Summary of Honours Topics in the School of Physics & Astronomy

Some topics have recommended background material or course prerequisites listed. For those that do not list specific prerequisites, a Bachelor of Science with a major in the discipline of Astrophysics or Physics is a suitable prerequisite.

Students should note that lecturers for these topics may change in 2020.

Astrophysics

Computational Astrophysics is compulsory for students enrolled in ASP4000. Part-time Honours students need to complete Computational Astrophysics in their first semester.

Computational Astrophysics

Lecturer: A/Prof Daniel Price

Computational methods underpin much of theoretical astrophysics. Developing these methods is one of our specialties here at Monash University. This module will cover the fundamentals needed to understand the methods used to simulate a variety of astrophysical phenomena. You will also gain experience in writing your own computer codes from scratch.

Recommended prerequisites: Third year astrophysics, particularly ASP3162.

Advanced Observational Astronomy

Lecturer: A/Prof Michael Brown

This module provides a practical introduction to modern optical and infrared astronomy, including techniques applicable to observations with large ground-based telescopes and satellites. There will be an emphasis on obtaining, understanding and utilising precision photometry and spectroscopy, including multiple observing runs with Monash University teaching telescopes. Students will learn to write their own computer codes to analyse their observational data, including calibrations, mitigating systematic errors, measuring uncertainties and fitting models to their observations.

Recommended prerequisites: Third year astrophysics, particularly ASP3231.

Foundations of General Relativity and Cosmology

Lecturers: A/Prof Eric Thrane and Dr. Bernhard Mueller

General relativity provides the framework in which we understand gravitation, spacetime, and cosmology. The theory makes a number of remarkable, subsequently verified predictions including the existence of black holes and gravitational waves, the gravitational dilation of time, and gravitational lensing. In this module we discuss the motivation for general relativity, introduce the underlying mathematics, and work out the observational consequences of the theory, such as modern physical cosmology.

Recommended prerequisites: Third year astrophysics, particularly ASP3051.

Dynamics of Exoplanets
Lecturer: Dr. Rosemary Mardling

This module will cover observational techniques, physical properties of planets, system architecture, and implications for theories of planet formation. The main focus of the course will be on the dynamics of planetary systems including chaos and stability, as well as the effects of tides and general relativity.

Recommended prerequisites: Background in vector calculus, Fourier series, and ordinary differential equations.

Stars and Stellar Processes (Stellar Astrophysics Part 1)
Lecturer: Prof Alexander Heger

Stars are the source of most light in the universe and forge almost all heavy elements beyond helium. This course will give an advanced overview of stellar evolution and nuclear astrophysics. It will cover evolution of stars and the nuclear burning phases over the entire mass range, from stars like the Sun to the most massive stars that die as supernovae, leaving behind a neutron star or a black hole. This course will combine theoretical background in lectures as well as practical aspects e.g., building your own stellar structure model or the use of stellar evolution codes to follow the evolution of your stellar model.

Recommended prerequisites: Third year astrophysics, particularly ASP3012.

Origin of the Elements (Stellar Astrophysics Part 2)
Lecturers: Dr. Bernhard Mueller and A/Prof Amanda Karakas

This module will build on previous coursework on stellar astrophysics by extending the study to include advanced phases of stellar structure and evolution. An emphasis will be placed on advanced nucleosynthesis, and the application of nuclear astrophysics to modern research problems, such as Galactic Archaeology and the chemical evolution of galaxies and stellar systems.

Recommended prerequisites: Third year astrophysics, particularly ASP3012.

Physics

Quantum Mechanics is compulsory for students enrolled in PHS4000. Part-time Honours students need to complete Quantum Mechanics in their first semester.

Quantum Mechanics
Lecturer: A/Prof Meera Parish

Quantum mechanics underpins a multitude of fields in physics, such as condensed matter physics, particle physics, and quantum information. This advanced course will cover the basics of the quantised electromagnetic field, quantum statistics, and models of complex many-particle systems.

Prerequisites: PHS3101 or an equivalent third-year level Quantum Mechanics subject from another university.

Classical Electrodynamics and Field Theory

Lecturer: Prof. German Valencia

This module on classical electrodynamic theory completes the path from the defining experimental laws to its Lagrangian formalism as an example of a classical field theory. We study in some detail the use of Green's functions to solve partial differential equations as they arise in electrodynamics. We formulate electrodynamics in covariant form emphasising the role played by special relativity in the construction of field theories. The course follows selected sections from the textbook: J.D.Jackson, Classical Electrodynamics.

Recommended prerequisites: PHS3201 or equivalent third-year level subject from another university.

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Lecturers: A/Prof Eric Thrane and Dr. Bernhard Mueller

General relativity provides the framework in which we understand gravitation, spacetime, and cosmology. The theory makes a number of remarkable, subsequently verified predictions including the existence of black holes and gravitational waves, the gravitational dilation of time, and gravitational lensing. In this module we discuss the motivation for general relativity, introduce the underlying mathematics, and work out the observational consequences of the theory, such as modern physical cosmology.

Recommended prerequisites: Background in special relativity, linear algebra and ordinary differential equations.

Introduction to Quantum Information Theory

Lecturer: Dr. Felix Pollock

Information theory is the study of patterns and how we can use them to communicate, compute and perform other useful tasks. All patterns are instantiated in some physical system, and quantum information theory recognises that the laws of physics are ultimately quantum mechanical. In this module, we investigate the logical structure of quantum theory and show how it can differ remarkably from the classical logic on which the modern world runs. Through concepts such as entanglement, information entropy and error correction, we will cover the basics of quantum encryption, quantum communication and quantum computing.

Prerequisites: PHS3101 or equivalent third-year level subject from another university.

X-ray Optics and Synchrotron Science

Lecturers: Dr. Marcus Kitchen and Dr. Kaye Morgan

X-ray imaging is used across the modern world, from medical imaging to airport security scanning to materials characterisation in scientific laboratories. Existing equipment relies almost entirely on attenuation, but emerging techniques are now looking at other properties of the X-ray wavefield, like phase and coherence, to extract new image modalities. This module will explore how these techniques and advanced X-ray sources, such as synchrotron facilities, are enabling us to see the world in amazing detail. Students will gain a theoretical underpinning in modern X-ray optics and apply this knowledge in practice.

Recommended: PHS3201, PHS3201 or equivalent third-year level subjects from another university.

Statistical Mechanics

Lecturer: Prof. Michael Morgan

This module of 18 lectures introduces the mathematical framework of classical and quantum statistical mechanics. The thermodynamic and statistical behaviour of systems comprised of many particles (typically of the order of Avogadro's number) are studied in detail, with the formalism applied to a wide range of physical systems.

Topics include: Thermodynamics; Microcanonical Ensemble; Canonical Ensemble; Grand Canonical Ensemble; Kinetic Theory and Boltzmann Statistics; Quantum Statistical Mechanics; Thermodynamics of Quantum Strings; Density Operator Formalism; The Ising Model; Introduction to Critical Phenomena; Mean Field Models in Statistical Mechanics; Introduction to Renormalisation Theory.

Recommended prerequisites**:** This module builds upon the Level 3 units in quantum mechanics (PHS3101) and statistical mechanics (PHS3102), or equivalent subjects at another university.

Condensed Matter Physics

Lecturers: Dr. Agustin Schiffrin and Prof. Michael Fuhrer

Condensed matter physics provides a comprehensive framework for understanding the structure, dynamics, properties and behaviour of many-particle material systems. The aim of this module is to provide the student with an advanced treatment of select topics in this field, including free electron gases, phonons, band theory, superconductivity, electronic transport in materials, low-dimensional electron systems and topological phases of matter.

Prerequisites: Third year level Quantum Mechanics (PHS3101), Condensed Matter Physics and Statistical Mechanics (PHS3102), or equivalent subjects at another university.

Introduction to Quantum Field Theory

Lecturer: Prof. Csaba Balazs

An 18 contact hours blended course providing an introduction to elements of quantum fields and quantum electrodynamics. Lectures and workshops cover aspects of classical field theory, quantisation of free spin 0 fields, interactions between bosonic fields, quantisation of ferminonic and vector fields and elements of quantum electrodynamics. At the end of this unit students will be able to understand and carry out the simplest calculations in perturbative quantum field theory.

Prerequisites: PHS3101. Students are also strongly encouraged to have taken PHS3201, and PHS3302, or equivalent subjects at another university.

Digital Image Processing and Scientific Visualisation

Lecturer: Dr. Imants Svalbe

This topic will cover the effects that finite discretisation and quantisation have on physical measurements. We examine the representation of signals on discrete lattices and how sampling patterns, various 1:1 transforms, rotations, resizing, linear and non-linear filters affect signal information (and noise) content. We include applications based on several discrete projective transforms that are relevant to the tomographic reconstruction of image data. Assessment is by submission of assignments written as Matlab or Python scripts.

Recommended: Background in linear algebra, transform theory and discrete mathematics.