Department of Physics and Electronics

RHODES UNIVERSITY
Grahamstown • South Africa

Honours Programme

2021

Contents

1. GENERAL INFORMATION

The Department offers Honours programmes in Physics, Electronics and, Physics and Electronics. The physics and electronics programmes may be used as components in Joint Honours programmes with other departments.

The Honours Year is intensive. You should expect to catch up on courses as well as work on your research project even during the holidays. The needs of each course vary and as such you should be aware of what is required, particularly in those subjects that also have a practical component. Note that not all courses in 4^{th} year have practical components.

The Honours class co-ordinator is Prof Makaiko Chithambo.

2. LEARNING OUTCOMES

The learning outcomes for the Honours Course are as follows:

Basic Knowledge
Demonstrate a sound knowledge and detailed understanding of the formalisms of Physics, especially the fundamental theoretical constructions that underpin the subject.

Problem solving
Formulate and solve problems using theory and methods of physics and /or electronics. These may involve mathematics, experiment or computational modelling.

Experiment
Design and conduct experiments of physical systems. Analyse the data including levels of uncertainty, interpret the results and draw valid conclusions.

Communication and record-keeping
Communicate results and ideas clearly, whether written or orally. Keep comprehensive records of procedures and results.

Independent- and team work
Develop skills to work independently and within a research group.

Nature and methods of physics
Understand the nature of physics, and show proficiency in the methods of scientific research. In particular, be able to access and evaluate information from appropriate sources.

3. CHOICE OF COURSES

The Honours course has two components: These are

- Lecture courses
- Research Project

You may choose any 7 of the lecture courses available, each of which comprises 100 marks, for a total of 700 marks. The research project is worth 300 marks, making a total of 1000 marks for the year. It is important to note that the research project runs throughout the year and you are encouraged to begin preliminary reading as early as possible in your Honours year.

The lecture courses may be either entirely theoretical, assessed by assignments and/or examinations or a combination of theory and experiment. For the breakdown between theory and experiment, if any, consult your lecturer. You may also choose to do a Joint Honours in Physics, Physics and Electronics, or Electronics with another Department, for which the Research Project may be done in the other Department. In that case, you may select an appropriate number of courses as part of your physics component.

There is also a course on the LaTeX typesetting system offered which is compulsory, although not assessed. This is to enable you to acquire proficiency in the standard typesetting system as used by scientists, especially physicists, in general.

On the first day of the programme, you are to discuss your selection of courses with the Honours Coordinator or the Head of Department for approval. Students who choose to carry out the research component in the Department of Physics and Electronics need to discuss their research project with the appropriate member of staff.

With regards to assessment, the lecturers will discuss with you the assessment tasks, which usually involve assignments and examinations. The assignments may also involve some experiments. Please note that all deadlines are FINAL. You will be required to provide regular oral reports to the Department on the progress of your course and project work. The reports offer an opportunity to discuss any problems that may arise along the way. In this regard it is advisable to prepare a timeline to monitor your progress.

Your final grade is presented as a percentage with the breakdown of 70% Course Work and 30% Research Project.

4. LIST OF COURSES

The list of lecture courses is as follows:

Classical Mechanics
Laplace and Hamilton formulations of Classical Mechanics. Solving the attendant Laplacian and Hamiltonian equations of motion. Symmetries of nature, applications to physical systems.

Computer Interfacing I
This course is an introduction to micro-controllers and their peripherals as well as assembly language. General techniques are taught with reference to the AVR8-bit RISC architecture of the Atmel ATMega16.

Computer Interfacing II
Introduction to higher level languages for micro-controllers and making use of pre-defined standards to simplify designs. Several common interfaces to hardware peripherals are introduced as well as more complicated micro-controller architectures and features (DMA and Event systems). Mixing C and assembler as well as the intricacies of the compiler/linker toolchain are also covered. The AVR Xmega architecture is used as a teaching example in this course.

FPGA Course
Introduction to VHDL as a hardware description language and the use of Field Programmable Gate Arrays to act as replacements for complex logic blocks, ASICs and Microcontrollers.

Control Theory
Introduction to classical and modern control theory. Topics may include: feeback control concepts, stability criteria, frequency domain approaches to the analysis and design of control systems, standard control configurations (PI, PID, cascade, etc), industrial applications. Possible advanced topics may include: multivariable control, non-linear control, state-space control methods.

Electronics Design
This course extends Electronics 3 to include designing of more complex circuits as well as the behaviour of "realistic" components rather than the theoretically perfect components used in undergraduate courses. Electronic Design Automation (EDA) and CAD/CAM tools are introduced to aid in the production of PCBs.

General Relativity
This provides a first step toward understanding Einstein's gravitational theory, with emphasis placed on the necessary tools of tensor algebra and calculus.

Nuclear Physics
Developing theoretical methods in nuclear structure and reactions. Application and analysis of experiments.

Optics
A thorough theoretical development of modern optics.

Particle Physics
Introduction to modern particle physics: Standard Model, Fundamental Interactions (strong, weak, electroweak) with a view to the underlying symmetries in nature.

Quantum Mechanics
Developing the underlying mathematical structures of Quantum Mechanics and the understanding of the symmetries of quantum mechanical systems.

Radio Astronomy
Introduction to the instruments and experimental methods of Radio Astronomy. It develops a deep understanding of the underlying astrophysics and cosmology.

Signal Processing
Development of analogue and digital linear systems using mathematical tools (transform theory).

Solid State Physics I
Studying the behaviour of electrons in solids particularly in crystalline solids.

Solid State Physics II
This course examines the magnetic properties of matter and the theory of superconductivity.

Statistical Mechanics
Concerned with models and applications of Bose-Einstein as well as Fermi-Dirac statistics and also touches on Information theory.

5. RESEARCH PROJECTS

Overview
This section describes the Honours Year Project Programme as taken by Physics, Physics and Electronics- as well as students combining physics with some other subject but with physics as the major.

Objectives
The aim of the programme is to offer Honours students an increased range of experience in experimental or theoretical physics or Electronics. Each project is associated with a particular research group and is typically related to current research within the group. Apart from providing students with mentally stimulating experimental or theoretical problems, the projects are intended to offer students the opportunity to develop transferable skills including project management, oral and written communication.

Regulations
The research project runs throughout the year. You are required to submit a report on completion of the project. The project is assessed by thesis and oral presentation. Deadlines specified in this document are final and should be adhered to. You will be required to give regular progress reports on your work to the Department. The course coordinator for the Honours Year is Prof M L Chithambo. However, issues specific to particular projects should normally be discussed with your supervisor.

Selection of project
A list of projects from which you can choose one is provided in this brochure. The project is a major component of the honours programme. It provides an opportunity for you to work to on a topic of interest to you and to show your initiative. You need to discuss a proposed project with the prospective supervisor and understand what is involved before selecting and working on any project.

Preliminary reading
For most projects, you will need to do preparatory reading to familiarise yourself with the work you will undertake. Again, it's best to discuss the necessary background reading with your supervisor. We expect that your reviews will use books and papers rather than only internet search engines.

Planning
We recommend that you should plan your project and have a time schedule and checkpoints. This will help you to keep within the allotted time frame. The project is only a part of the Honours programme and you should be careful not to let the project preoccupy you to the detriment of everything else.

Laboratory Notebook
You should keep a Laboratory Notebook for all experimental work. The notebook is the primary record of your experimental activities. Any other records, such as electronic data files, should be complimentary to a laboratory notebook. The book should be used to record experimental concepts, procedures, observations and results. The records should be accurate, clear, systematic and orderly. Date all entries and be consistent with your numbering and reference system. Treat your laboratory notebook with respect because as they say, if you can't listen to anyone else, you may have to listen to your own data.

Supervision
The role of the supervisor is to help and guide the student and not to give orders. The supervisor will have a good understanding of the topic and can offer advice on aspects of the work including on scope commensurate with the time available, sequence of measurements and preparation of your report. We expect you to work diligently and produce a report of reasonable standard and quality.

Assessment
The Research report is worth 300 marks.

Report Submission
All reports should be submitted to the Honours course Coordinator, Prof M L Chithambo.
*The submission deadline for all reports is 9:00 am on Thursday, 14 October 2021***.** The deadline is final.
There will be a penalty for late submissions. Marks will be reduced by 5% for each day the deadline is exceeded.

5.1 List of projects

- **Nuclear Physics**
  Contact: D Roux (room 40)

Nuclear structure
Nuclei are finite bound quantum systems consisting of strongly interacting particles. However, there are too few particles to permit statistical treatment, and too many for an exact understanding of the physics involved. So this makes the theory of nuclei somewhat complicated, and phenomenological. In order to understand the physics of a nucleus, one needs to analyse gamma-ray data measured with a multi-detector array. An aspect of this analysis is to determine the spin and parity of the nuclear states. In this context, the spin means the total angular momentum of the nucleus, and the parity refers to the symmetry properties of the nuclear wavefunction. The project will involve aspects of the analysis of experimental nuclear data sets with the aim of determining the spins and parity, and possibly constructing a nuclear level scheme, using existing data sets.

- **Solid State Physics**
  Contact: M L Chithambo (room 34a)

Point defects in solids

Various projects are available on the study of point defects in solids using luminescence techniques. These include experimental studies on the nature and characteristics of electron trapping defects and luminescence centres in materials and, theoretical studies on mathematical methods for use in such work.

- **Theoretical physics**
  Contact: J Medved (room 41)

Why are we here? What is the meaning of reality? Is the universe eternal?

Contrary to popular belief, the discipline best suited to answer such mind-boggling questions is Theoretical Physics. For instance, in his infamous "Vatican paper", Stephen Hawking proposed that the universe requires no initial conditions. His arguments are subject to debate, but the point is that theoretical Physics is central to the discussion.

Incoming Honour's Students with a solid background in mathematics are strongly encouraged to contact Dr. Joey Medved to discuss undertaking a Honour's project in theoretical physics.
Dr. Medved's primary field of research is in quantum field theory and gravity (especially, semi-classical aspects of quantum gravity and string theory). However, don't let that scare you. Any given project can be tailored to fit the aptitudes and interests of the student. Possible fields of study include field theory, cosmology, black holes, particle theory, quantum philosophy, quantum information theory, condensed matter theory and so forth.

Electronics
Contact: A Sullivan (room 39)

Electronic Design / Computer Interfacing I & II

Stand alone / PC controlled (via USB) power supply / arbitrary waveform generator.
Specifications:
• PSU should provide (at least) one floating output (i.e. not ground referenced) controllable via user accessible controls or via USB. (A dual floating output is preferable.)
• Current limiting on outputs.
• Display of current draw and terminal voltage is essential.
• Arbitrary waveform generation (0-1kHz)

Assessment criteria:

• Does it work as expected.
• Isolation.

• Cost to manufacture
• Bonus features
• Analysis of key PSU criteria

Impact-detection using ultrasound transducers.
Specifications:
An impact should be detected using an array of piezoelectric-transducers and the relative impact location should be reported as accurately as possible.

Assessment criteria:
The design of the signal conditioning.
The accuracy/precision of impact detection.
Multiple impact determination.

Micro-controller – Display Adapter
Specifications:
Electronics should be designed/built to enable simple connection of a MCU system to a standard computer monitor. The system should be accessed via SPI/I^{2}C/UART in much the same way as standard LCD modules are accessed. The monitor should be connected via VGA/HDMI/DVI interface.
An FPGA is recommended for this.

Assessment criteria:
Ease of use.
Quality of image.
Multiple interfaces are a bonus.

Wireless data acquisition system (CS a recommendation)
Specifications:
• Wirelessly capture accelerometer (and maybe other transducers as well) information from a number of sensors and display them in quasi real-time.
• To be used for motion capture, first year experiments etc.

Assessment Criteria:
• Ease of setup and use.
• Processing raw data to a variety of usable information.
• Range and limitations.
• Accuracy.

Specifications:
• FPGA based trigger system to emulate trigger to Transition Radiation Detector Front End Electronics.
• 1310nm (ST) fibre connector to supply biphase encoded trigger signal.
• One-shot and periodic trigger signal to be configurable.
• Final form-factor to match LogicBox add-on card form factor.

Assessment Criteria:
• Functionality
• Ease of configuration
• Documentation
• Overall Design

●Experimentation and measurement
Contact: J Williams (room 37), M L Chithambo (room 34), S Nsengiyumva (room 38)

The Department of Physics and Electronics has various equipment for use in its teaching laboratories. Interested students will have the opportunity to carry out a project to commission a piece of equipment. The student will be required to submit a comprehensive report that discusses the use of, results from, and in particular comment on any curve fitting, and to make recommendations as to the use of the particular equipment in student practicals at 3rd year or possibly Honours level in the department. Subject to confirmation, projects will be available on

a) Muon Physics experiment
b) Faraday Rotation
c) Fourier analyser

Muon Physics experiment

The muon is one of the fundamental particles in nature. The purpose of this project will be to carry out an experiment intended to study one or more physical properties of a muon, for example, its lifetime.

Faraday rotation

The aim of this project will be to study the features of polarized light propagating through matter in the presence of a magnetic field.

Fourier analyzer

This project will provide a package of equipment designed to demonstrate the use of Fourier transforms as a method of investigating dynamics of measurement.

Crystallography

X-rays are electromagnetic radiation of exactly the same nature as light but of very much shorter wavelength. Owing to this property, X-rays can be used for the investigation of the structure of crystalline materials. This is possible because their lattice spacing is comparable to X-ray wavelength which ranges from 10 to 10^{-3} nm.

The X-ray apparatus in our possession is a fully-featured, microprocessor-controlled device designed for conducting a wide variety of experiments in physics and related disciplines. Experiments at the boundary between physics and medicine include the trans-illumination of objects observed on a fluorescent screen or on an X-ray film and experiments on ionisation and dosimetry. In physics, the experiments range from atomic physics to solid state physics.

The experiments to be performed with X-ray apparatus will focus on the physics of atomic shell and X-ray structural analysis. They include:

(1) Bragg reflection: diffraction of X-rays at a monocrystal. Sodium chloride will be used as a monocrystal
(2) Investigation of the energy spectrum of an X-ray tube (Mo tube) as a function of the high voltage and the emission current
(3) Duane-Hunt relation and determination of Planck's constant
(4) Fine structure of the characteristic X-ray radiation of a molybdenum anode
(5) Edge absorption: filtering X-rays
(6) Bragg reflection: determination of the lattice constants of monocrystals

Laue diagrams: investigation of the lattice structure of monocrystals