Physics and Astronomy

General Course Information

PHYS203
Relativistic and Quantum Physics

0.125 EFTS 15 Points Second Semester

Quantum Mechanics Section
Daniel Sando
West 814 Ph 369 2293
daniel.sando@canterbury.ac.nz

Course Coordinator and Relativity Section
Jenni Adams
Beatrice Tinsley 412 Ph 369 5989
jenni.adams@canterbury.ac.nz

Tutors

Michael Williams, Ernest Rutherford 310
michael.williams@pg.canterbury.ac.nz

Sebastian Vergara Carrasco, Ernest Rutherford 302
sebastian.vergaracarrasco@pg.canterbury.ac.nz

Vagdhan Roy, Ernest Rutherford 302
vagdhan.roy@pg.canterbury.ac.nz

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
20% Homework Assignments (12, counting **best 10** @ 2% each).
15% Term test: Wednesday 16th August 6:30pm-7:30pm A3
60% Final Examination*
* If a student's exam score in the Quantum Mechanics section of the final examination is higher than their test score, their test score will be replaced by their quantum mechanics section exam score. 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.

Summary of Course Content

Part A. 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

Part B. 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.

Timetable

Lectures: Monday 1pm **Erskine 031**, **Tuesday** 9am **E16 (18/7-8/8) Erskine 031 (15/8-17/10)**, **Wednesday**12pm**,A5**.
Tutorial: Friday 12pm **Ernest Rutherford 140**

There will also be a drop-in help class at 3pm on Thursdays in Ernest Rutherford 465.

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 5:00pm on Fridays**, 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. You can also attend by zoom link, but in that case you should still submit your answer attempts to Learn.

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