Physics and Astronomy

UNIVERSITY OF CANTERBURY
Te Whare Wānanga o Waitaha
CHRISTCHURCH NEW ZEALAND

General Course Information

PHYS203-25S2
Relativistic and Quantum Physics

0.125 EFTS 15 Points Second Semester

Course Coordinator and Quantum Mechanics Section

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Relativity Section

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Description

Introduction to relativistic mechanics, including space-time transformations, dynamics and collisions of relativistic particles. Introduction to quantum physics, bringing out its applications, including wave-particle duality, one dimensional barriers and wells, hydrogen atom, electron spin, electron configuration of atoms.

Assessment

5%	Tutorial attendance
12%	Homework Assignments (11, counting **best 9** for a total of 12%).
8%	Learn quizzes (Weeks 2, 4, 6, 8, 10, 12, counting **best 5** for total of 8%)
25%	Term test: Week 6
50%	Final Examination*

A student who gains at least 50% in the Final Examination but who would otherwise fail the course, will be awarded a C-.

Pre-requisites P: (1) PHYS 102; (2) MATH102 or EMTH118; **RP**: MATH103 or EMTH119
These prerequisites may be replaced by a high level of achievement in NCEA Level 3 Physics and Mathematics with Calculus or other background as approved by the Head of Department.

Recommended Textbooks

- Serway, R A; Moses, C J; Moyer, C A. Modern physics. 3rd ed. 2005
  ISBN 9780357671023 [Main text]
- Thornton, S T; Rex, A. Modern physics for Scientists and Engineers. 5th ed. 2019
  ISBN 9781337919456 [Also recommended]

(There are copies on 3-hour and 3-day loan in the Engineering and Physical Sciences Library.)

Recommended Reading

- Kittel, Charles et al., *Mechanics* (Berkeley Physics Course Vol 1), 2nd ed., McGraw-Hill, 1973.
- French, Anthony P., *Special Relativity*, Norton, 1968.
- French, Anthony P. and Taylor, Edwin F. *An Introduction to Quantum Physics*. W.W. Norton, 1978.
- Griffiths, David J., *Introduction to Quantum Mechanics*., Prentice Hall, 1995.
- Krane, Kenneth S., *Modern Physics*, 2nd ed., J. Wiley & Sons, 1996.
  (Note: This book is very similar to Serway, Moses and Moyer.)

Lecture Notes and Videos

Some lecture notes will be available on the Learn system: http://learn.canterbury.ac.nz/

Lectures will be videoed by Echo360 and made available for a period of two weeks following each lecture. This is intended for students who miss a lecture due to a clash or illness etc, and is not a substitute for attending lectures in person if you can. Please attend and engage by asking questions whenever something is not clear.

Goal of the Course

Provide a thorough knowledge of relativistic dynamics and its application to various physical situations. Provide a conceptual understanding of the physical principles of quantum mechanics, together with the technical understanding for applying these principles to determine the quantitative properties of physical systems where quantum physics is applicable.

Learning Outcomes

Students will:

- Have mastered space-time transformations for reference frames travelling at relativistic speeds.
- Have mastered techniques to calculate the dynamics of relativistic particles and collisions between relativistic particles.
- Have acquired a conceptual understanding of the principles of quantum mechanics and their implications for physical measurements

- Have mastered the mathematical techniques used to solve the Schrödinger equation in simple situations, and quantitatively describe physical observables in related systems
- Have developed and be able to demonstrate competency to solve appropriate physics problems in the concepts of the course
- Have developed and be able to demonstrate writing and associated communication skills.

Summary of Course Content

Part A. Relativity (12 Lectures, 4 Tutorials)

1. Relativistic Kinematics
    - Inertial frames of reference;
    - Galilean Transformations.
    - Relativity Principle; Speed of light; Lorentz transformations;
    - Space-time.
2. Relativistic Dynamics
    - Relativistic energy and momentum;
    - Relativistic dynamics;
    - Relativistic collisions.
    - Electromagnetism and Relativity
    - Equivalence principle.

Part B. Quantum Physics (24 Lectures, 8 Tutorials)

1. Wave-Particle Duality
    - Black-body radiation; Photoelectric effect; Compton effect; X-ray production
    - Pair annihilation and production
    - Young's double slit experiment for light
2. Wave-like properties of particles
    - Electron diffraction
    - Davison-Germer experiment
    - Compton effect
    - Diffraction of other particles (neutrons, protons etc)
    - Young's double slit experiment for massive particles
    - Uncertainty and classical waves
    - Heisenberg uncertainty principle and classical waves
3. Schrödinger Equation
    - Justification and solution of time-independent Schrödinger Equation
    - Probabilities and interpretation
    - Schrödinger's cat
    - Particle in a box: infinite square well
    - Justification and solution of time-independent Schrödinger Equation
4. Applications of Schrödinger Equation
    - Potential steps
    - Reflection and transmission coefficients
    - Barrier penetration
    - Tunnelling and applications
    - Finite square well
    - Double barrier resonant tunneling
    - Particles in boxes in two and three dimensions
    - Quantum dots
    - Harmonic oscillator
5. Hydrogen atom
    - Properties of atoms and Bohr model
    - Three-dimensional eigenfunction solutions for H-atom

- Role of electron angular momentum
- Stern-Gerlach experiment and electron spin
- Atomic transitions and selection rules

6. Electron configuration of atoms and molecules
   - Pauli exclusion principle and properties of atoms
   - Bonding and molecules
   - Introduction to solids and band theory

Timetable

See Course, Subject and Qualifications Page | University of Canterbury

Homework should be handed into the collection box on the ground floor of Beatrice Tinsley by 5pm on Monday.

Tutorial attendance: 5% is allocated for tutorial attendance. A roll will be taken. There are 12 tutorials in total. **You may miss 2 tutorials with no penalty.** Tutorial questions will be posted each Tuesday.

If you are unable to attend a tutorial in person, to be marked as present, you should submit your answers to the tutorial questions **by 11am on Saturdays**, to a Learn portal with your reason for not being able to attend the tutorial in person (e.g., distance student, illness, isolating). The answers will not be marked; you simply need to demonstrate that you have made a good attempt to answer the questions. This should be viewed as a last resort; the tutorials are intended for discussion to aid learning.

Generative AI Tools Cannot Be Used for Assessment in this Course
In this assessment, you are strictly prohibited from using generative artificial intelligence (AI) to generate any materials or content related to the assessment. This is because students are expected to solve problems and demonstrate knowledge and understanding without the assistance of AI. The use of AI-generated content is not permitted and may be considered a breach of academic integrity. Please ensure that all work submitted is the result of your own human knowledge.

General Physics and Astronomy Information Please consult the document General Information for Physics and Astronomy Students on the web page: https://apps.canterbury.ac.nz/1/science/phys-chem/PHYS%20-%20Course%20Outlines/General.PDF