THIRD YEAR PHYSICS 2009

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The third year curriculum consists of core lecture courses, special topic options, and laboratory projects. The lecture course offerings are outlined below, followed by brief descriptions of contents. The laboratory projects are described later in this document. Options change each year, and students should consult the coordinator at the start of each semester for the most up to date listings. The tables below list the lecture courses, and the unit codes under which they are offered.

Core required units:
All majors in Physics are required to complete these 6 point units

PHYS3301 Classical and quantum physics
PHYS3302 Optics and electrodynamics
PHYS3311 Experimental physics
PHYS3312 Laboratory and quantum solids

Semester unit codes. Third units are numbered according to semester and consist of the following modules. Note that the module content depends on lecturer availability and is subject to change. The lecture numbers are indicated. All units are six points.

SEMESTER 1		SEMESTER 2
PHYSICS 301 **Classical and quantum physics**		**PHYSICS 302** **Optics and electrodynamics**
Quantum Mechanics (26) Electrodynamics (18)		Classical Mechanics (18) Special Relativity (11) Modern Optics (15)
PHYSICS 311 **Experimental physics**		**PHYSICS 312** **Laboratory and quantum solids**
Modern Astrophysics (9) Signals and Noise (12) Laboratories (3)		Solid State Physics (18) and one of either: Computational Quantum Mechanics (18) or Computational Physics (18) plus 2 Laboratories + write-up + Conference Discussions in Physics

Additional enrolment notes.

Double Majors
Students who wish to take a double major of Physics with *either* Chemistry *or* Computer Science/Information Technology enrol in 301, 311, 302 and 312. These special cases do not have a formal co-requisite of the third year mathematics 3M1 and 3M2. Double majors which include Mathematics do have this co-requisite however and in this case the minimum Physics enrolment is 301, 311, 302 and 312.

Course Planning
All students intending to proceed to third year are required to have their courses approved prior to enrolment. Normally, course approval is given by the course coordinator in the department in which the student's workload is largest, but students are recommended to discuss their plans with all appropriate course coordinators in order to maximise the depth of advice available to them. Please come along and discuss your plans with us after the November examinations.

3301 Marks Breakdown

26 lectures	=> 350 / 600
18 lectures	=> 250 / 600

3311 Marks Breakdown

12 lectures	=> 240 / 600
9 lectures	=> 180 / 600
3 labs	=> 180 / 600

3302 Marks Breakdown

18 lectures	=> 245 / 600
15 lectures	=> 205 / 600
11 lectures	=> 150 / 600

3312 Marks Breakdown

18 lectures (SS)	=>	200 / 600
18 lectures (CQM or CP)	=>	200 / 600
2 labs	=>	133 / 600
1 full write-up plus conference	=>	66 / 600

CORE LECTURE COURSES

The approximate contents of the core lecture courses are briefly described below. Some options are not available every year, and some are offered concurrent with Honours. Up to date syllabi are available on the third year web page, and can be checked at the beginning of each semester for the most recent information. A final list of available options will be presented at the start of the year.

Quantum Mechanics.

The essential structure of quantum mechanics is introduced through the concept of intrinsic spin using kets and operators to develop the Dirac, then matrix, algebra. Observations with a Stern-Gerlach apparatus for spin-1/2 particles are described with quantum state vectors, amplitudes and relative phases. Operator techniques are used to introduce the angular momentum eigenstates and eigenvalue spectrum for spin 1/2 and spin-1 particles. The spin-spin interaction of two spin 1/2 particles (electron and proton) leads to hyperfine splitting and total spin 0 and 1 systems. A total spin–zero state is used to introduce the Bell Inequalities and quantum computing. From the first lecture numerous examples show how to think and calculate in quantum mechanics.

The relation of symmetry of a physical system to conservation laws is developed as is the idea that rotational invariance is a reflection of the isotropy of space just as translational invariance is a reflection of its homogeneity. The time development of states is considered in relation to a superposition of energy eigenstates and examples are given for spin-1/2 precession in a magnetic field, magnetic resonance, the ammonia molecule in static and time-dependent electric fields (maser) and femtosecond reaction dynamics.

Raising and lowering operators are introduced with the harmonic oscillator. Bound states of central potentials are considered and vibrational and rotational motion of diatomic molecules described. Time-independent perturbation theory is applied to the ammonia molecule considered as a two-state system and to the hydrogen atom perturbed by an external electric field (Stark effect).

Electrodynamics & Special Relativity

Of the four known forces in nature, the electromagnetic force is all pervading, being effective at sub-atomic distances (the realm of the strong and the weak nuclear forces, each being of extremely short range) and at astronomical distances (the realm where the gravitational force is significant). A proper study of electromagnetism is therefore central to physics, being an excellent example of the evolution of a physical theory from basic experiments to a mathematical formulation of great beauty and elegance.

This course reveals the ‘secrets’ of Maxwell’s equations relating time-varying electric and magnetic fields, and the consequential behaviour of plane electromagnetic waves (the reflection and transmission) at interfaces of various pairs of materials. Radiation types will be described (electric and magnetic, dipole and quadrupole) and meaning assigned to complex indices of refraction - the (real) refractive indices and the extinction coefficients. Formulae will be established that describe the properties of radiation from an accelerated charge (examples include synchrotron radiation and cosmic synchrotrons) - the energy loss per cycle, the polarisation of the radiation, and the radiation’s distribution (likened to a searchlight) for charges moving with relativistic velocities.

Modern Optics

In the last 30 years there has been a total revolution in the field of optics and at the present time, the field of optics is one of the most rapidly changing fields in science. This has been brought about by the invention of the laser in 1960. New optical materials and techniques are finding their way into all aspects of everyday life, be it the supermarket scanner, copying machine, compact disc player, or hologram. In the research laboratory optical devices, such as the laser, optical modulator, or the optical fibre, have become essential tools.

In this course on modern optics, the student gets an overview of some of the changes and developments that are occurring in this exciting field. Because the laser has played a central part in these developments, the first part of the course deals with the basic workings of the laser. The discussion includes the interaction of radiation with matter, pumping processes, and the properties of laser light. A few practical applications of the laser are also discussed.

The remainder of the course looks at other areas of optics which have resulted from the development of the laser. Birefringence and optical activity are the basic physical processes used in the modulation of light and so are an essential component for current communication techniques. Equally as important has been the development of optical fibres for the fast and efficient transfer of information. Both modulation techniques, using the electro-optic effect, and a brief introduction to waveguides and optical fibres will be discussed in this final part of the course.

Solid State Physics

This course provides an important part of a framework for advanced studies in materials science and nanotechnology. It begins with a brief study of lattices, introduces the concepts of phonons to describe the dynamic lattice and moves on to a quantum mechanical study of the properties of electrons in solids. Some of the strange properties of quantum mechanical electrons are then easily understood in terms of the band structure of the solid. A description of both electrons and phonons as quantised quasi-particles lays the foundations for an understanding of electrical and thermal conductivity, and is at the basis of semiconductor physics, superconductivity etc.

Modern Astrophysics

Course Outline

1. Cosmology and the Large Scale Structure of the Universe : 8 lectures
    * The Hubble Law
    * The Friedman Equations
    * The History of the First Million Years -- the standard Big Bang Theory
    * The Origins of Galaxies
    * Problems in Classical Cosmology
        o The Age Problem
        o The Flatness Problem
2. Stars, Neutron Stars and Black Holes : 5 lectures
    * Stellar Populations and Calssification
    * Stellar Evolution and the HR Diagram: Nuclear Physics in Stars
    * Degenerate Stars: White Dwarfs and Neutron Stars
    * Supernovae and Gravitational Collapse
    * Radio Pulsars
    * X-ray Binaries and Black Holes
3. Galaxies, Clusters and Superclusters : optional material - not for examination
    * Properties of Galaxies
    * Jets, Radio Galaxies and Quasars
    * Properties of Galactic Nuclei
    * The Milky Way
    * Rotation Curves and the Missing Mass

LABORATORY PROJECTS

The experiments offered in third year are some of the most interesting and elegant laboratory activities you will encounter during your studies in Physics. There are no restrictions on which projects you with to work on, and you are free to choose those experiments which interest you most from the list of available projects. Each project takes three weeks and during this time the particular experiment is reserved for the exclusive use of your group. A short summary and detailed laboratory book entries are required for the completion of each project. A formal laboratory report is required for one project at the end of the year, and is submitted and presented at the annual Third Year Conference.

EXPERIMENTAL PROJECTS LIST

The following list is approximate in that we are constantly upgrading old experiments and developing new ones. Please check with the laboratory coordinator at the start of the year for an up to date list.

Spatial Filtering

A lens is a simple device for performing Fourier transforms. This project is an essential tutorial in image formation and filtering theory. Coherent light from a laser illuminates a variety of objects and the scattered light is viewed in both the image plane and the transform plane. By placing suitably chosen geometric masks in the latter plane, the reconstructed image can be modified in a number if interesting ways. The images can be collected using a reticon linear array of 1024 25mm photo detectors and down loaded to a computer for detailed analysis. As a result the theory of scattering can be tested to high precision. The project provides an ideal means of gaining an understanding of Fourier transforms.

Vacuum Techniques

A large proportion of present day experiments have to be performed under good vacuum conditions. This can be due to a number of reasons including, the prevention of frosting when low temperatures are required, or the need for clean, oxygen free environments to prevent oxidation or to provide long mean free paths for particle beams such as are used in the many particle accelerators around the world.

There are currently many techniques for achieving low pressures but the cheapest and simplest is to use a rotary pump in combination with a diffusion pump. In this experiment, experience in using this particular pump combination will be gained by setting up a tungsten filament diode and investigating its thermionic characteristics. This will also enable a better understanding of the physical processes involved in the emission process and also the Schottky Effect.

The Atomic Zeeman Effect

If an excited gas is observed through a suitable spectroscope, a discrete line spectra will be observed. If the excited gas is now observed while in an external magnetic field, the spectral lines are seen to split into further components. This splitting of the spectral lines in a magnetic field is a consequence of the quantisation of the total orbital angular momentum of the electron and is known as the Zeeman effect. This effect provided, at the turn of the century, many of the clues to the understanding of the structure of the atom and helped lead to the discovery of the spin of the electron which, in turn, led to the vector model of the atom.

In this experiment the normal Zeeman effect is observed from a Cadmium light source and the various states of polarisation of the emitted light are investigated. Using Zeeman theory, it is possible to determine a value for the e/m of the electron.

Complex Dielectric Constant of Silver

When light is totally internally reflected at a boundary, a non-propagating evanescent wave extends a small way into the less optically dense medium. Resonant conditions can be arranged so that if the latter is a thin metal film, charge density waves may be excited in its conduction electron ‘gas’. These plasmons, which are collective excitations, take energy from the electromagnetic field at resonance, so a careful study of the scattered photons can yield information about the photon/electron interaction and the thickness of the film. The latter can be determined independently by setting up an appropriate interference experiment. In this project the student learns how to use vacuum deposition equipment to lay down a film of silver about 50nm thick and then how to set up the desired resonance using a HeNe laser. Observations of the resonance, which depend critically on the quality of the film, then yield the desired parameters of the plasmons in the silver.

Laser Interferometry

One of the most accurate methods for measuring small distances or displacements is to use optical interferometry. A good example of the use of this technique is provided by the UWA Gravity Group's quest for the detection of Gravity Waves as predicted by the General Theory of Relativity. In this project it is proposed to use an interferometer to detect small changes in the optical path length as the gravity wave passes through the interferometer.

In the present third year laboratory project, two types of interferometer are set up, the Michelson and Mach Zender interferometer. A position sensitive detector is formed using one of the interferometer configurations which is then used to detect the resonant frequencies of one of the mirror arms and the minimum strain detectable by the interferometer. The experiment provides good experience in the setting up of optical systems and illustrates the potential use of these techniques in the detection of small displacements.

Whispering Gallery Modes.

Whispering gallery modes are electromagnetic resonances that can be excited in a cylindrical monocrystal . The name is applied becasue of the similarity with Lord Rayleigh's observations of whispers that would travel around the inside wall of "some famous catherdral" in England early this century. In this case, electromagnetic energy at microwave frequencies bounces around inside the dielectric/air interface, making total internal reflections. In this experiment a cylindrically cut piece of pure single crystal sapphire is examined at microwave frequencies to examine the natural electromagnetic resonances.

Microprocessor Laboratory

Intelligent electronic systems for data acquisition, data processing and apparatus control are now common in both scientific research and industrial environments. The principal aim of this laboratory is to familiarise students with the basic techniques for the design, construction and testing of microprocessor based systems for such applications, with particular emphasis on the interface between the microprocessor and the 'real world'. This requires both hardware and software and an understanding of their interrelation. Students obtain first hand experience in each of these by undertaking three projects, described below, which involve the challenge of design and implementation, and culminate in the satisfaction of 'making it work'.

Projects: Photon Coincidence Counter (Hardware); Reaction Timer (Software); Analog data acquisition system (both Hardware and Software). An 8-bit digital to analog converter built from discrete components and used with the SDK-85 to implement an analog to digital converter.

Optical Pumping in Rubidium Atoms

This is an atomic physics lab and as such involves investigating the realm of the very small – namely you will be probing the electronic structure of Rubidium atoms. By shining cirularly polarised light through a vapour of Rubidium atoms electrons can be pumped into a particular energy level allowing interesting effects, like zeeman resonances, to be observed. At these length scales classical theory is not valid and the analysis must be quantum mechanical. In particular, the theory behind magnetic resosance can be investigated. This is exactly the same principle that underlies the MRI (Nuclear Magnetic Imagining) which is used extensively in medicine the image the human body. By the end of the experiment the student should have gained an understanding of hyperfine structure, linear and quadratic Zeeman effects, angular momentum selection rules, g-factors and population rate equations.