physics assignments will consolidate the learning outcomes by providing students with a chance to practice their knowledge.
Mid-term	Mid-term tests are used to motivate and assess your understandings regularly.
Wooclap	Promote thinking in class and provide immediate feedback.

Assessment Structure

Assessment Components (includes both continuous and summative assessment)

No.	Component	ILO	Related PLO or Accreditation	Weightage	Team/Individual	Rubrics	Level of Understanding
1	Continuous Assessment (CA): Test/Quiz(Mid-term test 1)	1-10		15	Individual	Analytic	Multistructural
2	Continuous Assessment (CA): Test/Quiz(Mid-term Test 2)	11-20		15	Individual	Analytic	Multistructural
3	Continuous Assessment (CA): Assignment(Mastering Physics Assignments Online)	All		15	Individual	Analytic	Multistructural
4	Summative Assessment (EXAM): Final exam(Final Examination)	All		50	Individual	Analytic	Relational
5	Continuous Assessment (CA): Class Participation(Wooclap)	All		5	Individual	Analytic	Multistructural

Description of Assessment Components (if applicable)

Class Participation: a minimum of 8 participations to receive full marks.

Formative Feedback

Formative feedback is given through Wooclap in class and discussion within tutorial lessons. We will hold TA meeting regularly to discuss the progress and difficulty level of the course.

Feedback will be given after midterm tests to highlight the common mistakes and misunderstandings.

Past exam questions will be made available starting from the second year of offering.

The student can contact the lecturers after class or via email for individual questions and feedbacks.

NTU Graduate Attributes/Competency Mapping

This course intends to develop the following graduate attributes and competencies (maximum 5 most relevant)

Attributes/Competency	Level
Curiosity	Basic
Problem Solving	Basic
Sense Making	Basic

Course Policy

Policy (Academic Integrity)

Good academic work depends on honesty and ethical behaviour. The quality of your work as a student relies on adhering to the principles of academic integrity and to the NTU Honour Code, a set of values shared by the whole university community. Truth, Trust and Justice are at the core of NTU's shared values. As a student, it is important that you recognize your responsibilities in understanding and applying the principles of academic integrity in all the work you do at NTU. Not knowing what is involved in maintaining academic integrity does not excuse academic dishonesty. You need to actively equip yourself with strategies to avoid all forms of academic dishonesty, including plagiarism, academic fraud, collusion and cheating. If you are uncertain of the definitions of any of these terms, you should go to the academic integrity website for more information. On the use of technological tools (such as Generative AI tools), different courses / assignments have different intended learning outcomes. Students should refer to the specific assignment instructions on their use and requirements and/or consult your instructors on how you can use these tools to help your learning. Consult your instructor(s) if you need any clarification about the requirements of academic integrity in the course.

Policy (General)

You are expected to complete all assigned pre-class readings and activities, attend all classes and tutorials punctually, and take all scheduled assignments and tests by due dates. You are expected to participate in all tutorial discussions and activities.

Policy (Absenteeism)

Absence from the mid-term without a valid reason will affect your overall course grade. Valid reasons include falling sick supported by a medical certificate and participation in NTU's approved activities supported by an excuse letter from the relevant bodies.

If you are sick and unable to attend your class (particularly the mid-terms), you must:

1. Contact the lecturer to schedule an oral make-up exam within two weeks.
2. Submit the Medical Certificate* to administrator.

* The medical certificate mentioned above should be issued in Singapore by a medical practitioner registered with the Singapore Medical Association.

Policy (Others, if applicable)

Diversity and inclusion policy

Integrating a diverse set of experiences is important for a more comprehensive understanding of science.

It is our goal to create an inclusive and collaborative learning environment that supports a diversity of perspectives and learning experiences, and that honours your identities; including ethnicity, gender, socioeconomic status, sexual orientation, religion or ability.

To help accomplish this:

- If you are neuroatypical or neurodiverse, have dyslexia or ADHD (for example), or have a social anxiety

disorder or social phobia;

- If you feel like your performance in the class is being impacted by your experiences outside of class;
- If something was said in class (by anyone, including the instructor) that made you feel uncomfortable;

Please speak to your teaching team, our school pastoral officer or a peer or senior (either in-person or via email) about how we can help facilitate your learning experience.

As a participant in course discussions, you should also strive to honour the diversity of your classmates. You can do this by: using preferred pronouns and names; being respectful of others opinions and actively making sure all voices are being heard; and refraining from the use of derogatory or demeaning speech or actions.

All members of the class are expected to adhere to the NTU anti-harassment policy. if you witness something that goes against this or have any other concerns, please speak to your instructors or a faculty member.