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
Associate Professor Jenni Adams
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Course Coordinator and Quantum Section
Professor David Wiltshire
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Tutor
Rudeep Gaur, Ernest Rutherford 302
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Timetable
Lectures: Monday 4pm, and **Tuesday** 10am, Beatrice Tinsley 111; **Thursday** 4pm, E6.
Tutorial: Wednesday 3pm 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, Mon 10 August, E5; (ii) 6:30pm, Mon 21 September, E5.
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
- Thornton, S T; Rex, A. Modern physics for Scientists and Engineers. 4th ed. 2010

(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 Physics and Astronomy Web Page: https://apps.canterbury.ac.nz/1/science/phys-chem/PHYS%20-%20Course%20Outlines/2020_Course/General1_2020.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 34 ordinary lectures, 2 revision lectures and 12 tutorials.

*The tests will be held on **Monday 10 August, 6:30pm** and **Monday 21 September, 6:30pm**. In those weeks the Monday 4pm lecture will be a revision/discussion session (denoted Rev L) and will not be recorded. All other lectures will be recorded on Echo360.*

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 Tuesday 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 Tuesday; with the exception of the last homework due Friday. Items in italics are the Quantum Physics, the others Relativity:

Week	Mon Date	Lecture Mon 4pm	HW Due Mon 5pm	Lecture Tue 10am	Tute Wed 3pm	Lecture Thu 4pm	HW Due Fri 5pm
1	Jul 13	L1		L2	T1	L3	
2	Jul 20	L4	**H1**	L5	T2	L6	
3	Jul 27	L7	**H2**	L8	T3	L9	
4	Aug 3	L10	**H3**	L11	T4	*L12*	
5	Aug 10	Rev L		*L13*	*T5*	*L14*	
6	Aug 17	*L15*	***H4***	*L16*	*T6*	*L17*	
Break							
7	Sep 7	*L18*	***H5***	*L19*	*T7*	*L20*	
8	Sep 14	*L21*	***H6***	*L22*	*T8*	*L23*	
9	Sep 21	*Rev L*		*L24*	*T9*	*L25*	
10	Sep 28	*L26*	***H7***	*L27*	*T9*	*L28*	
11	Oct 5	*L29*	***H8***	*L30*	*T11*	*L31*	
12	Oct 12	*L32*	***H9***	*L33*	*T12*	*L34*	***H10***
	Oct 19						
Exams	Oct 26						