Nanyang Technological University
Division of Physics and Applied Physics

Academic Year	2022/23	**Semester**	1
Course Coordinator	Asst. Prof. Nelly Ng Huei Ying		
Course Code	PH1107 / PH117S[1]		
Course Title	Relativity and Quantum Physics		
Pre-requisites	Physics and Mathematics at A or H2 level, or equivalents		
No of AUs	3 AU		
Contact Hours	2 hr – lecture; 1 hr – tutorial		
Proposal Date	28 November 2022		

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.

Intended Learning Outcomes (ILO)

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

Foundation (FND):

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.
2. describe the key ideas in development of the atomic, nuclear and particle physics and explain how they impact our understanding of nature.

Special Relativity (SR):

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.
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).
5. derive and use the formulas for relativistic momentum, kinetic energy and total energy to solve problems in high energy Physics.

Basic Nuclear Physics (BNP):

6. analyse nuclear processes (such as fission, fusion and radioactive decay) and perform calculations using the mass-energy equivalence equation.
7. analyse problems involving radioactive decay (such as in radioactive dating and doses in biomedical physics).

Quantum Physics (QP):

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.
9. applying concepts of quantization to derive Bohr's model of the hydrogen atom and solve problems involving hydrogen-like atoms.
10. perform calculations where quantum properties are used in technology (such as photo-multiplier, solar sail and electron microscopes).

[1] PH117S is a self-paced version of the course.

Basic Quantum Mechanics (BQM):

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.
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).
13. use the orthogonality property of eigenfunctions and perform basic analysis of quantum systems in superposition.
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.
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 (BNP)
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

Assessment (includes both continuous and summative assessment)

Component	Course LO Tested	Related Programme LO or Graduate Attributes	Weighting	Team / Individual	Assessment Rubrics
1. Final Examination	All	Competence (1, 2, 3, 4, 5, 6) Creativity (1, 2) Communication (1, 2)	50%	Individual	Point-based marking (not rubric-based)
2. CA3: Assignment	FND 1-2 SR 3-5 BNP 6-7 QP 8-10	Competence (1, 2, 3, 4, 5, 6) Creativity (1, 2) Communication (1, 2, 3) Character (1, 2, 3)	20%	Pairs or in groups of three	Two assignments Open-ended marking scheme* [requirements will be communicated to students together with the assignment questions]
3. CA4: Quiz 1	FND 1-2 SR 3-5	Competence (1, 2, 3, 4, 5, 6) Communication (1, 2)	15%	Individual	Point-based marking (not rubric-based)
4. CA5: Quiz 2	BNP 6-7 QP 8-10	Competence (1, 2, 3, 4, 5, 6) Communication (1, 2)	15%	Individual	Point-based marking (not rubric-based)
Total			100%		

*You would be expected to synthesise the physics concepts learnt in the course to propose scientifically valid approaches to given situations or problems.

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 students you are required to answer on your mobile devices questions posted during lecture/tutorial. Feedback is always provided for student's your response to each question. Two assignments will be given to help you consolidate your learning. They will be marked and feedback will be provided on your learning.

Finally, 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.

Learning and Teaching approach

Approach	**How does this approach support students 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.
Assignment	The assignment comprises non-standard problems that will allow students to both learn together with their group members and exercise their creativity in problem solving.

Reading and References

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

Course Policies and Student Responsibilities Absence Due to Medical or Other Reasons

If you are sick and unable to attend your class / Mid-terms quizzes, 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.

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. Consult your instructor(s) if you need any clarification about the requirements of academic integrity in the course.

Course Instructors

Instructor	Office Location	Phone	Email
Asst. Prof Nelly Ng Huei Ying	SPMS-PAP-03-05	(65) 6514 7410	nelly.ng@ntu.edu.sg

Planned Weekly Schedule

Week	Topic	Course LO	Readings/ Activities
1	Review of concepts in waves 1 (superposition, interferometry, speed of light; diffraction, interference and standing waves)	FND 1	Lectures, Tutorials,
2	Review of concepts in waves 2 Development of the atomic, nuclear and particle physics	FND 1 FND 2	
3	The Two Postulates of Special Relativity and their Implications. Time Dilation and Length Contraction	SR 3	
4	Minkowski's Space-time diagrams Paradoxes in Special Relativity	SR 4	
5	Relativistic Momentum and Energy, Mass Energy Relation Mass Defect and Nuclear Processes	SR 5 BNP 6	
6	Radioactive decay and applications of Nuclear Physics Biological Effects of Radioactivity	BNP 7	Mid-term Quiz 1
7	Particle nature of light. Wave nature of particles.	QP 8	
8	Quantization. Bohr's model of the atom. Application of Quantum Physics in Technology	QP 9 QP 10	Lectures, Tutorials,
9	Basic concepts in Quantum Mechanics I (using two state systems).	BQM 11	
10	Potential Wells (Infinite potential wells, harmonic oscillator potential, finite potential wells and barriers) and their applications	BQM 12	
11	Basic concepts in Quantum Mechanics 2	BQMQP 11, 13	Mid-term Quiz 2
12	Quantum Superposition and other quantum phenomena (Collapse of the wave function and Heisenberg's uncertainty principle) The Hydrogen atom	BQM 13, 14 BQM 15	Assignment due
13	The Hydrogen atom 2 Revision	BQM 15	Lectures, Tutorials,

Graduate Attributes

What we want our graduates from Physics and Applied Physics to be able to do:

Upon the successful completion of the PHY, APHY, PHME, PHMP and PHMS programs, graduates should be able to:

Competency	1	demonstrate a rigorous understanding of the core theories and principles of physics involving (but not limited to) areas such as classical mechanics, electromagnetism, thermal physics and quantum mechanics [PHMS only] demonstrate a rigorous understanding of the core theories and principles of mathematical sciences involving (but not limited to) areas such as analysis, algebra and statistical analysis
	2	read and understand undergraduate level physics content independently;
	3	make educated guesses / estimations of physical quantities in general;
	4	apply fundamental physics knowledge, logical reasoning, mathematical and computational skills to analyse, model and solve problems;
	5	develop theoretical descriptions of physical phenomena with an understanding of the underlying assumptions and limitations;
	6	critically evaluate and distinguish sources of scientific/non-scientific information and to recommend appropriate decisions and choices when needed;
	7	demonstrate the ability to design and conduct experiments in a Physics laboratory, to make measurements, analyse and interpret data to draw valid conclusions.

Creativity	1	propose valid approaches to tackle open-ended problems in unexplored domains;
	2	offer valid alternative perspectives/approaches to a given situation or problem.

Communication	1	describe physical phenomena with scientifically sound principles;
	2	communicate (in writing and speaking) scientific and non-scientific ideas effectively to professional scientists and to the general public;
	3	communicate effectively with team members when working in a group.

Character	1	uphold absolute integrity when conducting scientific experiments, reporting and using the scientific results;
	2	readily pick up new skills, particularly technology related ones, to tackle new problems;
	3	contribute as a valued team member when working in a group.

Civic Mindedness	1	put together the skills and knowledge into their work in an effective, responsible and ethical manner for the benefits of society.