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	AY2019-2020
Semester/Trimester/Others (specify approx. Start/End date)	Semester 1
Course Author * Faculty proposing/revising the course	Chew Lock Yue
Course Author Email	lockyue@ntu.edu.sg
Course Title	Quantum Mechanics II
Course Code	PH3101
Academic Units	4
Contact Hours	52
Research Experience Components	Not Applicable

Course Requisites (if applicable)

Pre-requisites	PH2101 and MH2801
Co-requisites	
Pre-requisite to	
Mutually exclusive to	
Replacement course to	
Remarks (if any)	

Course Aims

Most introductory courses or books in QM start off with special systems (for example infinite square well) and derive its wave function in position representation from the Schrodinger's equation. Although this approach may be intuitive due to its physical setup, it tends to give the wrong impression that wave functions are fundamental objects in QM. In actual fact, wave functions are just the different representations of the state (ket in Dirac notation) of the system. One can always choose other representations or even not choose a representation.

This course aims to unteach wave mechanics and free you of particular representations and work with the formalism directly. You will explore the logical development of Quantum Mechanics (QM) formalism and develop QM systematically from finite to infinite dimensions in three parts.

Part 1 aims to give a complete and systematic run-down of basic quantum kinematics and quantum dynamics so that you have a working understanding of quantum mechanics for finite-dimensional and infinite dimensional systems. The concept of measurement will also be covered. This provides probabilistic results for experiments.

Part 2 aims to discuss symmetry within QM. Rotational symmetry (angular momentum is the generator of rotations) is the main and very important example. The rotational symmetry in Hydrogenic atoms will also be discussed, which will also introduce you to 3D QM.

Part 3 adds on to the formalism for systems that cannot be solved exactly. These are real-life QM examples and the standard method to solve these systems is via perturbation for time-independent/dependent and non-degenerate/degenerate systems.

Course's Intended Learning Outcomes (ILOs)

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

ILO 1	Apply kinematical formalism of quantum mechanics to analyse quantum systems with discrete and continuous eigenvalues and eigenstates.
ILO 2	Apply dynamical formalism of quantum mechanics using either Schrodinger, Heisenberg or Interaction picture to determine the time evolution of a quantum operator or state.
ILO 3	Demonstrate correspondence between classical mechanics and quantum mechanics in simple examples.
ILO 4	Identify symmetries in a quantum system via calculating certain commutation relations.
ILO 5	Perform orbital angular momentum algebra either in position representation (spherical harmonics) or in matrix representation.
ILO 6	Perform spin angular momentum algebra in matrix representation.
ILO 7	Generalise and perform operator algebra for general angular momentum.
ILO 8	Perform addition of angular momentum for orbital, spin and general angular momentum.
ILO 9	Solve separable 3D QM problems (such as Hydrogenic atom).
ILO 10	Apply Hellmann-Feynman theorem to simple systems.
ILO 11	Apply variational principle to estimate the energy of a ground state of a system.
ILO 12	Calculate 1st and 2nd order corrections to energy and states for time-independent Hamiltonians (including non-degenerate and degenerate unperturbed states).
ILO 13	Solve problems using the basic ideas of WKB approximation.
ILO 14	Calculate transition rates for 1st order time-dependent perturbation.

Course Content

Part 1: Basic Formalism – Kinematics and Dynamics (BF)

1. Recalling some formalism from mathematizing the educational Stern-Gerlach example.

2. Continuing with formalism: From 2 outcomes (eigenvalues) to N eigenvalues.

3. Continuing with formalism: From discrete N eigenvalues to continuous eigenvalues.

4. Quantum-Classical Correspondence.

5. Overall summary of formalism.

6. Simple examples.

7. Closing to Part 1 and some literature.

Not examinable:

A. Things to ponder: Interpretation of QM

B. Accidentally discovering another interpretation of QM

C. Geometrical aspect of Quantum Mechanics

Part 2: More Formalism – Symmetry, Angular Momenta and 3D QM (MF)

1. How to talk about symmetry in Quantum Mechanics?

2. Rotational symmetry: Orbital angular momentum $\vec{L}$.

3. Spin angular momentum $\vec{S}$.

4. Generic angular momentum $\vec{J}$.

5. Addition of angular momentum.

6. 3D QM Example: Hydrogen atom.

A. Separation of Variables: The multi-variable calculus way.

B. Hydrogenic atoms: More details.

C. Collection of special functions.

Part 3: Even More Formalism – Perturbation Theory (EMF)

1. Warm-up ideas.

2. Rayleigh-Ritz Variational Principle.

3. Time-independent perturbation theories.

4. Basic discussion on WKB approximation.

5. Time dependent perturbation theory.

A. Variation of operator exponential function and beta function.

B. More advanced discussion on WKB approximation (not examinable)

Reading and References (if applicable)

1. Berthold-Georg Englert, Volumes 1,2 and 3 - Lectures on Quantum Mechanics ISBN-13: 978-9812569714

2. B.H. Bransden & C.J. Joachain - Quantum Mechanics (Second Edition) ISBN-13: 978-0582356917

3. Nouredine Zettilli - Quantum Mechanics : Concepts and Applications (Second Edition) ISBN: 978-0-470-02679-3

Planned Schedule

Week or Session	Topics or Themes	ILO	Readings	Delivery Mode	Activities
1	Part 1: Basic Formalism – Kinematics and Dynamics	1	Textbook and lecture notes,		Videos
2	Part 1: Basic Formalism – Kinematics and Dynamics	1	Textbook and lecture notes		Videos
3	Part 1: Basic Formalism – Kinematics and Dynamics	2			
4	Part 2: More Formalism – Symmetry, Angular Momenta & 3D QM	3			Midterm Test 1
5	Part 2: More Formalism – Symmetry, Angular Momenta & 3D QM	4			
6	Part 2: More Formalism – Symmetry, Angular Momenta & 3D QM	5			
7	Part 2: More Formalism – Symmetry, Angular Momenta & 3D QM	6			

Week or Session	Topics or Themes	ILO	Readings	Delivery Mode	Activities
8	Part 2: More Formalism – Symmetry, Angular Momenta & 3D QM	7			
9	Part 3: Even More Formalism – Perturbation Theory	8			Midterm Test 2
10	Part 3: Even More Formalism - Perturbation Theory	9			
11	Part 3: Even More Formalism – Perturbation Theory	10			
12	Part 3: Even More Formalism – Perturbation Theory	11			
13	Part 3: Even More Formalism – Perturbation Theory	12, 13			

Learning and Teaching Approach

Approach	How does this approach support you in achieving the learning outcomes?
Use of Learning Catalytics (tutorial and lecture)	You are able to get on-the-spot checking of your understanding of concepts.
Lectures	Reviews of previous materials will be done first. The emphasis is on laying out the logic and the present material will follow on with the logical flow. Some conceptual questions will be interspersed during the lectures.
Tutorial	TAs will review the logical flow and concepts. Then simple questions will be discussed first, leading to longer, tougher questions.
Homework	Comprises of simple questions to check foundations and tougher questions to see if you can synthesize concepts together.

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	Summative Assessment (EXAM): Final exam(Final Examination)	All	Competence 1,2,3,4,5 Communication 1	60	Individual	Analytic	Relational
2	Continuous Assessment (CA): Others(CA1: Online Assessment)	All	Competence 1,2,3,4,5 Communication 1	10	Individual	Analytic	Multistructural
3	Continuous Assessment (CA): Assignment(CA2: Homework)	All	Competence 1,2,3,4,5 Communication 1	10	Individual	Analytic	Multistructural
4	Continuous Assessment (CA): Test/Quiz(CA3: Mid-term Test 1)	Range 1-3	Competence 1,2,3,4,5 Communication 1	10	Individual	Analytic	Relational
5	Continuous Assessment (CA): Test/Quiz(CA4: Mid-term Test 2)	Range 4-9	Competence 1,2,3,4,5 Communication 1	10	Individual	Analytic	Relational

Description of Assessment Components (if applicable)

Formative Feedback

Formative feedback is given through discussion within tutorial lessons as well as interactive, computer based hints and pointers in the Mastering Physics online assignment and resource system.

Formative feedback is given via the student response application Learning Catalytics where you are required to answer on your mobile devices questions posted during lecture/tutorial. Feedback is always provided for your response to each question.

Feedback is also given after each midterm on the common mistakes and level of difficulty of the problems. Past exam questions and examiner's report are made available for you.

NTU Graduate Attributes/Competency Mapping

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

Attributes/Competency	Level
Adaptability	Advanced
Learning Agility	Basic
Problem Solving	Intermediate

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)

Policy (Absenteeism)

Absence Due to Medical or Other Reasons
If you are sick and unable to attend your class / Mid-terms, you have to:

1. Send an email to the instructor regarding the absence and request for a replacement class and make-up mid-terms.
2. Submit the original Medical Certificate* or official letter of excuse to administrator.
3. Attend the assigned replacement class (subject to availability) and make-up mid-terms.

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

Policy (Others, if applicable)