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

Course Overview

Expected Implementation in Academic Year	AY2025-2026
Semester/Trimester/Others (specify approx. Start/End date)	Semester 2
Course Author * Faculty proposing/revising the course	Nelly Ng Huei Ying
Course Author Email	nelly.ng@ntu.edu.sg
Course Title	Relativity and Quantum Physics
Course Code	PH1107
Academic Units	3
Contact Hours	39
Research Experience Components	Not Applicable

Course Requisites (if applicable)

Pre-requisites	Physics and Mathematics at A or H2 level, or equivalents
Co-requisites	
Pre-requisite to	
Mutually exclusive to	
Replacement course to	
Remarks (if any)	

Course Aims

This course aims to equip you with the basic concepts and problem solving skills for analysing objects moving close to the speed of light and particles exhibiting quantum behaviour. You will develop physical insights and analytical skills which are important for studying relativistic problems and quantum systems. These knowledge and skills lay the foundation for subsequent higher level courses.

Course's Intended Learning Outcomes (ILOs)

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

ILO 1	apply the properties of waves to analyse interferometry in the context of measurement of the speed of light; and diffraction, interference, standing waves in quantum physics
ILO 2	describe the key ideas in development of the atomic, nuclear and particle physics and explain how they impact our understanding of nature
ILO 3	state and use Einstein's two postulates to derive Lorentz transformations, the length contraction and time dilation formulas and solve problems involving length and time measurements in different inertial reference frames
ILO 4	use the Minkowski's space-time diagram to solve problems and resolve paradoxes in special relativity (such as the barn-pole paradox, twin paradox)
ILO 5	derive and use the formulas for relativistic momentum, kinetic energy and total energy to solve problems in high energy Physics
ILO 6	analyse nuclear processes (such as fission, fusion and radioactive decay) and perform calculations using the mass-energy equivalence equation
ILO 7	analyse problems involving radioactive decay (such as in radioactive dating and doses in biomedical physics)
ILO 8	explain the significance of the physical phenomena related to wave-particle duality (such as photoelectric effect, Compton scattering, pair production/annihilation, electron double slit experiment, Davisson-Germer experiment) and perform calculations related to these experiments
ILO 9	applying concepts of quantization to derive Bohr's model of the hydrogen atom and solve problems involving hydrogen-like atoms
ILO 10	perform calculations where quantum properties are used in technology (such as photo-multiplier, solar sail and electron microscopes)
ILO 11	explain the terms operators, states, eigenvalues and eigenfunctions in the context of quantum mechanics (first for two state systems and then extending to systems with continuous eigenvalues) and determine expectation values and uncertainty of physical quantities.
ILO 12	determine the wave functions of a particle in a given potential wells (such as infinite potential wells and barriers) and cite examples of their applications in technology (such as quantum dots display, memory devices).
ILO 13	use the orthogonality property of eigenfunctions and perform basic analysis of quantum systems in superposition.
ILO 14	discuss quantum phenomena (such as quantum superposition, collapse of the wave function, quantum tunnelling and Heisenberg's uncertainty principle) and explain their conflicts with our perception of reality
ILO 15	Use the quantum numbers: n,l,m of the hydrogen atom to determine the corresponding eigenfunction (from a given table) and solve related simple problems.

Course Content

Foundation (FND)
Wave properties
Speed of Light
Superposition, Diffraction and Interference
Atoms and subatomic particles

Special Relativity (SR)
Frames of Reference and Galilean Transformation
Postulates of Special Relativity and Lorentz Transformation
Length Contraction and Time Dilation
Minkowski's Space-time diagrams
Resolving Paradoxes
Relativistic Momentum, Kinetic Energy and Energy

Basic Nuclear Physics (BN)
Radioactive particles (α,β $particles$ and $\gamma$$-radiation$)
Nuclear Fission and Fusion
Radioactivity
Mass-Energy Equivalence
Medical application and Dosage

Quantum Physics (QP)
Blackbody Radiation
Quantization of Physical Quantities
Photoelectric Effect
Compton Scattering and wavelength
Pair Production/Annihilation
Double Slit Experiment
Davidsson-Germer Experiment
Wave-Particle Duality
Hydrogen Atom (Bohr's Model & Atomic Spectra)

Basic Quantum Mechanics (BQM)
Eigenvalues, Eigenfunctions and Operators
Two level systems
Schrodinger's Equation and Wave function
Probability (Density)
Infinite and Finite Potential Well (Particle in a Box)
Quantum Harmonic Oscillator
Potential Barrier/Step
Expectation Value and Uncertainty
Heisenberg's Uncertainty Principle
Commuting Operators
Hydrogen Atom
Quantum Numbers, Degeneracy

Reading and References (if applicable)

1. University Physics with Modern Physics, 14th Edition, Hugh Young and Roger Freedman, Pearson (2015) ISBN-13: 978-0133977981.
2. Giancoli: Physics for Scientists and Engineers with modern Physics, 4th Edition, Pearson. ISBN-13: 978-0131495081
3. R Knight: Physics for Scientists and Engineers: A Strategic Approach with Modern Physics and Mastering Physics, 3rd Edition, Pearson. ISBN-13: 978-0133942651
4. Physics for Scientists and Engineers, 8th Edition, R A Serway and J W Jewett Jr, Brooks Cole (2009). ISBN-13: 978-1439048443
5. Leo Sartori: Understanding Relativity: A simplified Approach to Einstein's Theories, University of California Press (1996). ISBN-13: 978-0520200296
6. Albert Einstein: Relativity: The Special and General Theory. ISBN-13: 978-0517884416
7. Julian Schwinger: Quantum Mechanics, Springer (2001). ISBN-13: 978-3540414087
8. Berthold-Georg Englert: Lectures on Quantum Mechanics (Basic Matters), World Scientific Publication Company (2006). ISBN-13: 978-9812567901

NOTE: The above listing comprises the foundational readings for the course and more up-to-date relevant readings will be provided when they are available.

Planned Schedule

Week or Session	Topics or Themes	ILO	Delivery Mode	Activities	Readings
1	Review of concepts in waves 1 (superposition, interferometry, speed of light; diffraction, interference and standing waves)	1		Lectures, Tutorials	
2	Review of concepts in waves 2 Development of the atomic, nuclear and particle physics	1, 2		Lectures, Tutorials	
3	The Two Postulates of Special Relativity and their Implications. Time Dilation and Length Contraction	3		Lectures, Tutorials	
4	Minkowski's Space-time diagrams Paradoxes in Special Relativity	4		Lectures, Tutorials	
5	Relativistic Momentum and Energy, Mass Energy Relation Mass Defect and Nuclear Processes	5, 6		Lectures, Tutorials	
6	Radioactive decay and applications of Nuclear Physics Biological Effects of Radioactivity	7		Lectures, tutorial	
7	Particle nature of light. Wave nature of particles.	8			

Week or Session	Topics or Themes	ILO	Delivery Mode	Activities	Readings
8	Quantization. Bohr's model of the atom. Application of Quantum Physics in Technology	9, 10		Lectures, Tutorials	
9	Basic concepts in Quantum Mechanics I (using two state systems).	11		Lectures, Tutorials	
10	Potential Wells (Infinite potential wells, harmonic oscillator potential, finite potential wells and barriers) and their applications	12		Lectures, Tutorials	
11	Basic concepts in Quantum Mechanics 2	11, 13		Lectures, Tutorials	
12	Quantum Superposition and other quantum phenomena, such as the collapse of the wave function and Heisenberg's uncertainty principle. The Hydrogen atom	13, 14, 15		Lectures, tutorial	
13	The Hydrogen atom cont. , and overall revision of course	15		Lectures, Tutorials	

Learning and Teaching Approach

Approach	How does this approach support you in achieving the learning outcomes?
Problem solving (tutorial and lecture)	Develop competence and perseverance in solving physics problems
Peer Instruction (during lecture)	Develop communication skills and competence in physics.
Use of Learning Catalytics (tutorial and lecture)	The students are able to see how well their peers answer questions and thus understand their relative progress in comprehension.

Assessment Structure

Assessment Components (includes both continuous and summative assessment)

No.	Component	ILO	Related PLO or Accreditation	Weightage	Description of Assessment Component	Team/Individual	Rubrics	Level of Understanding
1	Summative Assessment (EXAM): Final exam(Final Examination)	All		60		Individual	Analytic	Multistructural
2	Continuous Assessment (CA): Test/Quiz(Quizzes distributed over the semester)	FND 1-2 SR 3-5 BNP 6-7 QP 8-10		20		Individual	Analytic	Multistructural
3	Continuous Assessment (CA): Class Participation(Questions via Learning Catalytics, best 3 out of 5)	FND 1-2 SR 3-5		10		Individual	Holistic	Multistructural
4	Continuous Assessment (CA): Assignment(Take home problem sheet)			10		Individual	Analytic	Multistructural

Description of Assessment Components (if applicable)

Formative Feedback

You will receive 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 also given via the student response applications (such as 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. This is part of class participation.

Feedback is also given after each Quiz on the common mistakes and level of difficulty of the problems. Past Quiz questions are also 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
Curiosity	Intermediate
Critical Thinking	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)

N/A

Policy (Absenteeism)

Attendance for quizzes are mandatory -- upon failure to attend a quiz, you will not receive any marks for it. There will be no make-ups.

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.