Physics and Astronomy

UNIVERSITY OF CANTERBURY
Te Whare Wānanga o Waitaha
CHRISTCHURCH NEW ZEALAND

General Course Information

PHYS203
Relativistic and Quantum Physics

0.125 EFTS 15 Points
Second Semester

Relativity Section
Professor Jenni Adams
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Course Coordinator and Quantum Section
Professor David Wiltshire
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Tutor
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Timetable
Lectures: Monday 1pm, **Tuesday** 4pm, **Wednesday** 3pm**, E14**.
Tutorial: Thursday 4pm Ernest Rutherford 319 and **320** (physics lab space).

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, electron spin, electron configuration of atoms, lasers, semiconductors and quantum dots.

Assessment
5% Tutorial attendance
16% Homework Assignments (10, counting **best 8** @ 2% each).
25% Two Tests* (@ 12.5% each): (i) 6:30pm, Thursday 12 August; (ii) 6:30pm, Mon 27 September.
54% Final Examination*
* If a student's exam score in either the Relativity or Quantum Mechanics section of the final examination is higher than the corresponding test score, the Test 1 and/or Test 2 score will be replaced by the higher mark from that section of the exam. 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.
- 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.

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

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
    - Tunneling 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

This year PHYS203 consists of 35 ordinary lectures, 11 tutorials and 2 revision tutorials**. There will also be a drop-in help class at 1pm on Fridays in Jack Erskine 031.**

*The tests will be held on **Thursday 12 August, 6:30pm** and **Monday 27 September, 6:30pm**. In those weeks the slot on the same day will be a revision/discussion tutorials (denoted Rev).*

Lectures 1-11, Tutorials 1-4, Homework 1-3 and Test 1 are on Relativity (Prof Adams); the rest are on Quantum Mechanics (Prof Wiltshire).

Homework may be handed in after the Monday lecture or placed in a collection box. If you miss the homework deadline you may hand them in up to three days later, with a 1/3 penalty on the marks. Homework is ordinarily due on Monday; with the exception of the last homework due Friday. Items in italics are the Quantum Physics, the others Relativity:

Week	**Mon Date**	**Lecture Mon 1pm**	**HW Due Mon 5pm**	**Lecture Tue 4pm**	**Lecture Wed 3pm**	**Tute Thu 4pm**	**HW Due Fri 5pm**
1	Jul 19	L1		L2	L3	T1	
2	Jul 26	L4	**H1**	L5	L6	T2	
3	Aug 2	L7	**H2**	L8	L9	T3	
4	Aug 9	L10	**H3**	L11	L12	**Rev**	
5	Aug 16	*L13*		*L14*	*L15*	*T4*	
6	Aug 23	*L16*	***H4***	*L17*	*L18*	*T5*	
Break							
7	Sep 13	*L19*	***H5***	*L20*	*L21*	*T6*	
8	Sep 20	*L22*	***H6***	*L23*	*L24*	*T7*	
9	Sep 27	***Rev***		*L25*	*L26*	*T8*	
10	Oct 4	*L27*	***H7***	*L28*	*L29*	*T9*	
11	Oct 11	*L30*	***H8***	*L31*	*L32*	*T10*	
12	Oct 18	*L33*	***H9***	*L34*	*L35*	*T11*	***H10***
	Oct 25						
Exams	Nov 1						