

# **SCHOOL OF PHYSICS AND ASTRONOMY**

## **MODULE CATALOGUE 2011-2012**

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# INTRODUCTION

This document summarises the modules taught in the School of Physics and Astronomy under its various degree programmes. Further detailed information concerning University regulations on modular programmes of study can be found either in the School's *Undergraduate Student Handbook* or in the current edition of the University's *Academic Regulations Handbook*.

## Academic Year

The modular structure affects the shape of the academic year as well as the way in which you pursue your studies and the way you are assessed. The academic year is divided into two Semesters. Modules are delivered during 11 teaching weeks and examinations and assessments take place during an assessment period at the end of each semester. A week-by-week Calendar is available on the final page of this catalogue.

## Mode of Study

You will select a certain number of modules, which in the main are either single or double. The criteria for your module selection and the range of choice available will depend on your individual degree programme and whether it is MPhys or BSc. A range of assessment methods will be used including written examinations, continuous assessment (coursework) and project submissions. (The module catalogue gives details concerning the method of teaching and assessment of all modules.) Modules are defined according to different levels which define their position in the degree programme.

Year 1	Level 0 or 1
Year 2	Level 2
Year 3	Level 3
Year 4	Level 4

## PHYSX Codes for Degree Schemes

Degree Title	Codes
Physics BSc	F300
Physics MPhys	F303
Astrophysics BSc	F511
Astrophysics MPhys	F510
Physics with Astronomy BSc	F3F5
Physics with Astronomy MPhys	F3FM
Physics (with Professional Placement) BSc	F302
Physics with Astronomy (with Professional Placement) BSc	F3FN
Theoretical and Computational Physics BSc	F340
Physics and Music BSc	FW33
Physics with Medical Physics BSc	F350
Mathematics and Physics BSc (Joint)	FG31

## Key Words

There is a certain amount of new terminology which may be unfamiliar to you. This list should provide a guide:

Module	A unit of study, described by a code, title and level designation
Credit	Points awarded for modules passed
CATS	Credit Accumulation Transfer Scheme
Level	Defines the position of a module in the degree scheme (i.e. 0,1,2,3 etc)
Code	Description of module in letters and numbers
Semester	Division of the academic year into Autumn and Spring semesters
Pre-requisite	Module which you must have <i>passed</i> in order to proceed to another specified module
Co-requisite	Module which you must study <i>in the same session</i> as another specified module
Pre-cursor	Module which must be completed (but not necessarily passed) in order to proceed to another specified module
Core Module	Compulsory module
Option Module	Optional module
Free-standing module	Module available to any student at the University subject to timetable and certain other restrictions given in the Free-Standing Module Catalogue (e.g. precursors)
SIMS	This is the Student Information Management System by which you can select modules electronically and also update your personal details
Progression	Moving from one level in the degree programme to the next level
Degree programme	The programme of study defined by your proposed degree title, e.g. "BSc in Physics with Medical Physics"

## What is a Module?

A module is a unit of study. You are assessed on this module at the end of the semester in which it is taught. The means of assessment and teaching methods for each module are given in the Module Catalogue. All modules have a code number and title both of which must be specified on your module selection.

## What is a Credit ?

Each module is equivalent to a certain number of credits. For each module passed you will gain "credits", 10 credits for a single module, 20 for a double module, etc. If you fail a module no credits will be awarded. Ideally you should complete a total of 360 credits at the appropriate levels of study during your time at university in order to qualify for the award of a BSc Honours degree or 480 credits for a MPhys Honours degree. You are advised to complete 120 credits at the appropriate level of study each academic year. The exact rules about what credits are required are given in "Rules for Progression" in the School's *Undergraduate Student Handbook* or in the University's *Academic Regulations Handbook* – but basically you should try to obtain 120 credits per year by satisfying the assessments for six modules in each semester. In Year 1 there is the possibility of "recovering" some failed modules by repeat assessments immediately before the start of the next Autumn Semester but if you do not gain at least 100 credits you will not be able to progress into Year 2. Summer resits are not normally available in other years.

## **Which Modules can I Choose ?**

You can make your choice from the modules listed in the University Module Catalogue and in individual school catalogues. Free-standing modules are listed in the University Free-Standing Module Catalogue (available on line). You will choose modules according to the requirements and regulations of your particular degree scheme (see "Degree Programmes: What Modules to Choose" starting on Page 5). Some modules may be compulsory for some programmes but not for others. Some modules will be optional, although individual schools may have specific requirements designed to help you make a balanced selection. You must conform to the requirements of any individual module, its precursors, co-requisites etc., as defined in the relevant module catalogue. Subject to the constraints of the timetable you may select a free-standing module which will be assessed at the level appropriate to your year of study. If you wish to choose a module offered by another school you are responsible for obtaining the Module Catalogue from them and conforming to their specific module requirements.

## **How do I choose my Modules ?**

First consult the necessary Module Catalogues to see what is on offer. Please feel free to seek advice and guidance. You should take care to comply with the requirements for your particular degree programme carefully and aim for a balanced selection of approximately six modules each semester. A 5/7 or 7/5 split is allowed, but it is not recommended. Having decided on your choice of modules you will have to submit your module choices electronically via SIMS (Student Information Management System). The School will be required to agree to any free choices you make through SIMS (or Schools outside physics for free-standing modules). Students entering the University for the first time (first year) will confirm their module selection (Level 0 or 1) during Registration-Enrolment week. Those of you entering Level 2 (second year) or Level 3 (third or final year) pre-enrol at a scheduled time during the Spring semester of the preceding year. For those of you on a joint degree scheme the module selection for your joint subject should be made in consultation with both Schools.

## **How do I Change my Module Selection ?**

If you feel you want to change your mind about your module selection, University regulations allow you to make alterations no later than the end of the second teaching week of any semester. You are not allowed to change later than this unless you are entering the University in your first year when you are allowed to change no later than the end of the third teaching week of your first Autumn semester only. If you wish to change your selection you should consult your Year Tutor in your school.

## Grading System for Assessment

In accordance with University regulations the School uses as a guide the following grading system for the assessment of assignments and other submissions, as well as for the final Honours Degree result (credits quoted for BSc degree – add 120 credits for MPhys):

First Class	70 % and above with 340 credits
Second Class Division One	60 % - 69 % with 340 credits
Second Class Division Two	50% - 59% with 340 credits
Third Class	40% - 49% with 340 credits
Pass	40% and above but with 320 or 330 credits
Fail	less than 40% or fewer than 320 credits

## Study Abroad and Erasmus

Students are encouraged to consider taking part of their studies abroad at one of the many European university departments with which Cardiff has established links through the Erasmus exchange scheme of the European Union. The scheme is open to all undergraduate and postgraduate students on any degree scheme but is particularly suited to those who have some knowledge of a modern European language. The period of study will contribute towards your Cardiff degree and is normally supported by an Erasmus grant. For undergraduates, study abroad is usually taken during your second year; either one semester abroad can be substituted for part of your study at Cardiff, or you may wish to study abroad for a full academic year. Further details will be available during the Autumn semester or on request.

## Plagiarism

Plagiarism is a serious issue with serious consequences. You should read the entry in the School's *Undergraduate Student Handbook* and think carefully about this matter. You should be particularly careful of plagiarism when obtaining and using information from web-based sources.

Plagiarism, which is defined as the unacknowledged verbatim quotation from one or more sources, is viewed as an unfair practice and is not accepted by the University and can lead to disciplinary procedures with very serious consequences. It is never regarded as merely accidental or innocent. Should plagiarism be found in any work, your mark for that assignment, assessment or the whole module could be in serious jeopardy, in accordance with University regulations.

## DEGREE PROGRAMMES: WHAT MODULES TO CHOOSE

The tables on the following pages summarise the compulsory and optional modules offered by the School of Physics and Astronomy on each of their single-honours and joint-honours degree schemes. Further details of modules which can be taken outside the School will be available at registration or can be discussed with the appropriate Year Tutor. Please seek advice from the School if you have any questions on choice, or if you feel you want to change degree programme.

The University advises all students that the modules listed in this catalogue may be changed or withdrawn both before and after selection, for any reason including the loss or absence of any key member of staff or insufficient take-up of a module. Cardiff University accepts no responsibility for any such changes or withdrawals of modules and students select modules at their own risk.

Modules offered by the School of Physics and Astronomy use the following naming convention: codes beginning with a '0' designate Level 0, Modules codes beginning with a '1' designate Level 1, '2' designate Level 2, etc. The second digit normally denotes the semester in which the module is given: 1 for Autumn, 2 for Spring, 3 for double modules which is spread over both semesters.

### **Preliminary Year (Level 0):**

All prelim physics students take:

#### *Autumn Semester*

PX0101 Structure and Properties of Matter

PX0102 Motion and Energy

#### *Spring Semester*

PX0201 Foundations of Modern Physics

PX0202 Electricity, Magnetism and Light

PX0203 Elementary Mathematical Methods

### **Foundation Year (Level 0):**

All students take:

#### *Autumn Semester*

PX0101 Structure and Properties of Matter

PX0102 Motion and Energy

#### *Spring Semester*

PX0201 Foundations of Modern Physics

### **Module Selection at a Glance:**

The following pages show the module selection guides (Module Timetables) for Session 2011-2012. Updated versions of this document can be viewed at

[www.astro.cardiff.ac.uk/undergrad/ModuleTimetable.pdf](http://www.astro.cardiff.ac.uk/undergrad/ModuleTimetable.pdf)

Comprehensive listings of required modules for joint-honours schemes are available at registration or from appropriate Year Tutors.

## Year 1 Module Timetables – 2011-2012

Module Code	Module Title	Semester	Credits	BSc Physics	MPhys Physics	BSc Theoretical and Computational Physics	BSc Physics with Medical Physics	BSc Physics with Astronomy	MPhys Physics with Astronomy	BSc Astrophysics	MPhys Astrophysics	BSc Physics and Music	BSc Joint Maths and Physics
PX1121	Mechanics and Matter [20-credit Autumn]	A	20	●	●	●	●	●	●	●	●	●	●
PX1122	Mathematical Methods for Physicists I	A	10	●	●	●	●	●	●	●	●	●	
PX1123	Experimental Physics I	A	10	●	●	●	●	●	●	●	●	●	●
PX1124	The Universe from Particles to Galaxies	A	10	●	●	●	●	●	●	●	●		
PX1125	Mathematical Practice for Physical Sciences	A	10	O <sup>1</sup>	O <sup>1</sup>	O <sup>1</sup>	O <sup>1</sup>	O <sup>1</sup>	O <sup>1</sup>	O <sup>1</sup>	O <sup>1</sup>	O <sup>1</sup>	
	Free Standing Module	A	10	O <sup>1</sup>	O <sup>1</sup>	O <sup>1</sup>	O <sup>1</sup>	O <sup>1</sup>	O <sup>1</sup>	O <sup>1</sup>	O <sup>1</sup>	O <sup>1</sup>	
PX1221	Electricity, Magnetism and Waves [20-credit Spring]	S	20	●	●	●	●	●	●	●	●	●	●
PX1222	Mathematical Methods for Physicists II	S	10	●	●	●	●	●	●	●	●	●	
PX1223	Experimental Physics II	S	10	●	●	●	●	●	●	●	●		
PX1224	Computational Skills for Problem Solving	S	10	●	●	●	●	●	●	●	●	●	●
PX1225	Planets and Exoplanets	S	10	O <sup>2</sup>	O <sup>2</sup>	O <sup>2</sup>		●	●	●	●		
PX1226	How the Human Body Works	S	10	O <sup>2</sup>	O <sup>2</sup>	O <sup>2</sup>	●						

Examination - Hours	Exam %	CA %
3	60	40
2	60	40
	0	100
2	80	20
2	60	40
3	60	40
2	60	40
	0	100
	0	100
2	80	20
2	80	20

Key: ●/ Compulsory Module      ○ Optional Module

Notes:

1. This is NOT a free choice. The School will advise students whether they are obliged to take Maths Practice or given a choice of a Free-Standing Module outside the School.
2. Select ONE from two choices.

Year 2 Module Timetables – 2011-2012		Semester	Credits	BSc Physics	MPhys Physics	BSc Theoretical and Computational Physics	BSc Physics with Medical Physics	BSc Physics with Astronomy	MPhys Physics with Astronomy	BSc Astrophysics	MPhys Astrophysics	BSc Physics and Music	BSc Joint Maths and Physics
Module Code	Module Title												
PX2101	Quantum Mechanics	A	10	●	●	●	●	●	●	●	●	●	●
PX2104	Theoretical Physics	A	10	●	●	●	●	●	●	●	●	●	
PX2107	Electronics and Instrumentation	A	10	O <sup>1</sup>	O <sup>2</sup>	O <sup>3</sup>	●	●	●	O <sup>4</sup>	O <sup>4</sup>	O <sup>4</sup>	O <sup>5</sup>
PX2108	Topics in Physics	A	10	●	●	●	●						●
PX2109	Topics in Astronomy	A	10					●	●	●	●		
PX2114	Practical Physics A	A	10	●	●		●	O <sup>5</sup>	O <sup>5</sup>			●	O <sup>5</sup>
PX2116	Computing in Physics	A	10	O <sup>1</sup>	●	●		O <sup>5</sup>	O <sup>5</sup>	●	●	O <sup>4</sup>	O <sup>5</sup>
PX2124	Electricity in the Human Body	A	10	O <sup>1</sup>	O <sup>2</sup>	O <sup>3</sup>	●						
	Free Standing Module	A	10	O <sup>1</sup>	O <sup>2</sup>	O <sup>3</sup>		O <sup>5</sup>	O <sup>5</sup>	O <sup>4</sup>	O <sup>4</sup>		
PX2203	Thermal Physics	S	10	●	●	●	●	●	●	●	●	●	●
PX2206	Mechanics and Special Relativity	S	10	●	●	●	O <sup>4</sup>	●	●	●	●		
PX2214	Practical Physics B	S	10	●	●		●	O <sup>6</sup>	O <sup>6</sup>				
PX2218	Acoustics and Studio Techniques	S	10									●	
PX2220	Planetary Systems	S	10			O <sup>4</sup>		O <sup>6</sup>	O <sup>6</sup>	●	●		
PX2221	Physics Applied	S	10	●	●	●	O <sup>4</sup>	O <sup>6</sup>	O <sup>6</sup>				
PX2223	Physics of Solids and Soft Matter	S	10	●	●	●	●	O <sup>6</sup>	O <sup>6</sup>			●	●
PX2224	Electromagnetism	S	10	●	●	●	●	●	●	●	●	●	●
PX2225	The Physics of Stars	S	10			O <sup>4</sup>		O <sup>6</sup>	O <sup>6</sup>	●	●		
PX2228	Radiation in Medicine	S	10				●						
PX2322	Observational Techniques in Astronomy	AS	20					●	●	●	●		

Notes:

1. Select TWO from four choices.
2. Select ONE from three choices.
3. Select TWO from three choices.
4. Select ONE from two choices.
5. Select ONE from three choices.
6. Select TWO from five choices.

Key: ● Compulsory Module ○ Optional Module

Year 3 Module Timetables – 2011-2012		Semester	Credits	BSc Physics	MPhys Physics	BSc Theoretical and Computational Physics	BSc Physics with Medical Physics	BSc Physics with Astronomy	MPhys Physics with Astronomy	BSc Astrophysics	MPhys Astrophysics	BSc Physics and Music	BSc Joint Chemistry and Physics	BSc Joint Maths and Physics
Module Code	Module Title													
PX3104	Theoretical Physics Techniques	A	10	●	●	●	●	●	●	●	●	●		
PX3105	Optics and Fourier Transforms	A	10	●	●	●	●	●	●	●	●	●	●	●
PX3109	Solid State Physics	A	10	●	●									
PX3110	Galaxies	A	10					●	●	●	●			
PX3121	Applications of Quantum Mechanics	A	10	●	●	●	●	●	●	●	●	●	●	●
PX3134	Digital Medical Imaging	A	10				●							
PX3136	Electromagnetic Radiation Detection	A	10	●	●	●	●	●	●	●	●			
PX4117	Computational Physics	A	10			●								
PX3206	Statistical Mechanics	S	10	●	●	●	●	●	●	●	●	●	●	●
PX3211	Advanced Mathematical Physics	S	10	O <sup>1</sup>	●	●	O <sup>4</sup>		●		●			
PX3212	Stellar Physics	S	10	O <sup>1</sup>	O <sup>2</sup>	O <sup>3</sup>	O <sup>4</sup>	●	●	●	●			
PX3214	Sound Synthesis	S	10	O <sup>1</sup>	O <sup>2</sup>	O <sup>3</sup>	O <sup>4</sup>					●		
PX3226	Physics of Semiconductor Devices	S	10	●	●			O <sup>5</sup>						
PX3231	Physical Cosmology	S	10	O <sup>1</sup>	O <sup>2</sup>	O <sup>3</sup>	O <sup>4</sup>	●	●	●	●			
PX3233	Laser Physics and Applications	S	10	O <sup>1</sup>	O <sup>2</sup>	O <sup>3</sup>	O <sup>4</sup>	O <sup>5</sup>						
PX3234	Medical Ultrasound	S	10				●							
PX3235	Chaos and Non-Linear Systems	S	10	O <sup>1</sup>	O <sup>2</sup>	O <sup>3</sup>	O <sup>4</sup>	O <sup>5</sup>						
PX3237	Nuclear and Particle Physics	S	10	●	●	●	●	●	●	●	●	●	●	●
PX4215	High-Energy Astrophysics	S	10					O <sup>5</sup>		●				
PX3315	Physics Project	AS	20	●	●	●						●	●	●
PX3316	Astrophysics Project	AS	20					●	●	●	●			
PX3317	Medical Physics Project	AS	30				●							

Notes:

1. Select TWO from six.
2. Select ONE from five.
3. Select TWO from five.
4. Select ONE from six.
5. Select ONE from four.

Key: ● Compulsory Module ○ Optional Module

Year 4 Module Timetables – 2011-2012		Semester	Credits	BSc Physics	MPhys Physics	BSc Theoretical and Computational Physics	BSc Physics with Medical Physics	BSc Physics with Astronomy	MPhys Physics with Astronomy	BSc Astrophysics	MPhys Astrophysics	BSc Physics and Music	BSc Joint Chemistry and Physics	BSc Joint Maths and Physics
Module Code	Module Title													
PX3226	Physics of Semiconductor Devices	S	10						○					
PX3231	Physical Cosmology	S	10		○									
PX3233	Laser Physics and Applications	S	10		○				○					
PX3235	Chaos and Non-Linear Systems	S	10						○					
PX3237	Nuclear and Particle Physics	S	10		○									
PX4106	Interstellar Medium and Star Formation	A	10						○		●			
PX4114	Advanced Quantum Mechanics	S	10		○				○		○			
PX4115	General Relativity and Relativistic Astrophysics	A	20		○				○		●			
PX4117	Computational Physics	A	10		○				○		○			
PX4119	Large Molecules and Life	A	10		○				○					
PX4120	Nanostructure Optoelectronics	A	10		○				○					
PX4121	Quantum Field Theory	A	10		○				○		●			
PX4122	Quantum Information Processing	A	10		○				○		○			
PX4215	High-Energy Astrophysics	S	10		○				○		●			
PX4310	Project	AS	60		●				●		●			

Key: ● Compulsory Module ○ Optional Module

Students must take PX3237 if this was not taken in Year 3. Students are not normally allowed to take more than one Level 3 module in Year 4. Select modules to 120-credit limit.

## TRANSFERABLE SKILLS

You would expect – quite rightly – to learn physics on a physics degree. We teach you plenty of theory and practice of physics, but we also want to teach you or help you to develop other important skills. These are the *transferable skills*. Depending on your subsequent career path, these transferable skills might be more highly regarded than your ability to remember equations or recall the more esoteric aspects of the subject.

The Institute of Physics recommends that the following transferable skills should be enhanced during your professional development on your degree programmes. This is achieved by embedding skills into particular modules as shown on each of the individual module entries in the catalogue.

### ***Problem-solving skills:***

Problem solving is one of the most important skills to develop as a physicist. As part of our teaching programme you will be introduced to many physics problems with well-defined solutions. Building confidence through your experience in lectures, exercises (with feedback) and more-personal support in tutorials, you are expected to learn how to apply these techniques to open-ended problems. Your degree programme will help you to develop the ability to formulate problems in precise terms and to identify key issues. We also expect you develop the confidence to try different approaches in order to make progress on challenging problems.

### ***Investigative Skills:***

Your degree programme will provide opportunities to develop skills of independent investigation. You are expected to learn how to find information by using textbooks and other available literature, by searching databases and the Internet, and through discussions with colleagues.

### ***Communications skills:***

During your time as an undergraduate you will be given many opportunities to develop your verbal and written communication skills. Good communications skills are an essential requirement of any professional career. Appropriate feedback will be given to enable you to develop the ability to communicate complex information effectively and concisely by means of written documents, presentations and discussion. You are expected to learn to use technical language appropriately.

### ***Analytical skills:***

Your degree programme will develop your ability to grasp complex concepts, to understand and interpret data precisely and to construct logical arguments. By the end of your degree you should be able to distil a problem to its basic elements.

### ***Computing skills:***

As part of the degree programme you will be introduced to various pieces of software, including programming languages. The IT facilities on site will allow you to develop your computing skills in a variety of areas including the preparation of documents, information searches, numerical calculations, and the manipulation and presentation of data.

### ***Personal skills:***

Regular exercise work, laboratory work, projects and other coursework helps you to develop the ability to work independently, to use your initiative and to organise yourself to meet deadlines. We also ensure that you gain some experience of group work so that you can learn to interact constructively with other people.

### ***Ethical behaviour:***

Scientists are expected to conduct research and present data in a transparent and unbiased manner – to act ethically. You will be required to demonstrate high ethical standards throughout your studies.

# MODULE DESCRIPTIONS

The following pages list the modules currently provided by the School of Physics and Astronomy.

The entries are shown in ascending order of module code.

*There may be a few unavoidable variations of module semester and organiser. Students will be informed of any changes at the beginning of the Autumn semester. Changes to the content of modules and syllabi will be announced by the module organiser at the start of the module.*

## Updated Module Descriptions:

Any revisions of module descriptions made after publication of this catalogue can be viewed at the following web address:

<http://www.astro.cardiff.ac.uk/currentstudents/resources/catalogue.pdf>

The module descriptions published on the web will supersede previously-published paper copies.

## Learning Central:

Most Module Organisers make use of Learning Central (Blackboard) to publish electronic versions of exercises, exercise solutions, handout notes etc. and also publish changes to syllabuses.

## Other Useful Web Links:

Various documents relating to course delivery and evaluation are given at:

<http://www.astro.cardiff.ac.uk/currentstudents>

These documents include:

- The Undergraduate Student Handbook
- Assessment Criteria
- Scheme Specifications
- Autumn and Spring Semester Timetables

## PX0101 THE STRUCTURE AND PROPERTIES OF MATTER

### MODULE INFORMATION:

- Autumn semester: 10 credits.
- Module organiser: Dr D I Westwood.
- Deputy Module Organiser: Prof P A R Ade.
- Teaching and feedback methods: Lectures 22 x 1 hr, Exercise classes 11 x 1 hr, marked Exercises.
- Assessment: Examination 90%. Coursework 10%. [Examination duration: 2 hours]
- Pre-cursors: None.
- Co-requisites: None.
- Pre-requisites: None.

### AIMS OF THE MODULE:

- To introduce the microscopic nature of matter.
- To relate the microscopic properties of matter to selected macroscopic properties of solids, liquids and gases through simple models.
- To explore practical applications through numerical examples.

### LEARNING OUTCOMES:

The student will be able to:

- Describe the electronic structure of the atom and its relationship with both chemical bonds and the periodic table.
- Describe how bonding and microscopic structure determines selected macroscopic properties of solids and liquid surfaces.
- Relate the concepts of temperature and pressure to the properties of an ideal gas and the kinetic theory of gases.
- Recall descriptive elements of the module and solve unseen numerical problems.

### OUTLINE SYLLABUS:

**Building Blocks of Matter:** The atomic model and its importance. Structure of the atom, isotopes, the Periodic table, calculating with moles. Differences between gases, liquids and solids.

**Bonds:** Forces between atoms or molecules - force/distance and potential energy/distance relationships. Types of bonding: ionic, covalent, van-der Waals and metallic bonds.

**Surface Tension:** Surface tension and surface energy of liquids: definition. Water and soap films, minimisation of surface area, idea of breaking molecular bonds to form a surface.

**Properties of Solids:** Stretching a wire, introduction to elastic moduli, theoretical maximum breaking stress and relation to microscopic properties. Explanations for the weakness of real solids.

**Properties of Fluids:** Liquids and gases as fluids. Properties of ideal gases. The concept and measurement of pressure and temperature. The universal gas law ( $pV = nRT$ ). Kinetic theory of ideal gases: Boltzmann constant, mean free paths, r.m.s. velocities and the Maxwell-Boatman distribution.

### TRANSFERABLE SKILLS:

Problem solving. Investigative skills. Mathematics. Analytical skills.

### READING LIST:

Advanced Physics, T Duncan, 4th Edition (John Murray).

University Physics (with Modern Physics), H D Young and R A Freedman, 12th Edition (Addison Wesley).

## PX0102 MOTION AND ENERGY

### MODULE INFORMATION:

- Autumn semester: 10 credits.
- Module organiser: Dr D Stamatellos.
- Deputy Module Organiser: Dr D I Westwood.
- Teaching and feedback methods: Lectures 11 x 1 hr, Laboratory 3 hrs per week, marked assignments.
- Assessment: Examination 60%. Assignments 10%. Lab 30%. [Examination duration: 1 hour]
- Pre-cursors: None.
- Co-requisites: None.
- Pre-requisites: None.

### AIMS OF THE MODULE:

- To provide a basic introduction to Newtonian mechanics.
- To provide an introduction to momentum and the energy of motion.
- To introduce the student to the application of these concepts in the solution of problems.
- To develop experimental physics methodology.

### LEARNING OUTCOMES:

The student will be able to:

- Distinguish between and apply the concepts of scalar and vector quantities.
- Differentiate between and apply the concepts of vector displacement, velocity, acceleration and force.
- Apply the equations of motion to solve problems.
- Recall and apply Newton's laws of motion and his universal law of gravitation.
- Describe the concepts of energy and momentum and the laws governing their conservation, and apply these conservation laws to solve problems.
- Apply the laws of motion to the case of circular motion.
- Make, record and interpret measurements made in laboratory practicals. Present these findings in written, scientific format.

### OUTLINE SYLLABUS:

**Motion:** An introduction to the laws of motion and the equations that describe them.

**Energy and Momentum:** A description of the concepts of energy and momentum and their relation to the motion of bodies. A study of the particular case of circular motion.

### TRANSFERABLE SKILLS:

Experimental physics. Communications skills. Personal skills. Problem solving. Investigative skills. Mathematics. Analytical skills. Ethical behaviour.

### READING LIST:

Advanced Physics, T Duncan, 4th Edition (John Murray).

University Physics (with Modern Physics), H D Young and R A Freedman, 12th Edition (Addison Wesley).

Laboratory manual.

## PX0201 FOUNDATIONS OF MODERN PHYSICS

### MODULE INFORMATION:

- Spring semester: 10 credits.
- Module organiser: Dr J Kirk.
- Deputy Module Organiser: Dr D Nutter.
- Teaching and feedback methods: Lectures 22 x 1 hr, Examples classes 11 x 1 hr, marked Exercises.
- Assessment: Examination 90%. Coursework 10%. [Examination duration: 2 hours]
- Pre-cursors: None.
- Co-requisites: None.
- Pre-requisites: None.

### AIMS OF THE MODULE:

- To provide an introduction to waves, diffraction and interference.
- To introduce the experimental evidence that lead to the development of modern physics.
- To introduce the Bohr model of single electron atoms and its use to understand atomic spectra.
- To provide a basic introduction to wave-particle duality and the Schrödinger equation.
- To discuss the basic structure of the nucleus and radioactive decay.

### LEARNING OUTCOMES:

The student will be able to:

- Describe the basic wave properties and explain diffraction and interference patterns (Young's slits).
- Describe and discuss the significance of crucial experiments that lead to the development of modern physics, including blackbody radiation, measurement of the charge and e/m ratio for electrons, the photoelectric effect and absorption and emission spectra.
- Give an account of the Bohr theory of single-electron atoms and use it to describe spectral series.
- Explain the concepts of wave-particle duality and its consequences, including a brief discussion of the Schrödinger equation and its physical interpretation.
- Discuss the structure of the nucleus and describe radioactive decay processes.
- Recall descriptive elements of the module and solve unseen numerical and algebraic problems.

### OUTLINE SYLLABUS:

**Waves:** Waves and simple harmonic motion, longitudinal and transverse waves, electromagnetic waves.

Principle of superposition, constructive and destructive interference, diffraction, Young's double slit and single slit patterns.

**Milestones in Modern Physics:** Crucial experiments and their interpretation: Blackbody radiation, the discovery of the electron, measurement of the electronic charge (Millikan oil-drop experiment), e/m for electrons, photoelectric effect and emission and absorption spectra.

**Bohr Model:** Bohr model of single-electron atoms and its use to describe the spectral series for hydrogen.

**Wave-particle duality:** The de Broglie wavelength of matter, a brief introduction to the Schrödinger wave equation, the interpretation of the wavefunction, application to one-dimensional particle in a box.

**The Nuclear Atom:** Protons and neutrons in a nucleus, isotopes, atomic number and mass, mass spectrometer, binding energies.

**Radioactivity:**  $\alpha$  and  $\beta$  particles and  $\gamma$  radiation, decay rates,  $C^{14}$  dating.

### TRANSFERABLE SKILLS:

Problem solving. Investigative skills. Mathematics. Analytical skills.

### READING LIST:

Advanced Physics, T Duncan, 4th Edition (John Murray).

University Physics (with Modern Physics), H D Young and R A Freedman, 12th Edition (Addison Wesley).

## PX0202 ELECTRICITY, MAGNETISM AND LIGHT

### MODULE INFORMATION:

- Spring semester: 10 credits.
- Module organiser: Dr R Auld.
- Deputy Module Organiser: Dr C Tucker.
- Teaching and feedback methods: Lectures 11 x 1 hr, Laboratory 3 hrs per week, marked assignments.
- Assessment: Examination 60%. Assignments 10%. Lab 30%. [Examination duration: 1 hour]
- Pre-cursors: None.
- Co-requisites: None.
- Pre-requisites: None.

### AIMS OF THE MODULE:

- To provide an introduction to the fundamentals of electrostatics, current electricity and basic electrical circuit theory.
- To describe magnetism and its relationship with electrical current and changing electrical fields.
- To provide an appreciation of the breadth of the electromagnetic spectrum and to understand the basic properties of light.
- To develop experimental physics methodology.

### LEARNING OUTCOMES:

The student will be able to:

- Recall the definitions of Coulomb's law, electric field strength and electric potential and describe the relationships between these quantities and use them for calculations on systems of point charges.
- Define what is meant by electrical current, emf, potential difference and resistance, and use these quantities for simple circuit analysis.
- Describe intrinsic and extrinsic semiconductors, electron and hole transport and basic band theory, and use these concepts to explain the operation of simple semiconducting devices.
- Describe the magnetic fields associated with current-carrying conductors and use these concepts to define the Ampere.
- Recall Faraday's and Lenz's laws of electromagnetic induction and use these concepts to describe the generation of a.c. electricity.
- Discuss the principal regions of the electromagnetic spectrum and use the wave properties of light to describe diffraction and interference.
- Make, record and interpret measurements made in laboratory practicals. Present these findings in written, scientific format.

### OUTLINE SYLLABUS:

**Electrostatics:** Coulomb's law; electric fields. Electric potential. Insulators and conductors.

**Current Electricity:** Current and charge; drift velocity; resistivity; superconductivity; Ohm's law; emf and internal resistance; electrical power.

**Electronics:** Resistors and capacitors in series and parallel; permittivity; semiconductors (intrinsic and extrinsic); electron and hole transport; p-n junction; the junction diode.

**Magnetism:** Permanent magnets; magnetic flux lines due to a current-carrying conductor; corkscrew rule; force on a current-carrying conductor in a magnetic field; Fleming's left-hand rule; force between two current-carrying conductors; definition of the Ampere.

**Electromagnetism:** Force on an electron in a magnetic field; electromagnetic induction (Faraday's law); Lenz's law; electrical generators; transformers; a.c. currents.

**Light:** The speed of light, wavelength and frequency; the electromagnetic spectrum; properties of light (reflection, refraction, diffraction, interference).

### TRANSFERABLE SKILLS:

Experimental physics. Communications skills. Personal skills. Problem solving. Investigative skills. Mathematics. Analytical skills. Ethical behaviour.

Reading List:

### ADVANCED PHYSICS, T DUNCAN, 4TH EDITION (JOHN MURRAY).

University Physics (with Modern Physics), H D Young and R A Freedman, 12th Edition (Addison Wesley).

Laboratory manual.

## PX0203 ELEMENTARY MATHEMATICAL METHODS

### MODULE INFORMATION:

- Spring semester: 10 credits.
- Module organiser: Dr C Messenger.
- Deputy Module Organiser: Dr C Tucker.
- Teaching and feedback methods: Lectures 22 x 1 hr, Examples classes 11 x 1 hr, marked Exercises.
- Assessment: Examination 70%. Coursework 20%. Class test 10%. [Examination duration: 2 hours]
- Pre-cursors: MA0001 Basic Mathematics 1.
- Co-requisites: None.
- Pre-requisites: None.

### AIMS OF THE MODULE:

- To build on the mathematics learned at GCSE and also that met in Basic Mathematics 1 (MA0001), and to provide a firm foundation for students intending to study for a numerate science degree.
- Learning Outcomes:
  - The student will be able to:
    - Solve simple problems involving the use of exponentials, logarithmic and trigonometric functions.
    - Demonstrate that they can differentiate the above functions.
    - Sketch the above and polynomial functions and appreciate limits.
    - Demonstrate the use of integration by parts, substitution and partial fractions to evaluate integrals.
    - Recall the solution of simple first-order differential equations.

### OUTLINE SYLLABUS:

**Algebra Recap:** Equations, identities and polynomials, factoring quadratics and cubic equations; expressing fractional functions as partial fractions.

**Differentiation:** The rules of differentiation, and differentiation and integration of the exponential, logarithmic and rational functions.

**Trigonometric equations:** Further trigonometry and the solution of simple trigonometric equations. Differentiation and integration of trigonometric functions.

**Curve sketching:** Turning points and elementary curve sketching. Area under a curve and between curves.

**Integration:** Integration by parts, by substitution and using partial fractions.

**Applications:** The solution of simple differential equations such as  $dq/dt = kq$ .

### TRANSFERABLE SKILLS:

Problem solving. Mathematics. Analytical skills.

### READING LIST:

Mathematics – The Core Course for A-Level, L Bostock and S Chandler (Stanley Thornes).

Engineering Mathematics, K A Stroud (Palgrave MacMillan).

## PX1121 MECHANICS AND MATTER

### MODULE INFORMATION:

- Autumn semester: 20 credits.
- Module organiser: Dr C C Matthai.
- Deputy Module Organiser: Prof P Coles.
- Teaching methods: 44 contact hours including lectures, weekly exercises and problem-solving sessions. Feedback: weekly marked exercises and tutorials.
- Assessment: Examination 60%. Coursework 40%. [Examination duration: 3 hours]
- Pre-cursors: None.
- Co-requisites: PX1122 (excepting joint Maths/Physics students).
- Pre-requisites: None.

### AIMS OF THE MODULE:

- To provide firm foundations for the concepts of classical mechanics and their extension into quantum theory and special relativity.
- To emphasise the applicability of simple physical ideas to a wide range of situations.
- To introduce and illustrate the use of conservation laws in dynamical problems.
- To introduce the key concepts underpinning the physical understanding of vibrations and oscillations in mechanical systems.
- To give instruction and practice in solving physics problem in a wide range of settings.

### LEARNING OUTCOMES:

The student will be able to:

- Apply the laws of classical Newtonian mechanics to describe rectilinear and circular motion.
- Use concepts of kinetic and potential energy and energy conservation to solve dynamical problems.
- Relate basic macroscopic properties of gases to microscopic dynamics.
- Show familiarity with the key concepts needed to describe circular orbits and rigid-body rotation.
- Define what is meant by moments of inertia and be able to calculate moments of inertia in simple situations.
- Recognise examples of Simple Harmonic Motion and apply the general solution to unseen problems.
- Describe the key evidence for the breakdown of the classical description of the properties of matter.
- Recall the postulates of special relativity and the basic equations for length contraction and time dilation and apply them to unseen problems.

### OUTLINE SYLLABUS:

1. **Concepts of Newtonian Mechanics:** Position, momentum (inc. conservation), force, velocity in 1D problems, with simple use of calculus; Newton's laws of motion.
2. **Energy and Potentials:** Conservation of energy, types of energy, friction. Force as gradient of potential.
3. **Mechanics in two and three dimensions:** Use of vectors; momentum, impulse, collisions, scattering. Centre of mass.
4. **Microscopic Mechanics:** Properties of ideal gas; pressure from collisions, very simple treatment of kinetic theory.
5. **Solid Bodies:** Mechanical properties of solids: stress and strain, bulk modulus, Young's modulus. Statics. Solid-body rotation, torques, moment of inertia.
6. **Frames of reference:** Galilean relativity; rotating frames, centrifugal and Coriolis forces.
7. **Orbits:** Central forces, circular motion, centripetal acceleration, Kepler's Laws, brief discussion of scattering.
8. **Vibrations and Oscillations:** Simple harmonic motion; mass on a spring, pendulum, etc. Equations of motion and general solution; application to atomic vibrations etc.
9. **Atomic Structure:** Bohr atom; hydrogen-like atoms, spectra; Rutherford scattering and existence of nucleus. Radioactivity (brief discussion). Fission and fusion.
10. **Particles and waves:** Photoelectric effect; black-body radiation; de Broglie relation; uncertainty principle.
11. **Introduction to Special Relativity:** Postulates, Galilean and Lorentz transformations, 4-vectors, mass-energy equivalence, atomic and nuclear binding energies, etc.

### TRANSFERABLE SKILLS:

Mathematics. Problem solving. Investigative skills. Analytical skills.

### READING LIST:

Principles of Physics (Extended Version), Halliday, Resnick and Walker (Wiley).

## PX1122 MATHEMATICAL METHODS FOR PHYSICISTS I

### MODULE INFORMATION:

- Autumn semester: 10 credits.
- Module organiser: Prof B S Sathyaprakash.
- Deputy Module Organiser: Dr E Pascale.
- Teaching and feedback methods: Lectures 22 x 1 hr, weekly exercise classes, marked exercises.
- Assessment: Examination 60%. Coursework 40%. [Examination duration: 2 hours]
- Pre-cursors: None.
- Co-requisites: None.
- Pre-requisites: None.

### AIMS OF THE MODULE:

- To provide the basic theoretical techniques required during first-year physics courses.
- To introduce post-A-Level students to vectors, matrices, series, functions and graphs, and elementary calculus.
- To give students practice in applying mathematical techniques to abstract and physical problems.

### LEARNING OUTCOMES:

The student will be able to:

- Use vectors to describe positional coordinates and lines and relate them to Cartesian coordinates and show proficiency at basic vector operations and scalar and vector products and their applications. Application of vector algebra to solve simple problems in physics.
- Demonstrate an understanding of how to perform and exploit basic matrix manipulations.
- Show familiarity with and make use of series and expansions of trigonometric, exponential and logarithmic functions.
- Show proficiency in plotting graphs of functions and their derivatives and at differentiation, partial differentiation and integration and their applications.

### OUTLINE SYLLABUS:

1. Vectors. Cartesian vectors. Importance in physics. Position. Force. Acceleration. Velocity, etc.
2. Operations on Vectors. Dot and cross product. Angular momentum.
3. Physical interpretation and examples of vectors.
4. Matrices. Definition and interpretation. Addition and multiplication. Matrices operating on vectors, e.g. rotation in the plane.
5. Inverse of a matrix. Determinants. Use for solving simultaneous equations. Symmetric, anti-symmetric and orthogonal matrices. Eigenvectors and eigenvalues for symmetric matrices.
6. Functions of a real variable. Exponential, trigonometric and hyperbolic functions. Physical examples. Series expansions. Binomial and Taylor series. Approximations using truncated series.
7. Differentiation of powers, logarithms, exponential and trigonometric functions. Product, quotient and chain rules. Implicit and parametric differentiation.
8. Integration of powers, logarithms, exponential and trigonometric functions. Definite and indefinite integrals.
9. Area under a curve. Transforming variables. Integration by parts.
10. Line integrals, multiple integrals, volumes. Curvilinear coordinates, e.g. spherical polar coordinates, introduced through volume elements.
11. Solution of linear first-order ODEs by separation of variables and by integrating factor.

### TRANSFERABLE SKILLS:

Mathematics. Problem solving. Analytical skills.

### READING LIST:

Modern Engineering Mathematics, G James (Addison Wesley).

Mathematical Methods for Physics and Engineering, K F Riley, M P Hobson and S J Bence (Cambridge University Press).

## PX1123 EXPERIMENTAL PHYSICS I

### MODULE INFORMATION:

- Autumn semester: 10 credits.
- Module organiser: Dr C Tucker.
- Deputy Module Organiser: Dr O Williams.
- Teaching and feedback methods: Year 1 laboratory 11 x 4 hr, marked weekly work and one formal report.
- Assessment: Continuous assessment 100%.
- Pre-cursors: None.
- Co-requisites: None.
- Pre-requisites: None.

### AIMS OF THE MODULE:

- To develop practical experimental and analytical skills through weekly structured laboratory sessions.
- To introduce select concepts of optics, scientific instrumentation and electronics.
- To introduce skills relating to the written communication of scientific information.
- Through select experiments to reinforce important physics concepts.

### LEARNING OUTCOMES:

The student will be able to:

- Demonstrate their practical ability by individually managing and conducting a range of experimental tasks in four-hour weekly laboratory sessions.
- Demonstrate awareness of safety issues for example through writing risk assessments.
- Produce a laboratory diary (assessed weekly) in which he/she records their measurements and observations, analyses data and draws conclusions.
- Determine best estimates for true values and random errors from multiple measurements of the same point or data represented by a hand-drawn straight line graph.
- Compare measured and theoretical Gaussian data distributions and extract statistical parameters.
- Determine whether a significant systematic error is present by comparison with known values.
- Write an assessed formal report, in a scientific style, based on one of the experiments conducted during the semester.

### OUTLINE SYLLABUS:

Induction and an introduction to interpreting data.

Experiments (subject to change):

- Young's modulus
- Coefficients of friction
- Variations of resistance with temperature
- The cathode ray oscilloscope and circuit construction
- Optical diffraction
- Computer data logging and RC circuits
- Statistics of experimental data (Gaussian distribution)
- Propagation of sound in gases
- AC to DC conversion using diode circuits
- Microwaves

### TRANSFERABLE SKILLS:

Practical physics. Verbal and written skills. Investigative skills. Computing skills. Analytical skills. Ethical behaviour.

### READING LIST:

Practical Physics, G L Squires, 4th Edition (Cambridge).

Principles of Physics (Extended Version), Halliday, Resnick and Walker (Wiley).

Laboratory manual.

### NOTES:

This module can be offered as a FSM.

It is a **requirement** that this module is passed in order to progress on all PHYSX programmes.

## PX1124 THE UNIVERSE FROM PARTICLES TO GALAXIES

### MODULE INFORMATION:

- Autumn semester: 10 credits.
- Module organiser: Dr P Hargrave.
- Deputy Module Organiser: Dr H L Gomez.
- Teaching and feedback methods: Lectures 22 x 1 hr, marked exercises.
- Assessment: Examination 80%. Coursework 20%. [Examination duration: 2 hours]
- Pre-cursors: None.
- Co-requisites: None.
- Pre-requisites: None.

### AIMS OF THE MODULE:

- To give an overview of the observed structure of stars, galaxies and the Universe.
- To give a simple descriptive account of the basic properties of matter, including nuclear and elementary particles.
- To introduce students to the application of physical and mathematical laws in formulating theories for the origin and evolution of astronomical structures.

### LEARNING OUTCOMES:

The student will be able to:

- Describe key developments in the history of astronomy.
- Explain the principles and design of astronomical telescopes.
- Identify and describe the physical properties of stars (distances, masses, magnitudes, temperatures).
- Describe the elementary structure of stars and stellar evolution and demonstrate basic knowledge of binary stars, supernovae and pulsars.
- Explain the basic structure of galaxies and the basic ideas of elementary cosmology.
- Relate key properties of stars and galaxies to the fundamental properties of matter.
- Demonstrate understanding of the physical make up of the Universe by answering both essay-style questions and solving unseen numerical problems under examination conditions.

### OUTLINE SYLLABUS:

**Introduction to Astronomy:** Historical background. Ancient astronomy. Scientific astronomy: Copernicus, Tycho Brahe, Kepler, Galileo and Newton, including brief discussion of Kepler's laws (circular orbits only).

**Light and telescopes:** The EM spectrum. Black body radiation. Background radiation. Principles of telescope design and instrumentation.

**The Sun and Stars:** The magnitude system. Parallax. Inverse square law for flux and the distance modulus. The luminosity function of stars. The HR diagram.

**Nuclear burning:** Nuclear matter (brief history). Energy production in stars. Main-sequence life.

**Stellar evolution:** The birth of stars and the inter-stellar medium. The life and death of stars. Supernovae, Neutron Stars (Pulsars) and Black holes.

**Our galaxy:** The Milky Way, rotation curves, the local group.

**Distances in the Universe:** Measuring astronomical distances. Hubble's law. Cosmological distances. Galaxies.

**Cosmology:** The creation and fate of the Universe. Simple models of the Universe. Missing mass. Particle physics and dark matter. The twin frontiers of physics.

### TRANSFERABLE SKILLS:

Problem solving. Investigative skills. Mathematics. Analytical skills.

### READING LIST:

Introductory Astronomy and Astrophysics, Zeilik and Gregory (Saunders College Publishing).

Universe, W Kaufmann (Freeman).

### NOTES:

This module can be offered as a FSM. External candidates for this module are advised to have taken A-Level Mathematics.

## PX1125 MATHEMATICAL PRACTICE FOR PHYSICAL SCIENCES

### MODULE INFORMATION:

- Autumn semester: 10 credits.
- Module organiser: Dr R M Smith.
- Deputy Module Organiser: Dr E A Muljarov.
- Teaching and feedback methods: Lectures 11 x 1 hr, examples classes 22 x 1 hr, marked exercises.
- Assessment: Examination 60%. Coursework 40%. [Examination duration: 2 hours]
- Pre-cursors: None.
- Co-requisites: None.
- Pre-requisites: None.

### AIMS OF THE MODULE:

- To provide practice at important elementary mathematical techniques.
- To strengthen and develop manipulative and analytical techniques learnt at AS and A level.
- To apply mathematical skills in the context of physics.

### LEARNING OUTCOMES:

The student will be able to:

- Manipulate, simplify and sketch simple functions.
- Find the derivatives of simple functions.
- Find the indefinite or definite integrals of simple functions.
- Find the general solution or particular solutions of simple differential equations using the techniques of direct integration and separation of variables.
- Perform basic manipulations of vectors and complex numbers.
- Calculate the permutations and combinations for selecting  $r$  from  $n$  objects and understand the distinction between them.
- Write out the Binomial expansion for expressions of the form  $(1 + x)^n$ .
- Recognise and be able to find the sum of arithmetic and geometric progressions.

### OUTLINE SYLLABUS:

Weekly worksheets

- Algebra
- Logarithms and exponentials
- Differentiation I
- Differentiation II
- Integration I
- Integration II
- Differential equations
- Determinants and vectors
- Complex numbers
- Permutations and combinations, binomial and other series

### TRANSFERABLE SKILLS:

Problem solving. Mathematics. Analytical skills.

### READING LIST:

Modern Engineering Mathematics, G James (Addison-Wesley Publishing).

Mathematical Methods for Physics and Engineering, K F Riley, M P Hobson and S J Bence (Cambridge University Press).

Less advanced books of use in support of this module:

Maths: A Students' Survival Guide, J Olive (Cambridge University Press).

Core Maths for A-Level, L Bostock and S Candler (Stanley Thornes Publishers).

Engineering Mathematics, K A Stroud (Palgrave).

## PX1221 ELECTRICITY, MAGNETISM AND WAVES

### MODULE INFORMATION:

- Spring semester: 20 credits.
- Module organiser: Dr J I Davies.
- Deputy Module Organiser: Prof P Coles.
- Teaching methods: 44 contact hours including lectures, weekly exercises and problem-solving sessions. Feedback: weekly marked exercises and tutorials.
- Assessment: Examination 60%. Coursework 40%. [Examination duration: 3 hours]
- Pre-cursors: PX1122 (excepting joint Maths/Physics students).
- Co-requisites: PX1222 (excepting joint Maths/Physics students).
- Pre-requisites: None.

### AIMS OF THE MODULE:

- To introduce the mathematical language of waves to describe wave formation, wave propagation and interference and diffraction.
- To examine matter at an atomic level to give insight into crystal bonding and the electrical, thermal and mechanical properties of matter.
- To introduce concepts of electrostatics, of magnetic fields associated with currents and of electromagnetic induction to provide a firm foundation for the study of electromagnetism in Year 2.
- To provide insight into forced vibration and resonance through examples of AC theory and mechanical analogues.
- To give instruction and practice in solving physics problem.

### LEARNING OUTCOMES:

The student will be able to:

- Distinguish between different wave types and describe wave and energy propagation mathematically in one or more dimensions.
- Apply boundary conditions to wave equations to determine the formation of standing waves in strings and pipes and explain refraction.
- Demonstrate an understanding of interference and diffraction, including crystal diffraction.
- Describe the distinguishing features between conductors, insulators and semiconductors.
- Discuss phase changes in matter.
- Describe the origin and nature of the various forces and fields associated with static and moving charges.
- Recall the basic laws of electromagnetism and use integration methods to apply Coulomb's law and the Biot-Savart law to complex systems of charges or circuits.
- Derive basic equations for free and forced oscillations of damped electrical and mechanical systems using both real and complex notation.

### OUTLINE SYLLABUS:

1. **Waves:** Classification of waves. One-dimensional non-dispersive waves. D'Alembert's solution. Harmonic waves. Derivation of the wave equation for transverse waves on a string. Energy density and power flow in a travelling wave.
2. **Refraction and dispersion:** Plane waves at boundaries. Refraction and Snell's laws. Refracting optics. Dispersion.
3. **Superposition:** Beats. Longitudinal waves in solids and sound waves. Sound intensity. Spherical waves and the inverse square law. Standing waves. Interference and diffraction. Examples.
4. **Waves and matter:** Light interaction with matter and elementary spectroscopy (Bohr theory). Diffraction studies of solids, leading to atoms, bonding and crystal structure.
5. **Electronic properties of matter:** Electrical properties of materials – conductors, insulators and semiconductors. Free electrons, energy bands and band gaps. Semiconductor doping and the p-n junction.
6. **Coulomb's and Gauss's Laws:** Electric charge and Coulomb's law.  $E$  and  $V$  fields. Field lines and forces. Electric flux. Gauss' law. Examples of charge distributions, including sphere and line.
7. **Capacitance:** Electric potential, potential difference, relationship between  $E$  and  $V$ . Electric energy and energy density. Capacitance. Dielectrics. Energy stored on a capacitor. Capacitance of sphere and coaxial cable.
8. **Electricity and magnetism:** Conductivity, resistivity and resistance. Electrical power. Magnetic effects of current-carrying wires. Magnetic field lines, flux and Lorentz force. Biot-Savart law and applications. Torque on a current loop.
9. **Electromagnetic induction:** Faraday's law and electromagnetic induction. Mutual and self inductance. Inductors.
10. **AC Theory:** Circuit elements:  $R$ ,  $C$  and  $L$ . RMS. Power factors. LCR circuits. Rotating vector and complex-exponential representation. Phasor diagrams.
11. **Resonance:** Damped free vibrations. Light, heavy and critical damping. Quality factor. Forced vibration. Response functions: displacement amplitude and phase as a function of frequency. Absorbed power. Steady-state and transient solutions. Electrical and mechanical analogues.

### TRANSFERABLE SKILLS:

Mathematics. Problem solving. Investigative skills. Analytical skills.

**READING LIST:**

Principles of Physics (Extended Version), Halliday, Resnick and Walker (Wiley).

## PX1222 MATHEMATICAL METHODS FOR PHYSICISTS II

### MODULE INFORMATION:

- Spring semester: 10 credits.
- Module organiser: Dr E Pascale.
- Deputy Module Organiser: Prof B S Sathyaprakash.
- Teaching and feedback methods: Lectures 22 x 1 hr, weekly exercise classes, marked exercises.
- Assessment: Examination 60%. Coursework 40%. [Examination duration: 2 hours]
- Pre-cursors: PX1122 (excepting joint Maths/Physics students).
- Co-requisites: None.
- Pre-requisites: None.

### AIMS OF THE MODULE:

- To provide the basic theoretical techniques required during first-year physics courses.
- To give post-A-Level students a solid grounding in complex numbers, vector calculus, second-order differential equations, matrices and basic probability theory.
- To give students practice in applying mathematical techniques to abstract and physical problems.

### LEARNING OUTCOMES:

The student will be able to:

- Demonstrate proficiency at basic representations, operations and applications of complex numbers.
- Demonstrate an understanding of the meaning of scalar and vector fields, and demonstrate the application of grad, div, curl, Laplacian to the formulation of the laws of physics.
- Set up and solve simple first-order differential equations.
- Show proficiency in using techniques for solving first- and second-order differential equations.
- Show familiarity with basic probability distributions, statistical measures and their use.

### OUTLINE SYLLABUS:

1. Argand diagrams. Polar and Euler representations. De Moivre's theorem. Complex functions. Physical applications of complex numbers. Relationship to 2D vectors and matrices.
2. Differentiation of a vector. Gradient vector. Conservative and non-conservative fields. Examples from physics. Differentiation of a function of more than one variable.
3. Partial differentiation. Idea of div, grad and curl (briefly). Stationary values, maxima and minima. Conditional stationary values.
4. Ordinary differential equations in physics. Setting up physical problems. General classification of ODEs. Superposition theorems. Boundary conditions
5. Second-order linear homogeneous equations. Examples.
6. Second-order linear inhomogeneous equations. Particular integrals and complementary functions. Trial solutions. Simple harmonic examples, use of  $\exp(i\omega t)$ .
7. Introduction to Fourier series.
8. Partial differential equations in physics. Examples (brief): Wave equation, heat equation, diffusion, Schrodinger equation.
9. Separation of variables method of solving PDE.
10. Probability Axioms. Discrete Events. Probability Distributions. Binomial and Poisson distributions.
11. Normal distribution, random walks and diffusion. Means and variances. Relevance to statistical treatment of errors.

### TRANSFERABLE SKILLS:

Problem solving. Investigative skills. Mathematics. Analytical skills.

### READING LIST:

Modern Engineering Mathematics, G James (Addison Wesley).

Mathematical Methods for Physics and Engineering, K F Riley, M P Hobson and S J Bence (Cambridge University Press).

## PX1223 EXPERIMENTAL PHYSICS II

### MODULE INFORMATION:

- Spring semester: 10 credits.
- Module organiser: Dr C Tucker.
- Deputy Module Organiser: Dr O Williams.
- Teaching and feedback methods: Year 1 laboratory 11 x 4 hr, marked weekly work and one formal report.
- Assessment: Continuous assessment 100%.
- Pre-cursors: PX1123.
- Co-requisites: None.
- Pre-requisites: None.

### AIMS OF THE MODULE:

- To develop practical experimental and analytical skills through weekly structured laboratory sessions.
- To introduce select concepts of optics, scientific instrumentation and electronics.
- To introduce skills relating to the written communication of scientific information.
- Through select experiments to reinforce important physics concepts.

### LEARNING OUTCOMES:

The student will be able to:

- Demonstrate their practical ability by individually managing and conducting a range of experimental tasks in four-hour weekly laboratory sessions.
- Demonstrate awareness of safety issues for example through writing risk assessments.
- Produce a laboratory diary (assessed weekly) in which he/she records their measurements and observations, analyses data and draws conclusions.
- Use a computer program to determine best estimates for true values and random errors from data represented by a straight line graph.
- Compare measurements from counting experiments with theoretical Poisson distributions data distributions and extract statistical parameters.
- Determine whether a significant systematic error is present by comparison with known values.
- Write an assessed formal report, in a scientific style, based on one of the experiments conducted during the semester.

### OUTLINE SYLLABUS:

Experiments (subject to change):

- Measurement of  $e/m$
- Planck's constant
- A-C Circuits
- Radioactive decay with Poisson Theory
- X-rays
- Lens systems and Telescopes
- Bragg X-ray Studies of Solids
- Vibrations and resonance (in electrical circuits)
- Hubble Constant
- Current Balance

### TRANSFERABLE SKILLS:

Practical physics. Verbal and written skills. Investigative skills. Computing skills. Analytical skills. Ethical behaviour.

### READING LIST:

Practical Physics, G L Squires, 4th Edition (Cambridge).

Principles of Physics (Extended Version), Halliday, Resnick and Walker (Wiley).

## PX1224 COMPUTATIONAL SKILLS FOR PROBLEM SOLVING

### MODULE INFORMATION:

- Autumn semester, 10 credits.
- Module organiser: Dr S Fairhurst.
- Deputy Module Organiser: Dr W F Grainger.
- Teaching and feedback methods: Computing laboratory 11 x 2 hr. Marked exercises and assignments.
- Assessment: Continuous assessment 100%.
- Pre-cursors: PX1121.
- Co-requisites: PX1221.
- Pre-requisites: None.

### AIMS OF THE MODULE:

- To give instruction on and provide practice in the use of computers to develop basic data handling skills required by physical scientists (e.g. graphing and data analysis skills).
- To develop the basic numerical computing skills required by physical scientists.
- To develop proficiency in problem solving by working through a series of examples which relate to the experimental and taught physics modules.

### LEARNING OUTCOMES:

The student will be able to:

- Enter or read in data from files (in standard formats); plot and export graphs suitable for inclusion in a report.
- Perform statistical analysis of data of the form  $y = mx + c$ ; best fit and error determinations.
- Use and manipulate simple mathematical functions in Python.
- Express mathematical integration and differentiation problems such that they may be solved numerically.
- Use numerical techniques with Python to solve a number of mathematical and physical problems.

### OUTLINE SYLLABUS:

**Introduction:** Data analysis and numerical techniques via computing with Python.

**Graphing skills:** Reading in and entering  $x$ - $y$  data, data plotting, fitting with straight line (including error determination).

**Random numbers:** Generation. Application to the generation of distributions (including plotting histograms).

**Using mathematical functions:** Use of basic mathematical functions (sine, exp etc.); introduction to more advanced functions.

**Simple numerical integration and differentiation:** Numerical techniques and the importance of step size. These will be practiced (and tested) mainly by application to basic mathematical functions.

**Application of Numerical Methods:** Approaches to solving physics problems, e.g. modelling the simple pendulum, projectile motion through a viscous medium, analysing real experimental data.

### TRANSFERABLE SKILLS:

Problem solving. Mathematics. Analytical skills. Computational skills.

### READING LIST:

Principles of Physics (Extended Version), Halliday, Resnick and Walker (Wiley).

## PX1225 PLANETS AND EXOPLANETS

### MODULE INFORMATION:

- Spring semester: 10 credits.
- Module organiser: Prof D Ward-Thompson.
- Deputy Module Organiser: Prof S A Eales.
- Teaching and feedback methods: Lectures 22 x 1 hr, marked exercises.
- Assessment: Examination 80%. Coursework 20%. [Examination duration: 2 hours]
- Pre-cursors: None.
- Co-requisites: None.
- Pre-requisites: None.

### AIMS OF THE MODULE:

- To introduce the basic constituents of the solar system, their orbits and physical properties.
- To describe the physical properties of planetary surfaces and atmospheres.
- To interpret these properties in terms of physical theory.
- To introduce the various observational methods of proto-planet and exoplanet detection.
- To introduce the basic ideas behind the current theories of planet formation and how they are related to observed properties of the Solar System and extra-solar planets.

### LEARNING OUTCOMES:

The student will be able to:

- Use the principle of hydrostatic equilibrium to model the internal structures and shapes of planets.
- Describe the properties of planetary systems in terms of basic physical concepts, such as tidal forces.
- Evaluate and discuss the observational arguments in favour of the standard model for the formation of planetary systems.
- Demonstrate their understanding of planetary systems by answering both essay-style questions and solving unseen numerical problems under examination conditions

### OUTLINE SYLLABUS:

**The Solar System:** Kepler's laws of planetary motion. Elliptical orbits. Applications to planets, moons and comets. Structure, age and composition of objects in the Solar System. A basic model for the formation of the Solar System. Existence of Lagrange points. Space travel; transfer orbits.

**Planetary Structure and Surfaces:** Atmospheres. Hydrostatic equilibrium. Plane-parallel atmosphere. Tides and tidal forces. Roche limit. Ring systems. Comparative planetology. Terrestrial planets and gas giants. The structures of planets from satellite orbits and precession, seismic waves and plate tectonics.

**Comets and Asteroids:** The properties of comets. The Oort cloud. The Kuiper belt. Plutinos. Evidence for impacts and the extinction of the dinosaurs. Near-Earth objects.

**Extra-solar Planets:** Detection methods. Properties of exoplanets. The habitable zone. Protoplanetary systems and theories of planet formation. The Drake equation.

### TRANSFERABLE SKILLS:

Problem solving. Investigative skills. Mathematics. Analytical skills.

### READING LIST:

Origins: How the Planets, Stars, Galaxies, and the Universe Began, S A Eales (Springer).

### NOTES:

This module can be offered as a FSM.

## PX1226 HOW THE HUMAN BODY WORKS

### MODULE INFORMATION:

- Spring semester: 10 credits.
- Module organiser: Dr N D Pugh.
- Deputy Module Organiser: Dr R J Morris.
- Teaching and feedback methods: Lectures 22 x 1 hr, exercises.
- Assessment: Examination 80%. Coursework 20%. [Examination duration: 2 hours]
- Pre-cursors: None.
- Co-requisites: None.
- Pre-requisites: None.

### AIMS OF THE MODULE:

- To provide to students of physics an introduction to human anatomy and physiology.
- To give an overview of the construction and function of cells, and the structure and operation of the musculoskeletal, nervous, cardiovascular, digestive and reproductive systems.
- To give a working knowledge of genetics and the basis of inheritance, infection and disease control.

### LEARNING OUTCOMES:

The student will be able to:

- Describe the structure and function of cells and processes such as osmosis, diffusion and active transport.
- Explain the concepts and mechanisms of inheritance.
- Outline the structure and role of the musculoskeletal system.
- Identify key features and mechanisms of nerve cells, the nervous system and sensory perception.
- Describe the role of the cardiovascular system, the composition and transport of blood, and the functions of respiration.
- Explain the functions of the digestive and renal systems.
- Describe the human reproductive system, including the hormonal controls of ovarian and male reproductive function.

### OUTLINE SYLLABUS:

**Cells:** Cell structure and function, DNA, proteins, carbohydrates. Cell membrane, osmosis, diffusion, active transport. Genetics, mitosis, meiosis. Inheritance, monohybrid inheritance, co-dominance, sex determination, sex linkage.

**Musculoskeletal System:** Bone and skeletal system. Types of bone, joints. Muscles, types of muscle, mechanics of muscle contraction and joint movement.

**Nervous and Control Systems:** Nerve cell, neuromuscular transmission, central nervous system, peripheral nervous system, sensory functions, motor functions. Endocrine system.

**Cardiovascular system:** Blood and constituents, blood groups, heart structure and function, blood pressure, blood vessels, lymphatics and lymph, diseases of cardiovascular system. Structure of respiratory system, respiration, functions of respiration, transport of oxygen and carbon dioxide, oxygen dissociation curve, maintenance of blood pH.

**Urinary system:** Kidney structure and function, water balance regulation.

**Digestive system:** Structure, food and nutrition, energy balance, homeostasis.

**Reproductive system:** Anatomy of the male reproductive system, spermatogenesis, hormonal control of male reproductive functions. Anatomy of the female reproductive system, ovarian function, control of ovarian function.

### TRANSFERABLE SKILLS:

Problem solving. Investigative skills. Mathematics. Analytical skills.

### READING LIST:

Any general anatomy and physiology textbook.

### NOTES:

This module can be offered as a FSM.

## PX2101 QUANTUM MECHANICS

### MODULE INFORMATION:

- Autumn semester: 10 credits.
- Module organiser: Dr B E Richardson.
- Deputy Module Organiser: Dr H L Gomez.
- Teaching and feedback methods: Lectures 22 x 1 hr, 10 x 1 hr Exercise classes, self-assessed Exercises.
- Assessment: Examination 100%. [Examination duration: 2 hours]
- Pre-cursors: PX1112, PX1116, PX1216 and PX1220.
- Co-requisites: PX2104.
- Pre-requisites: None.

### AIMS OF THE MODULE:

- To provide a description of matter and radiation by wave mechanics, in particular through the Schrödinger equation and the interpretation and use of its solutions.
- To introduce formal aspects of wave mechanics, and to provide worked examples to increase awareness of the meaning of wavefunctions, eigenvalues, eigenfunctions and operators.
- To apply quantum mechanics to a range of model systems.

### LEARNING OUTCOMES:

The student will be able to:

- Recall and use basic quantum-mechanical definitions, such as Schrödinger's time-independent and time-dependent wave equations, expectation values, energy and momentum operators.
- Derive, from first principles, normalised energy eigenfunctions and eigenvalues in 1-D potentials.
- Describe scattering from step potentials and explain the principles of quantum-mechanical tunnelling.
- Show an appreciation of the time development of quantum states and uncertainty.
- Solve problems relating to the quantum states of the hydrogen atom, showing some understanding of angular momentum.

### OUTLINE SYLLABUS:

Quantum Concepts: Planck's black body radiation theory. Wave-particle duality - photons and matter waves. The Rutherford-Bohr atom and quantisation of energy.

Introductory Wave Mechanics: Schrödinger's equation and its physical interpretation. Wave functions. Probability density. Normalisation. Expectation values. Operators. Schrödinger's time-independent wave equation. Energy eigenvalues and eigenfunctions.

1-D Potential Wells: The infinite square well. Energy-level diagrams. The finite square well (including graphical solution methods). The harmonic oscillator potential. Finite polynomials and Hermite's equation. Physical relevance of the solutions. (This section is completed on a work-sheet in the PC Laboratory.)

Scattering Potentials: Probability flux density. Step potentials and barrier potentials. Reflection and transmission coefficient. Tunnelling. The scanning tunnelling microscope.

Free Particles and the time development of quantum states: Uncertainty revisited. Wave groups. Wave function superposition. Wave function collapse and measurements. Compatibility of operators.

2-D and 3-D Systems: Operators and wave equations in 3-D. Symmetry and separation of variables. Worked example: particle in a 2-D box. Energy levels and degeneracy.

The Hydrogen Atom: Radial solutions (Laguerre's equation). Radial probability densities. H-atom energy levels. Separation of variables. The four quantum numbers. "Centrifugal barrier". Spherical harmonics. Angular momentum. Space quantisation. Full solution to the H-atom and its physical significance.

### TRANSFERABLE SKILLS:

Mathematics. Problem solving. Investigative skills. Analytical skills.

### READING LIST:

Introduction to Quantum Mechanics, A C Phillips (Wiley).

Introductory Quantum Mechanics, R C Greenhow (Adam Hilger). Now out of print, but copies in the library.

Concepts of Modern Physics, 5th Edn., A Beiser (McGraw-Hill).

## PX2104 THEORETICAL PHYSICS

### MODULE INFORMATION:

- Autumn semester: 10 credits.
- Module organiser: Prof S A Eales.
- Deputy Module Organiser: Prof A P Whitworth.
- Teaching and feedback methods: Lectures 22 x 1 hr, fortnightly Exercise classes, marked Exercises.
- Assessment: Examination 80%. Coursework 20%. [Examination duration: 2 hours]
- Pre-cursors: PX1116 and PX1216.
- Co-requisites: None.
- Pre-requisites: None.

### AIMS OF THE MODULE:

- To provide the background mathematical techniques needed by physicists.
- To provide practice in applying these techniques to physical problems.

### LEARNING OUTCOMES:

The student will be able to:

- Show proficiency in the use of vector algebra and vector calculus and their applications to scalar and vector fields.
- Perform multiple integrals of scalar fields, and line and surface integrals of vector fields.
- Show familiarity with the scalar and vector fields of physics and their associated partial differential equations.
- Set up and solve various second-order partial differential equations using separation of variables.
- Apply Fourier series and Fourier transforms to physical problems.
- Solve unseen problems using the methods developed in this course.

### OUTLINE SYLLABUS:

Vector calculus: Review of vector algebra. Index notation. Review of Taylor's theorem and partial differentiation. Scalar and vector fields. Multiple integrals. Line and surface integrals. Directional derivative and gradient of a scalar field. Divergence and Gauss' theorem. Curl and Stokes' theorem. Conservative forces. Del operator, Laplacian, meaning of del-squared. Orthogonal curvilinear coordinates.

Partial differential equations of physics: Continuity and diffusion equation. Laplace, Poisson and wave equations. Navier-Stokes equation. Maxwell's equations. Separation of variables and power-series solutions.

Fourier series and transforms: Fourier theorem. 1-D wave equation for a string. Fourier series in trigonometric and complex form. Orthogonality of sines and cosines. Non-periodic functions and Fourier transforms. Fourier transforms in time and frequency and in position and momentum. Applications of Fourier series and transforms to physics.

### TRANSFERABLE SKILLS:

Mathematics. Problem solving. Investigative skills. Computing skills. Analytical skills.

### READING LIST:

Mathematical Methods for Physics and Engineering, 2<sup>nd</sup> Edition, K F Riley, M P Hobson and S J Bence (Cambridge University Press).

## PX2107 ELECTRONICS AND INSTRUMENTATION

### MODULE INFORMATION:

- Autumn semester: 10 credits.
- Module organiser: Prof P M Smowton.
- Deputy Module Organiser: Prof M J Griffin.
- Teaching and feedback methods: Lectures, demonstrations and exercises 22 x 1 hr, marked Exercises.
- Assessment: Examination 80%. Coursework 20%. [Examination duration: 2 hours]
- Pre-cursors: PX1112, PX1117, PX1219 and PX1220.
- Co-requisites: None.
- Pre-requisites: None.

### AIMS OF THE MODULE:

- To provide an introduction to analogue and digital electronics.
- To provide some practical experience of electronic instrumentation and its use for measurement.
- To give an appreciation of detecting signals in the presence of noise.

### LEARNING OUTCOMES:

The student will be able to:

- Explain the basic properties of semiconductors, the importance of doping and the operating principles of the p-n junction.
- Recall the properties of an ideal operational amplifier and demonstrate how feedback can be used to produce a range of useful circuits, including amplifiers, oscillators, integrators and current-to-voltage converters.
- Describe the theory and practice of analogue-to-digital conversion.
- Identify the origins of noise in electronic systems and describe schemes for extracting signals from noise, including phase-sensitive detection.

### OUTLINE SYLLABUS:

LCR components: Passive Filters.

Diodes and their applications: p-n junction, transport through p-n junction. Rectifiers. Filters. Regulation. Simple dc power supply. Diode clamp. Transistors: Bipolar transistors and their operation. Field effect transistors.

Operational Amplifiers: Ideal amplifiers. Feedback and its benefits in amplifiers. Examples of applications: Inverting amplifier, Integrator, Differentiation, Voltage follower, Non-inverting amplifier, Summing amplifier, Comparator, Stable voltage source, Stable current source, Current-to-voltage converter. Non-ideality of operational amplifiers. Wien bridge oscillator.

Transducers: The diode as a light detector. Equivalent circuits. The avalanche photodiode photomultipliers image intensifiers CCD arrays.

Analogue and Digital signals: A simple logic gate. Analogue-to-digital and digital-to-analogue conversion. Impedance matching and power transfer.

Origins and kinds of noise: Interference. Extracting signals from noise - filtering, signal averaging, phase sensitive detection and boxcar detection. Radiofrequency communications - AM and FM modulation. Fourier series representation of complex waveforms.

### TRANSFERABLE SKILLS:

Problem solving. Experimental physics. Investigative skills. Mathematics. Analytical skills.

### READING LIST:

Principles of Electronic Instrumentation, A J Diefenderfer.

Basic Electronics for Scientists, J J Brophy.

The Art of Electronics, Horowitz and Hill.

Operational Amplifiers and Linear Integrated Circuits, Coughlin and Driscoll.

## PX2108 TOPICS IN PHYSICS

### MODULE INFORMATION:

- Autumn semester: 10 credits.
- Module organiser: Dr M Elliott.
- Deputy Module Organiser: Prof P M Smowton.
- Teaching and feedback methods: Lectures 6 x 1 hr, group work 12 hrs, skill sessions 4 hrs, written reports and oral presentations (marked).
- Assessment: Examination 50%, coursework 50%. [Examination duration: 1.5 hours]
- Pre-cursors: PX1112, PX1214, PX1219 and PX1220.
- Co-requisites: None.
- Pre-requisites: None.

### AIMS OF THE MODULE:

- To help stimulate active participation in discovering topics at the forefront of current understanding and in other topics not otherwise encountered.
- To develop group-work skills.
- To develop skills in communicating science, both in writing and speaking.
- To develop "real-life" problem-solving skills.

### LEARNING OUTCOMES:

The student will be able to:

- Use the library and other resources (e.g. the Web) to study, independently, selected topics in considerable depth.
- Apply physics and physical reasoning in novel situations.
- Work as part of a team to research, plan and present two oral presentations and written presentations.
- Undertake private study in selected topics in physics in preparation to answer both essay-style and numerically-based questions in an examination.

### OUTLINE SYLLABUS:

There is no set syllabus for the subject matter in this module, but students are normally introduced to five topics in contemporary physics. The current lecturer will provide some recommended reading and work sheets to accompany each topic.

### TRANSFERABLE SKILLS:

Communications skills. Investigative skills. Personal skills. Problem solving. Computing skills. Analytical skills.

### READING LIST:

Directed reading by the current topic lecturer.

## PX2109 TOPICS IN ASTRONOMY

### MODULE INFORMATION:

- Autumn semester: 10 credits.
- Module organiser: Dr A Cartwright.
- Deputy Module Organiser: Dr S Fairhurst.
- Teaching and feedback methods: Lectures, group work, skill sessions, written reports and oral presentations (marked).
- Assessment: Examination 50%, coursework 50%. [Examination duration: 1.5 hour]
- Pre-cursors: PX1112, PX1214, PX1219 and PX1220.
- Co-requisites: None.
- Pre-requisites: None.

### AIMS OF THE MODULE:

- To stimulate interest in astronomy and astrophysics at the frontiers.
- To encourage group work and active participation in discovering the excitement of working at the forefront of astronomy and astrophysics.
- To develop skills in communicating science and in problem solving.

### LEARNING OUTCOMES:

The student will be able to:

- Use library and IT facilities to study selected topics in considerable depth.
- Demonstrate an ability to apply physics and physical reasoning in novel situations.
- Research into, and write up an essay on a specialised area of astronomy.
- Work as part of a team to research, plan and present oral research reports to their peers.
- Undertake private study in selected topics in astronomy and astrophysics in preparation to answer both essay-style and numerically-based questions in an examination.

### OUTLINE SYLLABUS:

Each year five different astronomy researchers give a lecture on their work. The class is split into teams which are then assigned a topic set by one of the lecturers, which forms the basis of an in-depth investigation. The results of the studies are presented to the whole class, both orally and as a written report. All students must also answer questions in an examination which will be based on *all* material covered in lectures. Students will also be required to write an individual piece of work on a topic set by the module organiser. There will also be one set of problems to be completed by students working in their teams.

Example topics: galaxies; gravitational waves; star formation; gravitational lensing; comets.

### TRANSFERABLE SKILLS:

Communications skills. Investigative skills. Personal skills. Problem solving. Computing skills. Analytical skills.

### READING LIST:

Directed reading by the current topic lecturer.

## PX2114 PRACTICAL PHYSICS A

### MODULE INFORMATION:

- Autumn semester: 10 credits.
- Module organiser: Dr D I Westwood.
- Deputy Module Organiser: Dr A Cartwright.
- Teaching and feedback methods: Laboratories 11 x 4 hrs. Marked diaries and reports.
- Assessment: Coursework 100%.
- Pre-cursors: PX1117, PX1217.
- Co-requisites: None.
- Pre-requisites: None.

### AIMS OF THE MODULE:

- To extend practical skills by using set experiments illustrating a range of physical phenomena.
- To increase awareness of the design of experiments.
- To develop critical thinking about experimental technique and the treatment of errors.
- To develop awareness of safety issues and provide experience in risk assessment.
- To provide experience of performing (short) open ended projects.
- To develop written presentation skills.
- To provide the necessary skills to undertake a third or fourth-year practical physics project.

### LEARNING OUTCOMES:

The student will be able to:

- Keep an accurate and detailed record of their experimental procedures and data, including a risk assessment.
- Critically analyse data sets to extract relevant physical quantities (with estimated errors) and (possible) meaning.
- Decide on the course of experiments based on initial or earlier findings.
- Present self-contained reports of experiments they have performed.

### OUTLINE SYLLABUS:

Experiments:

- Magnetic hysteresis
- X-ray absorption
- X-ray fluorescence
- Electron spin resonance
- Nuclear magnetic resonance
- The Normal Zeeman effect
- Absorption spectrum of Iodine
- Transmission line
- Helmholtz pairs: uniform magnetic fields
- Magnetic hysteresis and magnetic circuits
- Vapour pressure of nitrogen
- Ratio of specific heat capacities
- Band gap of a semiconductor
- Measurement of G
- Normal modes in an acoustic resonant chamber
- Precession of a Gyroscope
- Torsion pendulum
- Vibrations of a classical guitar
- Refraction and dispersion in transparent solids
- Optical reflection (and Fresnel's equations)
- Airy's disc

### TRANSFERABLE SKILLS:

Experimental Physics. Communications skills. Personal skills. Investigative skills. Computing skills. Analytical skills. Ethical behaviour.

### READING LIST:

Practical Physics, G L Squires (Cambridge).

## PX2116 COMPUTING IN PHYSICS

### MODULE INFORMATION:

- Autumn semester: 10 credits.
- Module organiser: Dr R Philp.
- Deputy Module Organiser: Dr E Pascale.
- Teaching and feedback methods: Lectures 22 x 1 hr, Computing laboratory 11 x 3 hrs, marked worksheets.
- Assessment: Examination 50%. Course work 50%. [Examination duration: 2 hours]
- Pre-cursors: PX1111.
- Co-requisites: None.
- Pre-requisites: None.

### AIMS OF THE MODULE:

- To give a formal introduction to the structure of the computing language C++.
- To introduce computational and analytic methods commonly encountered in science.
- To undertake structured examples and assignments of in the computing laboratory to develop skills in computational physics.

### LEARNING OUTCOMES:

The student will be able to:

- Demonstrate an ability to write structured C++ computer code.
- Write working computer programs which handle input and output.
- Implement simple numerical methods which have particular relevance to Physics, such as finite difference schemes and Monte Carlo methods.
- Analyse a physical problem, develop suitable algorithms, model the problem and interpret the results of the numerical calculations.

### OUTLINE SYLLABUS:

C++: The formal structure of C++ to an advanced level. Variable types, naming conventions, variable storage, arithmetic operators, precedence rules, assignment operator, control statements, iteration, loop and control statement nesting.

Input and output and storage: Basic I/O. Binary and text file handling, advancing and non-advancing I/O, arrays, multi-dimensional arrays, dynamic memory, variable and array scope, array subscripting.

Program structure: Conformal operators, internal and external procedures, subroutines and functions, dummy and actual arguments, interface blocks, modules, program structure, global data, access rights to data, inheritance, intrinsic functions, derived types, polymorphism, recursion and a philosophy of programming style.

Numerical differentiation: Errors of numerical differentiation, rounding and truncation error. Taylor's theorem in error analysis.

Root finding: Method of bisection and Newton-Raphson method.

Numerical quadrature: The rectangle, trapezium and Simpson rules. Algorithmic optimisation.

Numerical integration of ordinary differential equations: Euler, mid-point and Runge-Kutta methods.

Random number and generators: Monte-Carlo methods, random walking.

Fourier trans forms

Correlation functions

### TRANSFERABLE SKILLS:

Computing skills. Mathematics. Problem solving. Analytical skills.

### READING LIST:

Computational Methods in Physics, Chemistry and Biology: An introduction. Paul Harison. John Wiley & Sons.

## PX2124 ELECTRICITY IN THE HUMAN BODY

### MODULE INFORMATION:

- Autumn semester: 10 credits.
- Module organiser: Dr N D Pugh.
- Deputy Module Organiser: Dr R J Morris.
- Teaching and feedback methods: Lectures and laboratory practical 11 x 2 hr. Marked experimental work.
- Assessment: Examination 50%. Laboratory 50%. [Examination duration: 1 hour]
- Pre-cursors: PX1116 and PX1216.
- Co-requisites: PX2107.
- Pre-requisites: None.

### AIMS OF THE MODULE:

- To initiate a study of electrical phenomena in the human body.
- To provide an appreciation of the body's natural electricity and its monitoring for diagnosis and therapy.
- To provide a working knowledge of electrical techniques in medicine.

### LEARNING OUTCOMES:

The student will be able to:

- Describe the electrical properties of cells.
- Describe how nerve and muscle impulses are generated and propagated.
- Describe the basic features of the electrocardiogram, electromyogram, electroencephalogram and how they are recorded.
- Explain the basic circuit features of an amplifier for bioelectric measurement and construct and test such an amplifier.
- Discuss the different types of electrodes used for recording bioelectric signals.
- Describe the function of different types electrical equipment used in medicine.
- Compare the physiological effects caused by an electrical current imposed on the body.
- Understand the principles of safety of biomedical equipment.

### OUTLINE SYLLABUS:

Cells: The cell as a generator of electricity, membrane potentials and conduction, sodium potassium pump, graded and action potentials and their propagation.

Neuromuscular Transmission: The nervous system, neural communication, muscle action potentials and contraction.

Electricity and the Heart: Cardiac muscle and contraction, the origin of cardiac signals, the cardiac cycle.

Monitoring of Electrical Signals: Electrodes and electrode design, measurement of electrical signals in the body (ECG, EEG, EMG), signal analysis, electrical noise.

Instrumentation: Amplifier design and construction, isolation, types of monitoring systems in current usage.

Clinical Devices: Cardiac pacemakers, defibrillators, diathermy, impedance measurements.

Physiological Effects: Electrolysis, bulk heating, nerve stimulation, electric shock.

Safety: Leakage currents, classes of equipment, basic safety testing & regulations.

### TRANSFERABLE SKILLS:

Problem solving. Investigative skills. Mathematics. Analytical skills.

### READING LIST:

Medical Physic and Physiological Measurement, B H Brown and R H Smallwood (Blackwell) (out of print but copies in the library).

## PX2203 THERMAL PHYSICS

### MODULE INFORMATION:

- Spring semester: 10 credits.
- Module organiser: Dr M Elliott.
- Deputy Module Organiser: Dr E A Muljarov.
- Teaching and feedback methods: Lectures 22 x 1 hr, Exercises, marked Exercises.
- Assessment: Examination 100%. [Examination duration: 2 hours]
- Pre-cursors: PX1112, PX1116 and PX1216.
- Co-requisites: None.
- Pre-requisites: None.

### AIMS OF THE MODULE:

- To provide an understanding of the laws and concepts of thermodynamics and their applications.
- To introduce the kinetic theory of gases.
- To introduce the quantum mechanics of radiation and develop the theory of black-body radiation.

### LEARNING OUTCOMES:

The student will be able to:

- Describe the basis and importance of the first and second laws of thermodynamics.
- Discuss the concept of entropy and identify its physical consequences.
- Apply the laws of thermodynamics to simple physical systems.
- Apply the kinetic theory to solve problems involving gases.
- Demonstrate an understanding of the quantum mechanics of radiation and the origin of the black-body radiation spectrum.

### OUTLINE SYLLABUS:

Basis of thermodynamics: Conceptual basis, microscopic and macroscopic theory. Zeroth law and definitions. First and second law and their applications. Concept of entropy. Thermodynamic potentials: H, F, G. Heat capacity and calorimetry. Third law of thermodynamics. Irreversible processes.

Equations of state: Equations of state of ideal and real gases. Phase changes. Liquefaction of gases.

Kinetic theory of gases: Introduction to kinetic theory and its applications.

Black-body radiation: Thermodynamics of radiation. Quantum theory of radiation and quantisation of light. Black-body radiation and its spectrum. Fluctuations.

Thermodynamics and modern physics: The arrow of time.

Selected applications: Black holes and stars.

### TRANSFERABLE SKILLS:

Mathematics. Problem solving. Investigative skills. Analytical skills.

### READING LIST:

Thermal Physics, M Sprackling (Macmillan).

An Introduction to Thermal Physics, C J Adkins (Cambridge University Press) (out of print, but copies in the library).

## PX2206 MECHANICS AND SPECIAL RELATIVITY

### MODULE INFORMATION:

- Spring semester: 10 credits.
- Module organiser: Prof P D Mauskopf.
- Deputy Module Organiser: Dr S A Eales.
- Teaching and feedback methods: Lectures 18 x 1 hr, Exercises 4 x 1 hr, marked Exercises.
- Assessment: Examination 80%. Coursework 20%. [Examination duration: 2 hours]
- Pre-cursors: PX1116, PX1214 and PX1216.
- Co-requisites: None.
- Pre-requisites: None.

### AIMS OF THE MODULE:

- To introduce further concepts in classical mechanics and fluid mechanics and provide further practice at problem solving.
- To introduce further concepts of special relativity and space-time.

### LEARNING OUTCOMES:

The student will be able to:

- Compare conservative and non-conservative forces.
- Derive, for a general system of particles: total momentum, energy and angular momentum, and the equations for linear and rotational motion, and to apply these to solve problems in physics.
- Derive equations for Coriolis and centrifugal forces and apply these to problems.
- Calculate moments and products of inertia, inertia matrices and principal axes and principal moments of inertia.
- Prove the relativistic Doppler effect and apply it to problems.
- Discuss the meaning of a four-vector.
- Prove the energy-momentum relationship for a particle (or photon).

### OUTLINE SYLLABUS:

Mechanics: Resumé of Newton's laws and conservation laws. Angular velocity, angular momentum and torque as vectors. Gyroscope (simple theory).

Forces and Fields: Conservative and non-conservative forces and fields. Inertial and non-inertial frames. Mechanics of a general system: total momentum, energy and angular momentum, equations of linear and rotational motion.

The two-body problem: Collisions between two bodies.

Rotating frames: Centrifugal and Coriolis forces, with examples. Foucault pendulum.

Matrices: Revision of matrices and their applications to mechanics. Eigenvalues and eigenvectors of a matrix.

Rotation: Rotation of a rigid body. Moments and products of inertia. Principal axes, and their orthogonality. Parallel axis theorem. Perpendicular axis theorem.

Special Relativity: Resumé of Lorentz transformation and their consequences. Relativistic Doppler effect. Space-time.

Relativistic mechanics: Dependence of mass on velocity. Transformation of total momentum and total mass. Four-vectors. Lorentz transformation as a rotation in 4-dimensional space. Energy-momentum relationship, including photons.

### TRANSFERABLE SKILLS:

Mathematics. Problem solving. Investigative skills. Analytical skills.

### READING LIST:

Classical Mechanics, T Kibble and F Berkshire (Longman).

## PX2214 PRACTICAL PHYSICS B

### MODULE INFORMATION:

- Spring semester: 10 credits.
- Module organiser: Dr D I Westwood.
- Deputy Module Organiser: Dr A Cartwright.
- Teaching and feedback methods: Laboratories 11 x 4 hrs. Marked diaries and reports.
- Assessment: Coursework 100%.
- Pre-cursors: PX1117, PX1217.
- Co-requisites: None.
- Pre-requisites: None.

### AIMS OF THE MODULE:

- To extend practical skills by using set experiments illustrating a range of physical phenomena.
- To increase awareness of the design of experiments.
- To develop critical thinking about experimental technique and the treatment of errors.
- To develop awareness of safety issues and provide experience in risk assessment.
- To develop written and oral presentation skills.
- To provide the necessary skills to undertake a third-year practical physics project.

### LEARNING OUTCOMES:

The student will be able to:

- Keep an accurate and detailed record of their experimental procedures and data, including a risk assessment.
- Analyse data sets to extract relevant physical quantities, and estimate errors in these quantities.
- Decide on the course of experiments based on initial or earlier findings.
- Present self-contained reports of experiments they have performed.

### OUTLINE SYLLABUS:

Experiments:

- Magnetic hysteresis
- X-ray absorption
- X-ray fluorescence
- Electron spin resonance
- Nuclear magnetic resonance
- The Normal Zeeman effect
- Absorption spectrum of Iodine
- Transmission line
- Helmholtz pairs: uniform magnetic fields
- Magnetic hysteresis and magnetic circuits
- Vapour pressure of nitrogen
- Ratio of specific heat capacities
- Band gap of a semiconductor
- Measurement of G
- Normal modes in an acoustic resonant chamber
- Precession of a Gyroscope
- Torsion pendulum
- Vibrations of a classical guitar
- Refraction and dispersion in transparent solids
- Optical reflection (and Fresnel's equations)
- Airy's disc

### TRANSFERABLE SKILLS:

Experimental Physics. Communications skills. Personal skills. Investigative skills. Computing skills. Analytical skills. Ethical behaviour.

### READING LIST:

Practical Physics, G L Squires (Cambridge).

## PX2218 ACOUSTICS AND STUDIO TECHNIQUES

### MODULE INFORMATION:

- Spring semester: 10 credits.
- Module organiser: Dr B E Richardson.
- Deputy Module Organiser: Dr D I Westwood.
- Teaching and feedback methods: Lectures, studio sessions and tutorials 11 x 2 hr. Marked weekly practical work.
- Assessment: Examination 50%. Coursework 50%. [Examination duration: 1 hours]
- Pre-cursors: PX1220. Preferably requires rudimentary musical knowledge (check with MO).
- Co-requisites: None.
- Pre-requisites: None.

### AIMS OF THE MODULE:

- To give an introduction to the production, recording and reproduction of musical sounds.
- To introduce basic concepts of physical acoustics and the physiology of hearing.
- To provide knowledge and experience of practical studio techniques.

### LEARNING OUTCOMES:

The student will be able to:

- Describe the physical principles involved in recording and reproducing sounds, including the mechanical and acoustical functions of microphones and loudspeakers.
- Discuss the structure and function of the human ear and compare objective and subjective properties of musical sounds.
- Show an appreciation of different recording hardware and the concepts of dynamic range and noise reduction.
- Recall basic ideas of architectural and room acoustics.
- Undertake practical assignments using a range of studio equipment to demonstrate competence in using microphones, recording equipment and the manipulation of sound.
- Demonstrate skill in making and interpreting acoustical measurements.

### OUTLINE SYLLABUS:

The human auditory system: Structure and function of the human ear. Objective and subjective properties of sound. Frequency and pitch. Intensity and loudness. The decibel scale. Sound localisation.

Microphones: Function and properties of the principal microphone types; polar response; stereo techniques; balanced lines, studio levels and amplification.

Monitoring: Loudspeaker units and enclosures and equalisation.

Room acoustics: Studio design and construction; sound insulation; sound absorption; reverberation time.

Sound recording and reproduction: Physical principles; analogue and digital methods; function and dynamic range of ADCs and DACs; metering; compression; noise and distortion.

Acoustic theory: The linearised wave equation; speed of sound; acoustic impedance. Sound radiation from point sources, dipoles and pistons. Sound waves in rectangular enclosures and modal density.

Practical work: Microphone polar responses and placement for stereo separation. Sound recording and editing using Audition. Acoustical measurements including sound reduction and reverberation time. Free access to the Sound Studio for practical assignments and mini-project with a creative element.

### TRANSFERABLE SKILLS:

Experimental physics. Communications skills. Investigative skills. Computing skills. Analytical skills.

### READING LIST:

The Art of Digital Audio, J Watkinson, 2nd Edn (Focal Press, 1994).

Sound Recording Practice, J Borwick, 4th Edn (Oxford University Press, 2001).

Fundamentals of Acoustics, Kinsler, Frey, Coppens & Sanders 4th Edn (John Wiley, 2000).

## PX2220 PLANETARY SYSTEMS

### MODULE INFORMATION:

- Spring semester: 10 credits.
- Module organiser: Prof S A Eales.
- Deputy Module Organiser: Prof W K Gear.
- Teaching and feedback methods: Lectures 22 x 1 hr, Exercises.
- Assessment: Examination 100%. [Examination duration: 2 hours]
- Pre-cursors: PX1110, PX1207, PX2104.
- Co-requisites: None.
- Pre-requisites: None.

### AIMS OF THE MODULE:

- To introduce the basic properties of the solar system and other planetary systems.
- To interpret these properties in terms of basic physics.
- To provide a framework for the application of theory to predict and understand the topology of planetary surfaces and other features of planetary systems.

### LEARNING OUTCOMES:

The student will be able to:

- Use the principle of hydrostatic equilibrium to model the internal structures and shapes of planets.
- Describe the properties of planetary systems in terms of basic physical concepts, such as tidal forces.
- Evaluate and discuss the observational arguments in favour of the standard model for the formation of planetary systems.
- Demonstrate their understanding of planetary systems by answering both essay-style questions and solving unseen numerical problems under examination conditions

### OUTLINE SYLLABUS:

The Solar System: Basic things about our planetary system: why planets are round, the date at which the Solar System was formed, and a model for the formation of the Solar System.

Searching for Planets: Detection method (successful and otherwise) for exoplanets. Properties of exoplanets. Darwin. Observations of proto-planetary systems.

Planetary Structure: The structures of planets from satellite orbits and precession, seismic waves and plate tectonics.

Planet Surfaces: The physics of atmospheres. Tidal forces. Comparatively planetology. The Galileo mission at Jupiter.

Comets and Asteroids: The properties of comets. The Oort cloud. The Kuiper Belt. Plutinos. Evidence for impacts and the extinction of the dinosaurs. Near Earth Objects – something else to worry about.

Life, the Universe and Everything: The Drake equation. The Search for Extraterrestrial Intelligence. The origin of life. Interplanetary spaceflight. Interstellar spaceflight. Exoplanets revisited.

### TRANSFERABLE SKILLS:

Problem solving. Investigative skills. Mathematics. Analytical skills.

### READING LIST:

Web-based notes for part of the module.

## PX2221 PHYSICS APPLIED

### MODULE INFORMATION:

- Spring semester: 10 credits.
- Module organiser: Dr J E Macdonald.
- Deputy Module Organiser: Prof M J Griffin.
- Teaching and feedback methods: Lectures 22 x 1 hr, marked Worksheets.
- Assessment: Examination 70%. Coursework 30%. [Examination duration: 2 hours]
- Pre-cursors: PX1111.
- Co-requisites: None.
- Pre-requisites: None.

### AIMS OF THE MODULE:

- To provide strategies for and give practical experience in solving physics problems.
- To increase the appreciation of elementary physics by solving problems relating to various practical contexts.

### LEARNING OUTCOMES:

The student will be able to:

- Identify the physics relevant to a particular problem.
- Demonstrate an ability to translate a problem into mathematical equations.
- Demonstrate, in exercises and unseen examination questions, an ability to solve problems involving a wide range of elementary physics.

### OUTLINE SYLLABUS:

Problem solving relating to the following areas:

- Elementary mechanics
- Friction
- Rotational and circular motion
- Thermal physics
- Electrostatics and AC circuits
- Optics
- Fluids
- Elementary physics of matter
- Waves and interference

### TRANSFERABLE SKILLS:

Problem solving. Mathematics. Personal skills. Investigative skills. Computing skills. Analytical skills.

### READING LIST:

University Physics (with Modern Physics), H D Young and R A Freedman, 12th Edition (Addison Wesley).

## PX2223 PHYSICS OF SOLIDS AND SOFT MATTER

### MODULE INFORMATION:

- Spring semester: 10 credits.
- Module organiser: Dr J E Macdonald.
- Deputy Module Organiser: Prof W W Langbein.
- Teaching and feedback methods: Lectures 22 x 1 hr, marked Exercises.
- Assessment: Examination 90%. Coursework 10%. [Examination duration: 2 hours]
- Pre-cursors: PX1112, PX1116, PX1216 and PX2101.
- Co-requisites: None.
- Pre-requisites: None.

### AIMS OF THE MODULE:

- To establish a basic understanding of the fundamental physics underlying the structural and electronic properties of condensed matter.
- To provide an understanding of crystal structure and the behaviour of waves in periodic lattices.
- To develop an understanding of the behaviour of electrons in the solid state.

### LEARNING OUTCOMES:

The student will be able to:

- Describe and compare quantitatively the various kinds of bonding in solids.
- Discuss the application of diffraction to study structural properties.
- Discuss simple models of the heat capacity of solids.
- Describe the behaviour of electrons in solid insulators, metals, and semiconductors.
- Describe the main features of and apply theory of the free-electron gas model for metals.
- Discuss, in qualitative terms, the reasons for the contrasting properties of crystals, amorphous materials, liquids and macromolecules.

### OUTLINE SYLLABUS:

Static and thermal properties of crystals: Atomic bonding in inorganic and organic materials. The meaning of lattice, basis, crystal structure. Simple crystal structures, in particular simple cubic, face-centred cubic and body-centred cubic. Diffraction by crystals. Heat capacity. The Einstein, Debye and monatomic linear chain models of heat capacity. Quantisation of vibrational energy.

Electron dynamics in crystals: Metals, insulators and semiconductors. Introduction to the concept of a hole. Classical free-electron gas. The quantised free-electron gas: Fermi distribution. Electron transport. Sommerfeld model. Temperature-dependence of the conductivity of a metal and semiconductor. Introduction to superconductivity.

Non-crystalline states of condensed matter: Amorphous solids, liquids. Introduction to macromolecules: classes of polymers, chain conformation, elasticity. Biomolecules: proteins and membranes.

### TRANSFERABLE SKILLS:

Problem solving. Investigative skills. Mathematics. Analytical skills.

### READING LIST:

Solid State Physics, Hook and Hall.

Introduction to Solid State Physics, C Kittel.

## PX2224 ELECTROMAGNETISM

### MODULE INFORMATION:

- Spring semester: 10 credits.
- Module organiser: Dr E Pascale.
- Deputy Module Organiser: Dr P Hargrave.
- Teaching and feedback methods: Lectures 22 x 1 hr. Exercises 11 x 1 hr, marked Exercises.
- Assessment: Examination 80%. Coursework 20%. [Examination duration: 2 hours]
- Pre-cursors: PX1116, PX1216 and PX1219.
- Co-requisites: PX2104.
- Pre-requisites: None.

### AIMS OF THE MODULE:

- To provide greater understanding of electric and magnetic forces and fields and their unification in Maxwell's equations.
- To show how Maxwell's equations can be used to demonstrate the existence of electromagnetic waves.
- To demonstrate how to apply Maxwell's equations with different boundary conditions to deduce the properties of electromagnetic fields in different circumstances.

### LEARNING OUTCOMES:

The student will be able to:

- Recall equations representing electrostatic forces and fields and solve problems involving electric potentials, electric fields and capacitance.
- Describe formally the relationships between steady electric currents and magnetic fields and use these relationships to solve problems.
- Describe formally the process of electromagnetic induction.
- Explain the motion of an electron in a magnetic field.
- Describe formally the formation and propagation of an electromagnetic wave in vacuum.
- Apply boundary conditions and solve Maxwell's equations for simple physical situations.

### OUTLINE SYLLABUS:

Electric fields: Review of vectors. Charge. Electrostatic force and electric fields. Gauss's Law in integral and differential form. Conservative forces. Capacitors. The electric dipole. Dielectrics and polarisation.

Moving charges: Equation of continuity. Ohm's Law in vector form.

Magnetic fields: Magnetic forces and fields. Biot-Savart law. Amperes' Law in integral and differential form. Magnetic dipoles. Magnetisation of matter.

Electromagnetic induction: Induced currents and Faraday's Law in integral and differential form. Induced electric fields, definition of inductance. Inductance and magnetic energy.

Electromagnetism: Displacement current and Maxwell's equations. The electromagnetic wave equation. Energy and momentum in EM waves. Applying boundary conditions to Maxwell's equations. Solving Maxwell's equations in simple physical situations. The Poynting vector. Generating EM radiation. Electromagnetism with special relativity and quantum mechanics.

### TRANSFERABLE SKILLS:

Mathematics. Problem solving. Investigative skills. Analytical skills.

### READING LIST:

Electromagnetism, I S Grant and W R Phillips (Wiley).

Electricity and Magnetism, W J Duffin (McGraw Hill).

University Physics (with Modern Physics), H D Young and R A Freedman, 12th Edition (Addison Wesley).

## PX2225 THE PHYSICS OF STARS

### MODULE INFORMATION:

- Spring semester: 10 credits.
- Module organiser: Dr D Nutter.
- Deputy Module Organiser: Dr R M Smith.
- Teaching and feedback methods: Lectures 22 x 1 hr, marked Exercises.
- Assessment: Examination 70%. Coursework 30%. [Examination duration: 2 hours]
- Pre-cursors: PX1110.
- Co-requisites: None.
- Pre-requisites: None.

### AIMS OF THE MODULE:

- To introduce the principal physical concepts of stellar bodies and their lifecycles.
- To develop an understanding of the Sun as a star.
- To introduce the fundamental physics of stars.
- To develop an understanding of different types of stars, both as single objects and as members of multiple systems.
- To develop strategies for solving astrophysical problems related to stars.

### LEARNING OUTCOMES:

The student will be able to:

- Describe the range of stellar properties and types.
- Describe the physical mechanisms at work within stars of different mass.
- Demonstrate an understanding of the processes that govern the birth, life and death of stars.
- Describe the different types of stellar systems currently known and their observational characteristics.
- Demonstrate an ability to approach problems with mathematical and physical reasoning.

### OUTLINE SYLLABUS:

Introduction: revision of the basic physics of stars and their formation; properties of stars; the range of stellar parameters; powering stars; observational properties of stars.

The Sun as a star: the solar interior; helioseismology; solar-terrestrial interactions; Coronal Mass Ejections.

Stellar classification: spectral classification of stars; mechanisms affecting spectral lines in stellar atmospheres; OBAFGKM stars; brown dwarfs; extreme stars.

Star death: formation and evolution of planetary nebulae, supernovae and hypernovae; Gamma Ray Bursts.

Stellar clusters: globular and open clusters.

Variable stars: eclipsing, pulsating, eruptive variables.

Binary systems: uses for determining stellar parameters; spectroscopic binaries; detached, semi-detached and contact binaries.

X-ray binary systems: white dwarf, neutron star and black hole binaries.

### TRANSFERABLE SKILLS:

Problem solving. Investigative skills. Mathematics. Communications skills. Analytical skills. Computing skills.

### READING LIST:

An Introduction to the Theory of Stellar Structure and Evolution, D Prialnik (Cambridge University Press)

An introduction to the Sun and Stars, S F Green and M H Jones (Open University Press)

## PX2228 RADIATION IN MEDICINE

### MODULE INFORMATION:

- Spring semester: 10 credits.
- Module organiser: Dr W D Evans. [Other lecturers: Ms A Burch and Dr D G Lewis].
- Deputy Module Organiser: Ms A Burch.
- Teaching and feedback methods: Lectures 22 x 1 hr, Exercises.
- Assessment: Examination 100%. [Examination duration: 2 hours].
- Pre-cursors: PX1112, PX1116, PX1214, PX1216, PX1218, PX1219 and PX2107.
- Co-requisites: None.
- Pre-requisites: None.

### AIMS OF THE MODULE:

- To give an overview of the properties of ionising radiation and its interaction with matter.
- To introduce the concept of radiation dose.
- To provide an introduction to the physical basis of the use of ionising radiation in diagnosis and therapy.

### LEARNING OUTCOMES:

The student will be able to:

- Identify the means by which ionising radiation interacts with matter and outline the dependence of attenuation on the properties of the radiation and the material with which it interacts.
- Describe the basic features of radioactivity.
- Define the meaning of radiation dose and outline the principles of radiation dosimetry.
- Discuss the basic principles of diagnostic radiography and explain the basis of spatial resolution and radiation contrast.
- Discuss the basic principles of diagnostic and therapeutic nuclear medicine including radionuclide imaging.
- Discuss the basic principles of radiotherapy and outline the main features of teletherapy and brachytherapy.

### OUTLINE SYLLABUS:

Radiation Physics: Radioactivity. Interaction of high energy particles and photons with matter. Attenuation coefficients.

Radiation Dose: Absorbed dose, equivalent dose and effective dose. Effects of radiation on living organisms.

Applications in Diagnostic Radiology: Construction and operation of x-ray tubes; radiation spectra and beam filtration. Contrast and other indices of image quality in radiographic imaging. Image receptors; screen-film, fluoroscopic and digital imaging systems. Quantitative techniques. Radiation dose and risk; dosimetry equipment and techniques.

Applications in Nuclear Medicine: Natural and artificial sources of radionuclides and their properties, reactor and cyclotron production. Construction, operation and properties of radiation detectors: Geiger-Muller tubes and scintillators; detector electronics. Tracer techniques using radiopharmaceuticals. Measurement of volume, uptake and clearance. Quantitative analysis. Radionuclide imaging and the construction and operation of a gamma camera. Radionuclide therapy. Radiation dose and risk.

Applications in Radiotherapy: Teletherapy and brachytherapy. Construction and operation of particle accelerators. Properties of radiation beams. Radiation dosimetry equipment and techniques.

### TRANSFERABLE SKILLS:

Problem solving. Investigative skills. Mathematics. Analytical skills.

### READING LIST:

Medical Physics and Biomedical Engineering; B H Brown, R H Smallwood, D C Barber, P V Lawford and D R Hose. (1998, Institute of Physics Publishing).

Physics for Diagnostic Radiology; P Dendy and B Heaton. (1999, Institute of Physics Publishing).

Radiotherapy Physics in Practice (second edition); J R Williams and D I Thwaites (editors). (2000, Oxford University Press).

## PX2322 OBSERVATIONAL TECHNIQUES IN ASTRONOMY

### MODULE INFORMATION:

- Autumn and Spring semester: 20 credits.
- Module organiser: Prof D Ward-Thompson.
- Deputy Module Organiser: Dr H L Gomez.
- Teaching and feedback methods: Lectures 24 x 1 hr, Exercises 4 x 1 hr, Project sessions 12 X 4 hrs. Marked exercises and practical work.
- Assessment: Examination 40%. Lab work 50%. Exercises 10%. [Examination duration: 2 hours]
- Pre-cursors: PX1110 and PX1207.
- Co-requisites: None.
- Pre-requisites: None.

### AIMS OF THE MODULE:

- To introduce the theory and practice of making and interpreting astronomical observations.
- To provide a practical introduction to, and in-depth knowledge of, the principles of telescopes, observational astronomy, detector technology and spectroscopy at various wavelengths.
- To provide the necessary skills to undertake a third-year or fourth-year practical astronomy project.

### LEARNING OUTCOMES:

The student will be able to:

- Demonstrate through theory and practice how to take, reduce and analyse astronomical data.
- Plan astronomical observations, take data from simple optical and radio telescopes and be able to interpret and discuss those data.
- Demonstrate a working knowledge of how to use basic astronomical instrumentation, including telescopes, CCD cameras, spectrographs and radio receivers.
- Describe and contrast the physical principles of telescopes, detectors and spectroscopes used for each range of the electromagnetic spectrum.
- Use statistical arguments to estimate the quality of observational data.

### OUTLINE SYLLABUS:

The properties of photons: the E-M spectrum, intensity flux and luminosity. Polarisation.

The atmosphere: Atmospheric absorption. Seeing and coherence length. Atmospheric windows. The secant law.

Colour-magnitude and colour-colour diagrams: Reddening and dust extinction. Column density. Dust mass.

Astronomical coordinate systems: Precession and time. Right ascension and declination. Altitude and azimuth. Hour angle. Epoch and equinox.

Statistics of detection: Mean and standard deviation. Binomial and gaussian distributions. Signal to noise ratio. The significance of a detection.

Focal stations: Newtonian, Cassegrain, Nasmyth, Coude, Schmidt.

Telescope and detector design: Optical spectroscopy, radio telescopes, infrared telescopes. UV and X-ray satellites, gamma-ray satellites. Gravitational wave detection and cosmic rays.

### TRANSFERABLE SKILLS:

Experimental physics. Communications skills. Personal skills. Problem solving. Investigative skills. Mathematics. Computing skills. Analytical skills. Ethical behaviour.

### READING LIST:

Astronomical Observations, G Walker.

Astrophysical Techniques, C R Kitchin.

Interpreting Astronomical Spectra, D Emerson.

Observational Astrophysics, R C Smith.

Introduction to Radio Astronomy, B F Burke and F Graham-Smith.

Introduction to Statistics, R E Walpole, 3rd Edn.

## PX3104 THEORETICAL PHYSICS TECHNIQUES

### MODULE INFORMATION:

- Autumn semester: 10 credits.
- Module organiser: Dr E A Muljarov.
- Deputy Module Organiser: Dr C C Matthai.
- Teaching and feedback methods: Lectures 22 x 1 hr, Exercises.
- Assessment: Examination 100%. [Examination duration: 2 hours]
- Pre-cursors: PX2104.
- Co-requisites: None.
- Pre-requisites: None.

### AIMS OF THE MODULE:

- To provide an understanding of some of the more advanced techniques of theoretical physics.
- To develop proficiency in manipulating mathematical formalism.
- To apply these skills to physical problems.

### LEARNING OUTCOMES:

The student will be able to:

- Find the eigenvalues and eigenvectors of simple matrices and derive their properties, diagonalise matrices, and apply these to simple problems in physics.
- Describe and apply the properties of groups, be able to construct group multiplication tables, and derive representations and apply them to simple problems.
- Derive the wave equation and diffusion equation in one, two and three dimensions, and in different coordinate systems, and solve these equations given boundary conditions and initial conditions.
- Solve unseen problems based on the techniques studied in this course.

### OUTLINE SYLLABUS:

Matrices: Revision of earlier material on matrices, determinants, linear equations, and matrix inversion. Eigenvalues and eigenvectors and their determination. Properties of eigenvalues and eigenvectors of real symmetric and Hermitian matrices. Diagonalisation of matrices.

Group Theory: Properties of groups and their application to symmetry and other problems. Group multiplication tables, character tables, representations. Degenerate modes forming a representation.

Partial Differential Equations: Derivation of the wave equation in one, two and three dimensions, and in Cartesian, spherical and cylindrical polar coordinates. General solution of the wave equation in one dimension. Solution of the wave and diffusion equations in one, two and three dimensions using separation of variables method. The role of initial and boundary conditions in the solution.

### TRANSFERABLE SKILLS:

Mathematics. Problem solving. Investigative skills. Analytical skills.

### READING LIST:

Mathematical Methods for Physics and Engineering, K F Riley, M P Hobson and S J Bence (Cambridge University Press).

More details of the course, with notes, problems, and module answers are given in

<http://www.astro.cf.ac.uk/undergrad/module/PX3104>

# PX3105 OPTICS AND FOURIER TRANSFORMS

## MODULE INFORMATION:

- Autumn semester: 10 credits.
- Module organiser: Prof P A R Ade.
- Deputy Module Organiser: Dr B E Richardson.
- Teaching and feedback methods: Lectures 22 x 1 hr, marked Exercises.
- Assessment: Examination 80%. Coursework 20%. [Examination duration: 2 hours]
- Pre-cursors: PX1220 and PX2104.
- Co-requisites: None.
- Pre-requisites: None.

## AIMS OF THE MODULE:

- To introduce concepts of “imaging” through a study of geometrical and physical optics.
- To study optical system design and evaluation and image processing using Fourier techniques.
- To apply optical theory to solve a variety of real problems.

## LEARNING OUTCOMES:

The student will be able to:

- Apply ray-tracing methods to describe the basic function of reflecting and refracting optical systems and identify sources of aberrations.
- Describe from first principles the formation of interference fringes in thin-film interference and discuss their use in interferometry and metrology.
- Derive the functional form of a variety of 1-D and 2-D Fraunhofer diffraction patterns using both Huygen’s principle and Fourier techniques and apply the theory to describe the diffraction-limited resolution of optical systems and to grating spectroscopy.
- Demonstrate a working knowledge of Fourier transforms and convolution theory to solve problems in optical system design and simple image processing.

## OUTLINE SYLLABUS:

Introduction and Revision: Electromagnetic spectrum. EM waves in free space and in dielectrics. Light sources. Coherence.

Reflection and Refraction: Reflection and refraction at plane boundaries. Brewster angle. Total internal reflection. Refractive index and dispersion. Fresnel's equations.

Lenses, Mirrors and Optical Systems: Gaussian lens theory. Formulae and ray tracing. Apertures. Lens aberrations. Catadioptric systems. Reflecting telescopes.

Interference: Two-beam interference. Fringe visibility. Michelson interferometer. Thin-film interference. Multiple-beam interference. Antireflection coatings.

Fraunhofer and Fresnel Diffraction: Diffraction from single slit, rectangular and circular apertures. Rayleigh criterion and resolving power. Double slit and multiple slit diffraction. Grating spectroscopy. Semi-infinite opaque screen.

Fourier Optics: Revision of Fourier series. Introduction to Fourier transforms. Spatial frequencies. FTs and Fraunhofer diffraction. Fourier theory. Convolution.

Optical Systems: Point spread functions. Optical and modulation transfer functions.

Coherent Optical Processing: Abbe theory. Spatial filtering and image processing.

## TRANSFERABLE SKILLS:

Mathematics. Problem solving. Investigative skills. Analytical skills.

## READING LIST:

Optics, E Hecht, 3rd Edn (Addison Wesley).

# PX3109 SOLID STATE PHYSICS

## MODULE INFORMATION:

- Autumn semester: 10 credits.
- Module organiser: Prof W W Langbein.
- Deputy Module Organiser: Dr J E Macdonald.
- Teaching and feedback methods: Lectures 22 x 1 hr, Exercises.
- Assessment: Examination 100%. [Examination duration: 2 hours]
- Pre-cursors: PX2101 and PX2223.
- Co-requisites: None.
- Pre-requisites: None.

## AIMS OF THE MODULE:

- To establish detailed understanding of the structural, vibrational and electronic properties of solids.
- To establish understanding of diffraction from crystals.
- To establish understanding of the optical properties of solids.

## LEARNING OUTCOMES:

The student will be able to:

- Assign simple crystal structures to Bravais lattices, and determine their point symmetries.
- Classify lattice defects.
- Show how the reciprocal lattice can be used to describe diffraction from a three-dimensional crystal and to calculate and apply the reciprocal lattice and structure factors to diffraction studies.
- Describe lattice vibrations in terms of phonons and their dispersion curves.
- Explain how inelastic neutron or light scattering can be used to investigate phonons.
- Give an account of models of lattice vibrations and the related heat capacity behaviour.
- Demonstrate understanding of lattice heat conduction and thermal expansion.
- Describe the properties of electron waves in crystals and explain the formation of energy bands.
- Explain the distinction between metals, insulators and semiconductors in terms of simple band theory of solids.
- Explain the concept of effective mass, derive an expression for effective mass for a given dispersion relation.
- Explain the concept of the Fermi surface.
- Demonstrate understanding of electronic heat and current conduction.
- Describe the frequency-dependent electronic susceptibility of metals and dielectrics.

## OUTLINE SYLLABUS:

Crystal structure: Lattice, basis, crystal structure. Simple, body-centred and face-centred cubic lattices.

Examples of crystal structures. Hexagonal closed packed lattices.

The reciprocal lattice: Definition, reciprocal lattice vectors. Examples. Fourier representation.

Diffraction by crystals: Bragg law. Laue equations. Ewald construction. Brillouin zones. Structure factor.

Atomic form factor. Scattering of Neutrons and Electrons from Solids. Comparison of neutrons, electrons and X-rays.

Lattice vibrations: Dispersion in 3D, examples 1D monoatomic and diatomic chain, phase and group velocity, localized modes, phonons, light and neutron scattering by phonons, lattice heat capacity. Thermal distribution functions, Einstein & Debye model. Lattice anharmonicity: heat conduction, transport equations.

Electrons in crystals: Free electron model. Nearly free electron model. Tight binding model. Bloch functions.

Zone schemes. Classification of crystalline solids into metals, semiconductors and insulators. Electron dynamics and effective mass. Examples of Fermi surfaces. Electrical conductivity and electronic specific heat.

Optical properties of solids: The Drude-Lorentz oscillator model, complex refractive index, frequency dependence of the susceptibility for metals and insulators.

## TRANSFERABLE SKILLS:

Problem solving. Investigative skills. Mathematics. Analytical skills.

## READING LIST:

Introduction to Solid State Physics, C Kittel.

Solid State Physics, Hook and Hall.

Optical Properties of Solids, M Fox.

## PX3110 GALAXIES

### MODULE INFORMATION:

- Autumn semester: 10 credits.
- Module organiser: Dr J I Davies.
- Deputy Module Organiser: Dr D Munshi.
- Teaching and feedback methods: Lectures 22 x 1 hr, Exercises.
- Assessment: Examination 100%. [Examination duration: 2 hours]
- Pre-cursors: PX1116, PX1207 and PX1216.
- Co-requisites: None.
- Pre-requisites: None.

### AIMS OF THE MODULE:

- To explain how the structure of our Galaxy can be determined experimentally.
- To compare the properties of our Galaxy with other galaxies.
- To explain how galaxies are used to derive fundamental cosmological parameters.
- To develop an understanding of how galaxies form and evolve.

### LEARNING OUTCOMES:

The student will be able to:

- Explain how the structure and nature of our Galaxy can be determined experimentally.
- Describe the observed differences between galaxies of various types and how these differences might arise.
- Describe how galaxies can be used to derive the cosmological parameters  $H_0$  and  $\Omega_0$ .
- Discuss possible explanations of how structures like galaxies might have formed in the early Universe and how they can evolve into the galaxies we see today.

### OUTLINE SYLLABUS:

The Observed Properties of Galaxies: The historical development of ideas about the nature of our Galaxy, stellar populations and distributions, gas (HI, H<sub>2</sub> etc.), dust (interstellar extinction), stellar kinematics, rotation, mass (Oort's model).

The Observed Properties of Other Galaxies: Galaxy types, stellar populations, gas and dust, rotation curves (21cm observations), luminosity function, mass-to-light ratios, surface brightness.

The Distribution of Galaxies in the Universe: The selection of large samples of galaxies and selection effects ( $V/V_{\max}$  test), measuring the large-scale structure defined by the galaxies (the two-point correlation function), using galaxies as cosmological probes.

The Formation and Evolution of Galaxies: Jean's mass before and after recombination.

The Chemical Evolution of Galaxies: The simple closed box model.

Case Study: The faint blue galaxy problem.

### TRANSFERABLE SKILLS:

Problem solving. Investigative skills. Mathematics. Analytical skills.

### READING LIST:

Galactic Astronomy by Binney and Merrifield (Princeton University Press).

## PX3121 APPLICATIONS OF QUANTUM MECHANICS

### MODULE INFORMATION:

- Autumn semester: 10 credits.
- Module organiser: Prof B S Sathyaprakash.
- Deputy Module Organiser: Dr P J Sutton.
- Teaching and feedback methods: Lectures 22 x 1 hr, Exercises.
- Assessment: Examination 100%. [Examination duration: 2 hours]
- Pre-cursors: PX2101.
- Co-requisites: None.
- Pre-requisites: None.

### AIMS OF THE MODULE:

- To provide the basis for the physical interpretation of quantum mechanics.
- To develop an understanding of advanced topics and techniques in quantum mechanics.
- To develop skills in applying these techniques to problems in various branches of physics.

### LEARNING OUTCOMES:

The student will be able to:

- Demonstrate an insight into the *principle of superposition* and the *uncertainty principle*.
- Obtain an understanding of the fundamental postulates of quantum mechanics in the operator formalism and use the Dirac notation in simple cases.
- Derive the orbital magnetic moment of the H atom, show an understanding of the electron spin and explain the Stern-Gerlach experiment.
- Demonstrate an understanding of what causes atoms to radiate, specifically atomic electric dipole radiation and selection rules.
- Discuss how symmetries are related to conservation laws, in particular parity and translational and rotational symmetries.
- Explain the significance of the *Pauli exclusion principle*, and *central field approximation* and periodic table.
- Demonstrate application of time-independent perturbation theory to simple problems.
- Show comprehension of the concepts of generalised angular momentum and the angular momentum addition theorem and apply these concepts to explaining the fine structure in atomic spectra.
- Study the nature of observations in quantum mechanics and the EPR paradox.

### OUTLINE SYLLABUS:

Fundamentals of quantum mechanics: Observables and operators. Expectation values. Uncertainty principle. Schrödinger equation. Conservation laws.

Hydrogen atom, magnetic moment and spin: Stern-Gerlach experiment and electron spin. Magnetic moment due to orbital motion. Spin-orbit interaction in H. Explanation of the Stern-Gerlach experiment.

Symmetry and Conservation Laws: Translation and rotation symmetries and conservation of energy, linear and angular momenta. Parity symmetry and Laporte's rule. Tau-Sigma puzzle and violation of parity.

Multi-electron atoms: Indistinguishability of particles and the exclusion principle, central field approximation, electronic configuration and the Periodic table.

Operator formalism: Eigenstates and eigenvalues. Complete normalized orthogonal sets. Dirac notation.

Generalized angular momentum: Commutation relations, ladder operators, integer and half-integer spin.

Two-electron system: Angular momentum addition theorem, multiplets and fine structure in atomic spectra.

Time-independent perturbation theory: introduction to perturbation methods in quantum mechanics.

Corrections to the wave function and energy levels due to spin-orbit.

Observations in quantum mechanics: Process of making an observation. EPR paradox. Bell's inequality and resolution of the EPR paradox.

### TRANSFERABLE SKILLS:

Mathematics. Problem solving. Investigative skills. Analytical skills.

### READING LIST:

Quantum Mechanics, F Mandl (Wiley).

An Introduction to Quantum Physics, A French and E Taylor (Nelson).

## PX3134 DIGITAL MEDICAL IMAGING

### MODULE INFORMATION:

- Autumn semester: 10 credits.
- Module organiser: Dr G W Middleton.
- Deputy Module Organiser: Miss H Blundell.
- Teaching and feedback methods: Lectures 22 x 1 hr, Demonstrations, Exercises.
- Assessment: Examination 100%. [Examination duration: 2 hours]
- Pre-cursors: PX1218 and 2124 and PX2213.
- Co-requisites: None.
- Pre-requisites: None.

### AIMS OF THE MODULE:

- To establish a firm understanding of the principles, technologies and applications of digital imaging techniques in medicine.
- To give an appreciation of the practical aspects of operating digital imaging systems in the modern health service.

### LEARNING OUTCOMES:

The student will be able to:

- Describe the important medical imaging modalities and give examples of their application.
- Describe the physical principles applicable to the important medical imaging modalities.
- Illustrate, using examples, the application of digital-image-processing methods to medical imaging.
- Demonstrate, both mathematically and diagrammatically, the principles of tomography.
- Describe the main components of a range of tomographic imaging equipment.
- Distinguish between tomography using X-rays and radionuclides.
- Describe the image formation process in Magnetic Resonance Imaging.
- Outline the principal components of a Picture Archive and Communication System (PACS).

### OUTLINE SYLLABUS:

Digital Medical Imaging: Introduction to modern medical imaging modalities. Production and display of digital images, contrast enhancement, histogram equalisation.

Image Processing Techniques: Image filtering, frequency space, spatial and temporal filtering. Image quantification, analysis of dynamic studies, texture analysis, feature extraction, gating techniques, parametric imaging.

Tomography: Tomographic reconstruction, radon transform, convolution theorem, forward and back projection, iterative reconstruction.

Tomographic Techniques and Instrumentation: X-ray CT: detectors, scanners, multislice and spiral systems, radiation dose.

Single Photon Emission Computed Tomography (SPECT) and Positron Emission Tomography (PET): gamma camera and dedicated systems, filter functions, attenuation correction.

Magnetic Resonance Imaging (MRI): gradient fields, slice selection, pulse sequences, contrast agents, safety.

The Digital Imaging Department: Introduction to picture archive and communication systems (PACS). Computed Radiography (CR). Image registration and image fusion techniques, 3-D image display

### TRANSFERABLE SKILLS:

Problem solving. Investigative skills. Mathematics. Analytical skills.

### READING LIST:

The Physics of Medical Imaging, Webb.

Introduction to Medical Electronic Applications, Jennings, Flint, Truton and Noakes.

# PX3136 ELECTROMAGNETIC RADIATION DETECTION

## MODULE INFORMATION:

- Autumn semester: 10 credits.
- Module organiser: Prof M J Griffin.
- Deputy Module Organiser: Dr S Doyle.
- Teaching and feedback methods: Lectures 20 x 1 hr, Ex. classes 2 x 1 hr, marked Exercises (5).
- Assessment: Examination 80%. Exercises 20%. [Examination duration: 2 hours]
- Pre-cursors: PX1219 and PX2224.
- Co-requisites: None.
- Pre-requisites: None.

## AIMS OF THE MODULE:

- To introduce the concepts involved in the detection of electromagnetic radiation across the entire spectrum from radio waves to  $\gamma$ -rays.
- To describe and explain the physical processes involved in detection and their application in current technology.
- To explain the fundamental limits to the sensitivity of radiation detection, and how closely they can be approached in practice.
- To note and understand the implications of the fundamental physical and practical limits to the detection process.

## LEARNING OUTCOMES:

The student will be able to:

- Quantify the fundamental limits to electromagnetic (EM) radiation detection.
- Describe the physical mechanisms and the technologies used to detect EM radiation across the spectrum.
- Outline the basics of low-noise signal processing.
- Describe some detectors and techniques used in research and industrial environments.

## OUTLINE SYLLABUS:

Electromagnetic radiation mechanisms from radio to  $\gamma$ -rays: continuum and line radiation; black body radiation; free-free radiation; cyclotron and synchrotron radiation; line radiation - nuclear, electronic, vibrational, rotational, fine structure, Zeeman splitting.

Interaction of radiation with matter: absorption mechanisms and characterisation at radio, infrared, visible-UV, X-ray and gamma-ray wavelengths.

Radiation theory: power, flux, intensity; equation of radiative transfer and applications.

Key concepts in measurement: transduction, responsivity, response time, background, noise, direct and coherent detection.

Noise in photon detection: the ideal photon detector, photon shot noise and wave noise; fundamental limits to sensitivity; responsive and detective quantum efficiencies, NEP, noise temperature, noise spectral density, signal-to-noise; noise mechanisms - thermal, electron shot noise, phonon noise, read noise,  $1/f$  noise, interference; integration; minimising noise.

Radio detection: single-mode detection, basic total power radiometer, heterodyne receiver, spectral line detection, receiver sensitivity.

Infrared and millimetre-wave detection: photoconductive and photovoltaic detectors, infrared imaging; bolometric detectors; superconducting detectors; cryogenic systems.

Visible-UV detection: photoemissive detectors; CCD arrays, adaptive optics.

X-ray and  $\gamma$ -ray detection: photon absorption mechanisms; proportional counters; X-ray spectrometers; low-temperature X-ray calorimeters; scintillators; semiconductor detectors; spark chamber; anticoincidence and veto detection systems.

High-energy particle physics detectors

## TRANSFERABLE SKILLS:

Mathematics. Problem solving. Investigative skills. Analytical skills.

## READING LIST:

Detection of Light from the Ultraviolet to the Submillimeter, G H Rieke  
Suitable texts on particular aspects of the course will be recommended

## PX3206 STATISTICAL MECHANICS

### MODULE INFORMATION:

- Spring semester: 10 credits.
- Module organiser: Prof M G Edmunds.
- Deputy Module Organiser: Dr M Elliott.
- Teaching and feedback methods: Lectures 20 x 1 hr, Workshops 2 x 1 hr, marked Exercises.
- Assessment: Examination 80%. Coursework 20%. [Examination duration: 2 hours]
- Pre-cursors: PX2203.
- Co-requisites: None.
- Pre-requisites: None.

### AIMS OF THE MODULE:

- To provide an introduction of the basic concepts of statistical mechanics.
- To establish the relation between statistical mechanics and thermodynamics.
- To develop the ability to use statistical mechanics to solve and give insight into a wide range of physical problems.

### LEARNING OUTCOMES:

The student will be able to:

- Make inferences based on classical (Maxwell-Boltzmann) and quantum (Fermi-Dirac and Bose-Einstein) statistics.
- Develop and use the statistical mechanical partition function for a system.
- Relate macroscopic thermodynamic properties to the underlying microscopic quantum mechanical energy levels.
- Apply statistical mechanical methods to model a number of classical and quantum systems.

### OUTLINE SYLLABUS:

Basic concepts of statistical mechanics: Revision of elementary statistics. Distribution functions and occupation numbers. Fluctuations.

Thermodynamics and statistical mechanics: Formulation and justification of the thermodynamic picture – particularly the Boltzmann distribution and temperature – by applying statistical mechanics methods. Microcanonical, Canonical and Grand Canonical distributions. Statistical interpretation of entropy and other thermodynamic variables. Partition Functions. Chemical potentials.

Bosons and fermions in statistical mechanics: Maxwell-Boltzmann (classical), Fermi-Dirac and Bose-Einstein statistics. Derivation of properties of ideal gases law by using statistical mechanics methods. Quantum degenerate gases: Degeneracy pressure. The Bose-Einstein condensation.

Applications in condensed matter: Electron gas in solids. The heat capacity of solids. Magnetism – paramagnetic crystals, adiabatic demagnetisation, ferromagnetism and the Ising model.

Other applications: Diatomic molecules. The quantised Planck oscillator. Black-body radiation. Phase changes. Dynamics of star clusters.

Fluids: Phase space. Boltzmann kinetic equation for classical particles. Equilibrium distributions and kinetic equations. General ideas and concepts of hydrodynamics.

### TRANSFERABLE SKILLS:

Mathematics. Problem solving. Investigative skills. Analytical skills.

### Reading List:

Statistical Mechanics: A Survival Guide, A M Glazer and J S Walk (Oxford 2001).

Detailed lecture notes, exercise solutions and reading suggestions will be made available during the course.

A deep, but challenging, source is Statistical Mechanics, Vol 5 of Course of Theoretical Physics, Paragraphs 1-60 (first 150-170 pages), L D Landau and E M Lifshitz. (Butterworth-Heinmann).

## PX3211 ADVANCED MATHEMATICAL PHYSICS

### MODULE INFORMATION:

- Spring semester: 10 credits.
- Module organiser: Dr M Elliott.
- Deputy Module Organiser: Dr E A Muljarov.
- Teaching and feedback methods: Lectures 22 x 1 hr, marked Exercises.
- Assessment: Examination 80%. Coursework 20%. [Examination duration: 2 hours]
- Pre-cursors: PX3104.
- Co-requisites: None.
- Pre-requisites: None.

### AIMS OF THE MODULE:

- To develop understanding in the use of advanced techniques of mathematical physics.
- To develop proficiency in using these techniques.
- To apply these methods to physical problems.

### LEARNING OUTCOMES:

The student will be able to:

- Describe and apply the concept of complex functions of a complex variable, analytic functions and the singularities of poles and branch cuts.
- Derive Cauchy's integral theorem and the residue theorem.
- Use the residue theorem to evaluate a variety of integrals.
- Derive and apply the concept of functionals, variational methods and the use of constraints to a range of problems.
- Derive and use Lagrangian and Hamiltonian mechanics.
- Solve unseen problems based on the techniques studied in this course.

### OUTLINE SYLLABUS:

Complex functions of a complex variable: Concept of functions of a complex variable, mapping, singularities, poles and branch cuts. Differentiation and the Cauchy-Riemann equations, analytic functions. Power series, Taylor series, analytic continuation. Laurent series, orders of poles, residues.

Integrals in the complex plane: Cauchy's theorem and the residue theorem. Cauchy's integral formula. Evaluation of integrals with the residue theorem, including integrals round circular contours and integrals along the real axis. Application to black hole quasi-normal modes and gravitational waves.

Calculus of variations: Extrema of real functions of one, two and more variables. Extrema with constraints. Concept of a functional and its variation. Stationary points and Euler-Lagrange equations. Functional constraints and isoperimetric problems.

Lagrange and Hamiltonian mechanics: Concepts of action, Lagrangian and Hamiltonian. Variational derivation of the Lagrange equations of motion, Hamilton's equations. Canonical variables, canonical transformations, Poisson brackets. Links with continuous systems, physical fields, and quantum mechanics.

### TRANSFERABLE SKILLS:

Mathematics. Problem solving. Investigative skills. Analytical skills.

### READING LIST:

Mathematical Methods for Physics and Engineering, K F Riley, M P Hobson and S J Bence (Cambridge University Press).

Mathematical Methods for Physicists, G B Arfken and H J Weber (Academic Press).

Course notes available on <http://www.astro.cf.ac.uk/undergrad/module/PX3211>

## PX3212 STELLAR PHYSICS

### MODULE INFORMATION:

- Spring semester: 10 credits.
- Module organiser: Prof A P Whitworth.
- Deputy Module Organiser: Prof D Ward-Thompson.
- Teaching and feedback methods: Lectures 22 x 1 hr, Exercise classes 11 x 1hr.
- Assessment: Examination 100%. [Examination duration: 2 hours]
- Pre-cursors: PX1116, PX1207 and PX1216.
- Co-requisites: None.
- Pre-requisites: None.

### AIMS OF THE MODULE:

- To establish the fundamentals of the constitutive physics, structure and evolution of single stars.
- To develop an understanding of the workings of an equilibrium star, energy generation and transport, hydrostatic balance and the evolutionary stages of a star.

### LEARNING OUTCOMES:

The student will be able to:

- Describe from first principles the physics of the inner workings of an isolated, spherically symmetric, equilibrium star.
- Use equations describing the physics of hydrostatic balance, equations of state, nuclear energy generation and radiative and convective energy transport.
- Describe the main features of the evolutionary stages of a star from formation to white dwarf or supernova.
- Discuss stellar stability and its underlying causes.

### OUTLINE SYLLABUS:

Microphysics of the stellar interior: Elemental composition and ionisation balance. Local thermodynamic equilibrium and local functions of state. Pressure: basic kinetic theory, ideal gas, radiation, momentum states, non-relativistic and relativistic electron-degeneracy pressure. Nuclear reactions, binding energy, quantum-mechanical tunnelling, energy generation rates for the pp-chain, CN-cycle and 3-alpha process. Opacity: absorption, emission and scattering. Ratio of specific heats.

Continuum physics of the stellar interior: Conservation of mass. Gravitational acceleration. Hydrostatic balance. Energy conservation. Radiative energy transport: basic parameters and equations, the diffusion approximation, the Rosseland-mean opacity,  $H^-$ -opacity, Kramers opacity, electron-scattering opacity. Convective energy transport: Schwarzschild criterion, mixing-length theory, adiabatic approximation.

Global stellar structure: Gravity: potential energy, freefall, tides. Rotational and magnetic distortions. Polytropes, including physical interpretation. Virial theorem. Time-scales: dynamical, radiative, gravitational, nuclear, evolutionary. Energy budget. Which source of pressure dominates? Quasistatic evolution and stability. Kelvin-Helmholtz contraction. Homologous sequences and the Eddington Limit. Degenerate stars: white and black dwarves.

Global stellar evolution: Length- and time-scales. Mass dependence. Critical thermodynamic processes. Star formation and final states.

### TRANSFERABLE SKILLS:

Mathematics. Problem solving. Investigative skills. Analytical skills.

### READING LIST:

Printed text with embedded questions provided by the lecturer.

## PX3214 SOUND SYNTHESIS

### MODULE INFORMATION:

- Spring semester: 10 credits.
- Module organiser: Dr B E Richardson.
- Deputy Module Organiser: Dr D I Westwood.
- Teaching and feedback methods: Lectures, demonstrations and studio work 11 x 4 hr. Marked assignments and project work.
- Assessment: Continuous assessment (including essay) 100%.
- Pre-cursors: Preferably requires rudimentary music knowledge (check with MO).
- Co-requisites: None.
- Pre-requisites: None.

### AIMS OF THE MODULE:

- To introduce analogue and digital techniques of sound synthesis.
- To provide an understanding and practical working knowledge of techniques and equipment used in sound synthesis.
- To introduce the physical characteristics of musical sounds and those features of importance to the perception of sounds.

### LEARNING OUTCOMES:

The student will be able to:

- Describe the mechanisms by which conventional musical instruments create musical sounds and identify those features of a waveform which are important for perception, including its time-varying spectral content.
- Demonstrate a general awareness of electronic and computer generated sound.
- Demonstrate an ability to use studio equipment by undertaking practical assignments.
- Show competency in using computational methods to analyse and synthesise musical sounds.
- Undertake a short project to demonstrate the use of a computer for sequencing and/or more general programming.
- Use studio equipment to generate a piece of creative music.

### OUTLINE SYLLABUS:

Musical sounds: Envelopes, waveforms and spectra. Transients. The harmonic series. The human auditory system and some basic psychoacoustics.

Analogue techniques: Modulation techniques including: AM, FM, RM and frequency shifting.

Voltage control: Use of VCS3 synthesiser. Problems of notation. Examples of synthesised music.

Digital techniques: Effects of amplitude and time quantisation. 'MIDI' systems. Stochastic music-generating systems. Questions of human and machine creativity. Simple digital processing of signals.

Audition: The use of Audition for generating, analysing and editing musical sounds.

Practical work: The module is assessed 100% from coursework, which comprises five specified assignments, one essay and a short project. Open access is given to the Sound Studio for undertaking individual study and completion of practical work.

### TRANSFERABLE SKILLS:

Communications skills. Investigative skills. Mathematics. Computing skills. Personal skills. Analytical skills.

### READING LIST:

Sound Synthesis and Sampling, M Russ (Focal Press, 1996).

The Art of Digital Audio, J Watkinson, 2nd Edn (Focal Press, 1994).

Sound Recording Practice, J Borwick, 4th Edn (Oxford University Press, 2001).

## PX3226 PHYSICS OF SEMICONDUCTOR DEVICES

### MODULE INFORMATION:

- Spring semester: 10 credits.
- Module organiser: Prof M J Griffin.
- Deputy Module Organiser: Dr P Hargrave.
- Teaching and feedback methods: Lectures 22 x 1 hr, marked Exercises (5).
- Assessment: Examination 80%. Coursework 20%. [Examination duration: 2 hours]
- Pre-cursors: PX2223 and PX3109.
- Co-requisites: None.
- Pre-requisites: None.

### AIMS OF THE MODULE:

- To establish a framework for understanding of the physics of semiconducting materials.
- To develop a basic knowledge of the physics of typical semiconductor devices, as well as some of their practical applications.

### LEARNING OUTCOMES:

The student will be able to:

- Explain and interpret the energy band structure of semiconductors.
- Relate the band structures of real semiconductors to their physical properties.
- Describe the types of charge carrier, their energies and their spatial distributions in semiconductors and semiconductor devices.
- Recall and use the key equations governing device physics and apply these to important systems.
- Describe the operating principles of several types of device.
- Describe the main processes used in material growth and device fabrication.

### OUTLINE SYLLABUS:

Revision: Essential atomic physics.

Electronic properties of semiconductors: Band structure, effective mass, densities of states of bulk material, quantum wells and quantum wires. Fermi distribution and Fermi level.

Intrinsic and extrinsic semiconductors: Donor and acceptor impurities, energy band diagrams; generation and recombination.

Transport properties: Drift and mobility; conductivity and resistivity; the Hall effect; diffusion; the continuity equation; minority carrier injection (steady state and transient).

Semiconductor Manufacture: Fabrication of semiconductor wafers; epitaxial growth – MBE and MOVPE; methods of semiconductor device processing.

Semiconductor devices: The P-N junction, metal-semiconductor contacts, photovoltaic solar cells, bipolar transistors, junction and MOS field effect transistors, heterojunctions, transistor amplifiers and switches, negative conductance and microwave devices.

### TRANSFERABLE SKILLS:

Problem solving. Investigative skills. Mathematics. Analytical skills.

### READING LIST:

Solid State Physics, 2nd Edition. J R Hook and H E Hall (Wiley, 1991)

Solid State Electronic Devices, B G Streetman and S Banerjee (Prentice Hall, 2000)

Semiconductor Devices: Physics and Technology, 2nd edition, S M Sze (Wiley 2002)

Semiconductor Devices, K Kano (Prentice Hall, 1998)

Semiconductor Devices, M J Cooke (Prentice Hall, 1990)

Introduction to Solid State Devices, L Ibbotson (Arnold, 1997)

# PX3231 PHYSICAL COSMOLOGY

## MODULE INFORMATION:

- Spring semester: 10 credits.
- Module organiser: Dr H L Gomez.
- Deputy Module Organiser: Dr J I Davies.
- Teaching and feedback methods: Lectures 22 x 1 hr, marked Exercises.
- Assessment: Examination 80%, Continuous Assessment 20%. [Examination duration: 2 hours]
- Pre-cursors: PX1116, PX1207 and PX1216.
- Co-requisites: None.
- Pre-requisites: None.

## AIMS OF THE MODULE:

- To introduce the basic mathematics and physics of the Big Bang theory.
- To discuss issues of contemporary cosmology, including the cosmic background radiation, the concordance model, dark matter and dark energy.

## LEARNING OUTCOMES:

The student will be able to:

- Describe cosmological concepts and definitions including the geometry of the universe.
- Derive from first principles the concept of cosmological redshift.
- Derive the Robertson-Walker metric and use this to derive Hubble's Law and to determine the size of the observable universe.
- Derive Friedmann's equation and use it to determine the properties of the universe at different cosmic epochs, for different values of the key cosmological parameters such as  $k$  and  $\Lambda$ .
- Describe and critique the latest techniques used to determine the age of the Universe, distance scales and the mass of astrophysical systems.
- Use an observational toolkit to determine the distance and angular size of distant objects given a cosmological model.
- Describe how the cosmological model affects the power spectrum of the CMB.
- Predict the abundance of elements formed in Big Bang nucleosynthesis and compare with present-day observations.
- Describe in words and mathematically a timeline from the Big Bang to present day.
- Critically discuss the evidence for different cosmological models and problems in contemporary cosmology, including the CMB, Big Bang theory, the concordance model, dark matter and energy.

## OUTLINE SYLLABUS:

The big questions: What do we know about the universe? The cosmological principle; derivation of Hubble's law from the cosmological principle; the idea of a metric space.

Curved space: Comoving observers; the Robertson-Walker metric; closed and open universes; the Hubble constant again.

Cosmic dynamics: Birkhoff's theorem; Einstein's greatest mistake; the Friedmann equation; solutions of equations; the density constant; first attempt to determine the structure of the universe experimentally.

The hot big bang: The redshift; the microwave background; the hot big bang; the radiation and matter dominated eras; peculiar motions.

The origin of the elements: Origin of helium; determining the density of baryons; deuterium at high redshift.

The concordance model: The BOOMERANG project. The supernova cosmology project. The cosmic microwave project. WMAP results.

The distance ladder: The HST key-project to determine the Hubble constant; the Tully-Fisher and Faber-Jackson method; a final (?) value for  $H_0$ ; methods for determining the age of the universe.

Nucleocosmochronology: Isochrone fitting to clusters; white dwarf luminosity function; comparison to age obtained from  $H_0$ .

Extensions to the Big Bang theory: Inflation; the mysterious dark energy and dark matter.

The flaky stuff: The anthropic principle; the "multiverse"; Dirac's large number coincidence.

## TRANSFERABLE SKILLS:

Mathematics. Problem solving. Investigative skills. Analytical skills. Communications skills.

## READING LIST:

Printed text and questions provided by lecturer.

An Introduction to Modern Cosmology (2nd Ed.). A R Liddle. John Wiley.

## PX3233 LASER PHYSICS AND APPLICATIONS

### MODULE INFORMATION:

- Spring semester: 10 credits.
- Module organiser: Dr P M Smowton.
- Deputy Module Organiser: Prof W W Langbein.
- Teaching and feedback methods: Lectures 18 x 1 hr, marked Exercises and literature-based research exercise.
- Assessment: Examination 80%. Coursework 20%. [Examination duration: 2 hours]
- Pre-cursors: None.
- Co-requisites: None.
- Pre-requisites: None.

### AIMS OF THE MODULE:

- To develop an understanding of the fundamental physics of lasers.
- To provide an awareness of some applications of lasers and the associated physics.
- To introduce students to laser device design and performance.

### LEARNING OUTCOMES:

The student will be able to:

- Describe the interaction of light with matter using classical and semi-classical theories, and express this mathematically.
- Evaluate the conditions necessary for coherent optical amplification, and describe how this may be achieved in various laser systems.
- Describe the effect of optical cavities upon the laser radiation and explain laser threshold.
- Formulate an analytical description of laser operation using differential equations for the electron and photon populations within a laser.
- Explain the meaning of Q-switching and mode-locking within lasers, and describe how they lead to short pulse operation.
- Demonstrate an understanding of specific examples of laser devices and applications.

### OUTLINE SYLLABUS:

Introduction to laser physics: Classical electron oscillator model. Fundamental optical processes: absorption, spontaneous emission, stimulated emission.

Basic principles of lasers: Gain processes, optical feedback, spectral linewidth.

Laser performance: Frequency and intensity distributions, temporal behaviour, pulsed systems.

Laser systems: Solid, liquid and gaseous systems.

Applications of lasers: CD players, optical fibre communications, gas sensing and LIDAR, medical applications.

### TRANSFERABLE SKILLS:

Problem solving. Investigative skills. Mathematics. Analytical skills.

### READING LIST:

Optoelectronics, J Wilson and J F B Hawkes.

Laser Fundamentals, W T Silfvast.

Lasers, A Siegman.

Optics, E Hecht, 3rd Edn (Addison Wesley).

## PX3234 MEDICAL ULTRASOUND

### MODULE INFORMATION:

- Spring semester: 10 credits.
- Module organiser: Dr R J Morris.
- Deputy Module Organiser: Dr K Wells.
- Teaching and feedback methods: Lectures 22 x 1 hr, Demonstrations, Exercises.
- Assessment: Examination 100%. [Examination duration: 2 hours]
- Pre-cursors: PX1218.
- Co-requisites: None.
- Pre-requisites: None.

### AIMS OF THE MODULE:

- To provide an understanding of the principles and applications of ultrasound in medicine.
- To give a working knowledge of the construction and operation of diagnostic ultrasound equipment and ultrasound safety issues.
- To give an overview of the particular features of diagnostic ultrasound in the main application areas.

### LEARNING OUTCOMES:

The student will be able to:

- Explain the wave nature of ultrasound and describe the interactions of ultrasound with tissue.
- Define the Doppler effect and understand its application to medical ultrasound.
- Design a basic ultrasound transducer and describe the principles of a pulse-echo imaging system.
- Describe the basic design of continuous wave and colour-flow Doppler instruments.
- Describe the artefacts that occur in echo and Doppler imaging.
- Explain the characteristics of blood flow in normal and diseased states.
- Describe the general applications of ultrasound imaging, and the methods of improving those images, including the use of contrast agents.
- Explain the basic principles of echocardiography.
- Discuss the value of 3D and 4D imaging, the use of ultrasound in obstetric and gynaecological imaging, and the safety implications of ultrasound.

### OUTLINE SYLLABUS:

The nature of ultrasound: The wave concept as applied to ultrasound. Velocity, power and energy. Acoustic impedance. Interactions of ultrasound with tissue. The Doppler effect. Basic principles of Doppler ultrasound.

Transducers and instrumentation: Generation of ultrasound. Transducer design. Manipulation of ultrasound waves. B-mode systems. CW devices. Colour flow mappers.

Image interpretation: Artefacts in echo and Doppler imaging. Image optimisation. Ultrasound quality assurance.

Vascular ultrasound: Characteristics of blood flow in normal and diseased states. Doppler waveform analysis and pattern recognition. Broad-band Doppler. Vascular applications.

General ultrasound: Applications of ultrasound imaging – abdominal organs, musculoskeletal. Contrast agents. Harmonic imaging. Flash echo techniques.

Cardiac ultrasound: Principles of echocardiography. Phased arrays. M-mode.

Obstetric and gynaecological ultrasound: Features of obstetric and gynaecological ultrasound. Power Doppler. 3D/4D imaging. Safety aspects and bioeffects of medical ultrasound.

### TRANSFERABLE SKILLS:

Problem solving. Investigative skills. Mathematics. Analytical skills.

### READING LIST:

Physics and Instrumentation of Diagnostic Medical Ultrasound, P Fish.

Diagnostic Ultrasonics: Principles and Uses of Instruments, W N McDicken.

Diagnostic Ultrasound: Physics and Equipment. P R Hoskins et al.

Diagnostic Ultrasound: Principles and Instruments: F W Kremkau.

## PX3235 CHAOS AND NON-LINEAR SYSTEMS

### MODULE INFORMATION:

- Spring semester: 10 credits.
- Module organiser: Dr C C Matthai.
- Deputy Module Organiser: Prof P A R Ade.
- Teaching and feedback methods: Lectures 18 x 1 hr, Exercises 4 x 1 hr, marked Exercises.
- Assessment: Examination 80%. Continuous assessment 20%. [Examination duration: 2 hours]
- Pre-cursors: PX1116, PX1216 and PX2104.
- Co-requisites: None.
- Pre-requisites: None.

### AIMS OF THE MODULE:

- To introduce the basic methods for the understanding and characterising the behaviour of linear and non-linear dynamical systems.
- To use examples and computer exercises to illustrate the physics of non-linear and chaotic systems.

### LEARNING OUTCOMES:

The student will be able to:

- Recall and evaluate physical examples of non-linear behaviour.
- Demonstrate an appreciation of the mathematical methods used for studying dynamical systems.
- Describe the methods used for characterising and measuring chaotic systems.
- Solve unseen problems, both analytical and computational, on non-linear, chaotic and fractal systems.

### OUTLINE SYLLABUS:

Linear dynamical systems: First- and second-order continuous and discrete systems. Predator-prey models and applications in economics.

Non-linear coupled differential equations: Solutions of non-linear coupled differential equations, including the damped driven pendulum, the Duffing oscillator and the Lorenz model of weather.

Characterising chaos: Phase maps and Poincare sections, power spectra, Lyapunov exponents. Strange attractors.

Maps: Graphical iteration of the logistic map. Fixed points and stability. Bifurcations, period doubling.

Period-3 windows and intermittency. Quadratic maps and universal behaviour. 2-D maps.

Measures of chaos. Kolmogorov entropy, Information and Correlation dimensions.

Routes to chaos: Period doubling and intermittency routes to chaos.

Fractals: Hausdorff capacity dimension of fractal sets. Cantor set, Koch curve, fat fractals. Mandelbrot and Julia sets. Examples of fractals in physics.

### TRANSFERABLE SKILLS:

Mathematics. Problem solving. Investigative skills. Analytical skills.

### READING LIST:

## PX3237 NUCLEAR AND PARTICLE PHYSICS

### MODULE INFORMATION:

- Spring semester: 10 credits.
- Module organiser: Prof P Coles.
- Deputy module organiser: Dr J I Davies.
- Teaching and feedback methods: Lectures 22 x 1 hr, Exercises.
- Assessment: Examination 100%. [Examination duration: 2 hours]
- Pre-cursors: PX2101 and PX2224.
- Co-requisites: None.
- Pre-requisites: None.

### AIMS OF THE MODULE:

- To develop a basic understanding of nuclear physics, using quantum mechanical concepts.
- To apply this to nuclear stability and nuclear reactions.
- To introduce the basic concepts and methods of particle physics.
- To outline the Standard Model for particle properties and interactions.

### LEARNING OUTCOMES:

The student will be able to:

- Describe the properties of the nucleus in terms of fundamental forces and quantum mechanics and apply this to nuclear stability.
- Give an account of, and be able to apply, the systematics of decay processes and nuclear reactions.
- Describe the nature and properties of the elementary forces and particles.
- Explain the importance of symmetries in determining conservation laws.
- Explain the consequences of boson exchange in the mediation of forces.
- Recognise allowed and forbidden processes.
- Use natural units, and be able to calculate the kinematics of 2-body interactions and decays.
- Give an account of the basic principles of modern particle physics accelerators and detectors.
- Solve unseen problems based on the material in this course.

### OUTLINE SYLLABUS:

Properties of the nucleus: Atomic number, mass number, nuclear mass, binding energy, size and shape.

Nuclear forces and binding energy: Binding energy of the deuteron, and its implications for nuclear forces, trends in nuclear binding energy, liquid drop model and semi-empirical mass formula.

Nuclear stability and reactions: Stability to alpha-decay, barrier penetration, stability to beta-decay and the existence of the neutrino. Scattering theory. Cross-sections and reaction rates in nuclear reactions.

Particle physics basics: Natural units. Coupling constants. Cross sections. Matrix Elements. Fundamental Interactions.

The standard model: Quarks and Leptons. Antimatter. Conservation laws. Gauge Bosons. Electroweak unification.

Quark States: Baryons and mesons. Existence of the colour charge. Isospin. Hadron conservation laws.

Feynmann Diagrams: Basics vertices. Matrix elements. QED processes. Electron-positron collisions.

Quark jets. Evidence for colour. Weak interactions. Lepton symmetries. Quark mixing.

Symmetries: Parity (P), Charge-conjugation (C), CP and CPT. Parity violation and CP violation.

Beyond the Standard Model: Grand Unified Theories. Supersymmetry. The Planck scale. Theories of Everything.

### TRANSFERABLE SKILLS:

Problem solving. Investigative skills. Mathematics. Analytical skills.

### READING LIST:

Nuclear Physics: An Introduction to Nuclear Physics, 2nd Edn, W N Cottingham and D A Greenwood (Cambridge University Press, 2001).

Particle Physics: Ch 1 – 6 of *Particle Physics* by B.R. Martin & G. Shaw 2<sup>nd</sup> Edition Wiley 1997. For a light, but useful, introduction try *The Particle Adventure* on <http://durpdg.dur.ac.uk/lbl/particleadventure/index.html>

## PX3315 PHYSICS PROJECT

### MODULE INFORMATION:

- Autumn and Spring semester: 20 credits.
- Module organiser: Dr B E Richardson.
- Deputy Module Organiser: Prof D Ward-Thompson.
- Teaching and feedback methods: Supervised individual project work. Marked oral and written work.
- Assessment: Continuous assessment and reports 100%.
- Pre-cursors: None.
- Co-requisites: None.
- Pre-requisites: None.

### AIMS OF THE MODULE:

- To develop investigative skills.
- To provide experience of research work in physics and develop the skills needed for planning, organising and executing projects.
- To enhance verbal and written communications skills.
- To learn to be self motivated and work independently.

### LEARNING OUTCOMES:

The student will be able to:

- Plan, organise and conduct a research project.
- Make use of the library and other facilities to undertake private study in subject areas related to the theme of the project.
- Analyse critically data acquired during the course of conducting the project.
- Write an extended report and give a short presentation on their work.
- Appraise health and safety issues connected with their project work.

### OUTLINE SYLLABUS:

A range of project topics are available. Projects can be practically or theoretically biased and might involve computational work. Most students work alone or in pairs, but the reporting and analysis of data is always done individually.

The project work extends over two semesters. At the end of the Autumn semester, students submit an interim report of their work and are assessed in an oral examination (viva) by their supervisor and an assessor. The full report is submitted towards the end of the Spring Semester. Students also give a conference-style presentation on their work to a group of assessors and other students.

### TRANSFERABLE SKILLS:

Communications skills. Investigative skills. Personal skills. Analytical skills. Ethical behaviour. They may also include some or all of the following: problem solving; experimental skills; computing skills; mathematics.

### READING LIST:

Directed reading by project supervisor.

## PX3316 ASTROPHYSICS PROJECT

### MODULE INFORMATION:

- Autumn and Spring semester: 20 credits.
- Module organiser: Dr B E Richardson.
- Deputy Module Organiser: Prof D Ward-Thompson.
- Teaching and feedback methods: Supervised individual project work. Marked oral and written work.
- Assessment: Continuous assessment and reports 100%.
- Pre-cursors: None.
- Co-requisites: None.
- Pre-requisites: None.

### AIMS OF THE MODULE:

- To develop investigative skills.
- To provide experience of research work in astrophysics and develop the skills needed for planning, organising and executing projects.
- To enhance verbal and written communications skills.
- To learn to be self motivated and work independently.

### LEARNING OUTCOMES:

The student will be able to:

- Plan, organise and conduct a research project.
- Make use of the library and other facilities to undertake private study in subject areas related to the theme of the project.
- Analyse critically data acquired during the course of conducting the project.
- Write an extended report and give a short presentation on their work.
- Appraise health and safety issues connected with their project work.

### OUTLINE SYLLABUS:

A range of project topics are available. Projects can be practically or theoretically biased and might involve computational work. Most students work alone or in pairs, but the reporting and analysis of data is always done individually.

The project work extends over two semesters. At the end of the Autumn semester, students submit an interim report of their work and are assessed in an oral examination (viva) by their supervisor and an assessor. The full report is submitted towards the end of the Spring Semester. Students also give a conference-style presentation on their work to a group of assessors and other students.

### TRANSFERABLE SKILLS:

Communications skills. Investigative skills. Personal skills. Analytical skills. Ethical behaviour. They may also include some or all of the following: problem solving; experimental skills; computing skills; mathematics.

### READING LIST:

Directed reading by project supervisor.

## **PX3317 MEDICAL PHYSICS PROJECT**

### **MODULE INFORMATION:**

- Autumn and Spring semester: 30 credits.
- Module organiser: Dr B E Richardson.
- Deputy Module Organiser: Prof D Ward-Thompson.
- Teaching and feedback methods: Supervised individual project work. Marked oral and written work.
- Assessment: Continuous assessment and reports 100%.
- Pre-cursors: None.
- Co-requisites: None.
- Pre-requisites: None.

### **AIMS OF THE MODULE:**

- To develop investigative skills.
- To provide experience of research work in medical physics and develop the skills needed for planning, organising and executing projects.
- To enhance verbal and written communications skills.
- To learn to be self motivated and work independently.

### **LEARNING OUTCOMES:**

The student will be able to:

- Plan, organise and conduct a research project.
- Make use of the library and other facilities to undertake private study in subject areas related to the theme of the project.
- Analyse critically data acquired during the course of conducting the project.
- Write an extended report and give a short presentation on their work.
- Appraise health and safety issues connected with their project work.

### **OUTLINE SYLLABUS:**

A range of project topics are available. Projects can be practically or theoretically biased and might involve computational work. Most students work alone or in pairs, but the reporting and analysis of data is always done individually. Medical physics projects are usually conducted in a medical physics research environment.

The project work extends over two semesters. At the end of the Autumn semester, students submit an interim report of their work and are assessed in an oral examination (viva) by their supervisor and an assessor. The full report is submitted towards the end of the Spring Semester. Students also give a conference-style presentation on their work to a group of assessors and other students and have a second viva on the basis of their final report.

### **TRANSFERABLE SKILLS:**

Communications skills. Investigative skills. Personal skills. Analytical skills. Ethical behaviour. They may also include some or all of the following: problem solving; experimental skills; computing skills; mathematics.

### **READING LIST:**

Directed reading by project supervisor.

# PX4106 INTERSTELLAR MEDIUM AND STAR FORMATION

## MODULE INFORMATION:

- Autumn semester: 10 credits.
- Module organiser: Prof A P Whitworth.
- Deputy Module Organiser: Prof D Ward-Thompson.
- Teaching and feedback methods: Lectures 22 x 1 hr, Exercises classes 14 x 1hr.
- Assessment: Examination 100%. [Examination duration: 2 hours]
- Pre-cursors: PX3110, PX3121, PX3206 and PX3212.
- Co-requisites: None.
- Pre-requisites: None.

## AIMS OF THE MODULE:

- To introduce the physics of the interstellar medium and star formation, and how they are observed.
- To provide an understanding of thermal balance in the interstellar medium, radiative transfer, the dynamics of interstellar gas, interstellar clouds and the physics of star formation.

## LEARNING OUTCOMES:

The student will be able to:

- Describe the location and evolution of the interstellar medium in a galactic context.
- Explain the physics of thermal and ionisation balance in the interstellar medium.
- Use the equations of statistical equilibrium and radiative transfer to interpret observations of interstellar gas and dust in terms of its physical state.
- Describe the basic equations for the explanation of an HII region, or a stellar wind bubble, isothermal and adiabatic shocks, steady-state accretion, and the collapse of a protostar.
- Manipulate notions like the Initial Mass Function to obtain the properties of star clusters.
- Expound the basic physics of star formation and identify outstanding problems.

## OUTLINE SYLLABUS:

The interstellar medium in a galactic context: Location, different phases, radial variations, spiral structure, feedback from star formation, astration.

Microphysics of the interstellar medium: Heating and ionisation, collisional and radiative processes, cooling and recombination, thermalisation and equipartition, molecule formation and destruction, dust formation, thermal and charge balance for dust grains.

Phases of interstellar gas: Thermal and ionisation balance, the general interstellar medium, HI clouds, intercloud medium, coronal gas, HII regions, molecular clouds.

Diagnostic techniques for the interstellar medium: Equivalent width and curve of growth, recombination lines and emission measure, free-free radiation, 21cm radiation, CO emission, forbidden-line ratios, the extinction curve, star counts, reflection nebulae and infrared sources.

Star formation: Sites of star formation, the initial-mass function, gravitational instability in 3D and 2D, fragmentation, the minimum and maximum stellar masses, Hayashi and Henyey tracks, accretion discs and bipolar outflows.

Dynamics: Time-dependent Virial Theorem, HII regions, ionisation fronts, shock fronts (isothermal and adiabatic), stellar-wind bubbles, supernova remnants, spiral shocks, Bondi accretion.

## TRANSFERABLE SKILLS:

Mathematics. Problem solving. Investigative skills. Analytical skills.

## READING LIST:

Printed text provided by the lecturer.

**MODULE INFORMATION:**

- Spring semester: 10 credits.
- Module organiser: Prof P D Mauskopf.
- Deputy Module Organiser: Dr P J Sutton.
- Teaching and feedback methods: Lectures 22 x 1 hr, Exercises.
- Assessment: Examination 100%. [Examination duration: 2 hours]
- Pre-cursors: PX2101, PX2104.
- Co-requisites: None.
- Pre-requisites: None.

**AIMS OF THE MODULE:**

- To provide an understanding of the concepts of quantum mechanics, with an emphasis on operator formalism.
- To apply this formalism to basic problems and to show that it leads to a unified approach.
- To develop approximate solutions to real physical problems in atomic and molecular physics.

**LEARNING OUTCOMES:**

The student will be able to:

- Describe and apply the concepts of quantum mechanical states and observations in terms of operators and use Dirac notation.
- Use creation and annihilation operators in the simple harmonic oscillator problem and demonstrate their wider significance for bosons.
- Apply operator techniques and ladder operators to angular momentum and explain the role of spin.
- Apply time-independent and time-dependent perturbation theory to simple problems and apply the variational method to solutions of the Schrödinger equation.
- Solve unseen problems based on the techniques studied in this course.

**OUTLINE SYLLABUS:**

Quantum mechanical states: States as vectors in Hilbert space. Observations as operators acting on these states. Use of Dirac notation. Commuting and non-commuting observables, the use of commutators and uncertainty principles.

Harmonic oscillator: Creation and annihilation operators, and direct solution of the harmonic oscillator problem. Application of operator methods to boson problems in general.

Angular momentum: Angular momentum operators and their commutation relations. Ladder operators and the eigenvalues of angular momentum operators - the possibility of spin. Pauli spin matrices, and Stern-Gerlach experiments. Combining angular momenta.

Perturbation theory: Applications of time-dependent perturbation theory to transition rates and Fermi's golden rule.

Variational methods: Use of variational methods for finding approximate solutions of the Schrödinger equation. Matrix methods for finding solutions. Application to many-electron atoms, and diatomic molecules.

**TRANSFERABLE SKILLS:**

Mathematics. Problem solving. Investigative skills. Analytical skills.

**READING LIST:**

Quantum Mechanics, E Merzbacher (J Wiley, New York, 1998).

More details of the course, with notes, problems, and module answers are given in <http://www.astro.cf.ac.uk/undergrad/module/PX4114>

# PX4115 GENERAL RELATIVITY AND RELATIVISTIC ASTROPHYSICS

## MODULE INFORMATION:

- Autumn semester: 20 credits.
- Module organiser: Dr P J Sutton.
- Deputy Module Organiser: Prof B S Sathyaprakash.
- Teaching and feedback methods: Lectures 44 x 1 hr, Exercises 11 x 1 hr, marked exercises.
- Assessment: Examination 80%. Continuous assessment 20%. [Examination duration: 3 hours]
- Pre-cursors: PX3104 and PX3211.
- Co-requisites: None.
- Pre-requisites: None.

## AIMS OF THE MODULE:

- To provide a thorough introduction to the theory of general relativity, with applications to spherical stars, black holes and gravitational waves.
- To develop skills in the use of tensor calculus and differential geometry.

## LEARNING OUTCOMES:

The student will be able to:

- Demonstrate understanding of some simple consequences of special relativity (e.g. special relativistic Doppler effect, composition of velocities).
- Describe the equivalence principle and how gravity can be interpreted as the curvature of spacetime.
- Describe the three basic tests of general relativity (perihelion precession of Mercury, bending of light by the sun, and gravitational red-shift).
- Write down and solve the geodesic equation in some simple cases.
- Write down and interpret the metric outside a spherical star or black hole.
- Derive the potential that governs the trajectory of a particle or light ray in the Schwarzschild geometry and solve for the trajectory in some simple cases.
- Describe how an interferometric gravitational-wave antenna functions.
- Carry out basic operations on tensor and tensor components (e.g. addition and subtraction, inner and outer products, contraction, transformation of tensor components, covariant derivatives, parallel transport).
- Compute the curvature tensor, Ricci tensor, curvature scalar, and Einstein tensor given the metric of spacetime.
- Write down and interpret the Einstein equation.
- Compute the gravitational-wave luminosity for some simple sources, like a compact binary system or rotating ellipsoidal body.

## OUTLINE SYLLABUS:

Introduction: Importance of gravitational physics. Geometry as physics. Space and time in Newtonian physics. Review of variational principles.

Review of special relativity: Fundamental postulates. Spacetime diagrams. Time dilation. Length contraction. 4-vectors. Light rays.

Gravity as geometry: Equivalence principle. Gravitational redshift. Description of curved spacetime. Metric. Vectors. Geodesics.

Spherical Stars: Schwarzschild geometry. Gravitational redshift. Particle trajectories and light ray orbits.

Schwarzschild black holes: Gravitational collapse. Kruskal-Szekeres coordinates. Astrophysical black holes.

Gravitational waves: Linearized gravity. Detecting gravitational waves. Laser interferometers.

Differential Geometry: Tensor algebra. Covariant derivative. Geodesic deviation. Riemann curvature tensor. Vacuum Einstein equation.

Sources of curvature: Stress-energy tensor. Conservation of energy-momentum. Production of gravitational waves. Quadrupole formula.

## TRANSFERABLE SKILLS:

Mathematics. Problem solving. Investigative skills. Analytical skills.

## READING LIST:

An Introduction to Einstein's General Relativity, J B Hartle (Addison Wesley, 2003)

## PX4117 COMPUTATIONAL PHYSICS

### MODULE INFORMATION:

- Autumn semester: 10 credits.
- Module organiser: Dr C C Matthai.
- Deputy Module Organiser: Dr B E Richardson.
- Teaching and feedback methods: Computing-based classes and lectures. Marked assignments.
- Assessment: Coursework 100%.
- Pre-cursors: PX1116, PX1216 and PX2104. (PX2116 would be an advantage.)
- Co-requisites: None.
- Pre-requisites: None.

### AIMS OF THE MODULE:

- To apply computational techniques to solving problems in different areas of physics.
- To develop an appreciation of the use of numerical simulations in modelling physical processes.

### LEARNING OUTCOMES:

The student will be able to:

- Demonstrate the ability to set up a problem in a form in order to solve it numerically.
- Demonstrate the ability to set up simulation of a physical process.
- Write a formal report describing and presenting data from the application of a numerical technique (algorithm) for solving a differential equation or an integral describing a physical quantity (e.g. applying the adaptive step method to trace the trajectory of a spacecraft sent to the moon).
- Write a formal report to describe the results of a simulation of a physical process (e.g. the Ising model of phase transitions in two dimensions).

### OUTLINE SYLLABUS:

Numerical simulations will be performed on systems in the fields of:

- Fractals and non-linear systems
- Classical mechanics
- Quantum theory
- Condensed matter

### TRANSFERABLE SKILLS:

Computing skills. Problem solving. Mathematics. Investigative skills. Analytical skills.

### READING LIST:

**MODULE INFORMATION:**

- Spring semester: 10 credits.
- Module organiser: TBA.
- Deputy Module Organiser: Prof P Blood.
- Teaching and feedback methods: Lectures 20 x 1 hr, Exercises, marked exercises.
- Assessment: Examination 85%. Continuous assessment 15%. [Examination duration: 2 hours]
- Pre-cursors: PX3109.
- Co-requisites: None.
- Pre-requisites: None.

**AIMS OF THE MODULE:**

- To introduce a selection of advanced topics in solid state physics.
- To develop an understanding of the important quasiparticles and excitations in solids.
- To show the importance of the electron-phonon interaction and its role in transport in solids.

**LEARNING OUTCOMES:**

The student will be able to:

- Display an understanding of the concepts and methods of the quantum theory of phonons.
- Recall and use the nearly-free electron, tight-binding and Kronig-Penney models for electronic structure.
- Demonstrate an understanding of quasi-classical dynamics of electrons in solids.
- Describe the general concepts and methods of many-electron theory, in particular second quantisation.
- Derive the Hartree-Fock equations for many-electron systems.
- Show an understanding of plasmon collective eigenstates and Wigner crystallization of electrons.
- Discuss the deformation potential and the Fröhlich electron-phonon interaction.
- Show an understanding of the BCS theory of superconductivity.

**OUTLINE SYLLABUS:**

Basics: Bloch's theorem. The adiabatic approximation.

Quantum theory of phonons: Acoustic and optical phonons, phonon-phonon interaction, Umklapp processes. Phonons in polar crystals, interaction of optical phonons with photons, polaritons.

Schrödinger equation for a periodic potential: Exactly solvable 1D models, nearly-free electron model, tight-binding method, density of states.

Electron-electron interaction: Hartree and Hartree-Fock approximations, random phase approximation, screening.

Collective excitations: Plasmons, Wigner crystallization, excitons. Exciton-photon interaction. Electrons, holes and excitons in nano-structures.

Electron-phonon coupling: Deformation potential, Fröhlich interaction. Transport properties of electrons. Wannier-Stark oscillations.

Magnetism: Magnetic susceptibility, diamagnetism and paramagnetism.

Superconductivity: Superconductivity and the Meissner effect. Superconducting phase transition and the energy gap. BCS theory.

**TRANSFERABLE SKILLS:**

Mathematics. Problem solving. Investigative skills. Analytical skills.

**READING LIST:**

Principles of the Theory of Solids, J M Ziman. Cambridge University Press.

## PX4119 LARGE MOLECULES AND LIFE

### MODULE INFORMATION:

- Autumn semester: 10 credits.
- Module organiser: Dr J E Macdonald.
- Deputy Module Organiser: Dr C C Matthai.
- Teaching and feedback methods: Lectures 10 x 1 hr, Project work, marked project.
- Assessment: Examination 70%. Continuous assessment 30%. [Examination duration: 2 hours]
- Pre-cursors: PX2223.
- Co-requisites: None.
- Pre-requisites: None.

### AIMS OF THE MODULE:

- To introduce physical concepts relevant to understanding macromolecules
- To outline the role of macromolecules in important processes in life and to relate their behaviour to that observed in conventional polymers

### LEARNING OUTCOMES:

The student will be able to:

- Identify different classes of polymers and describe their general characteristics.
- Describe the size and shape of macromolecules using macroscopic parameters and the way that these are influenced by solvents.
- Compare techniques for studying macromolecular structure and interpret the resulting data.
- Discuss the nature, magnitude and role of chemical bonds in macromolecules.
- Recall the monomeric structure of DNA and proteins and to describe the physical mechanisms that account for their structure on the macromolecular scale.
- Describe the primary, secondary, tertiary and quaternary structure of proteins and the way that these affect function and folding.
- Analyse the thermodynamic and chemical effects involved in polymer solutions and to demonstrate their significance in a range of physical phenomena.
- Assimilate information about macromolecules from research literature and to give written and oral reports which describe the molecular behaviour and outline the underlying physical principles.

### OUTLINE SYLLABUS:

Introduction to polymers: Polymerisation; Bonding in Polymers; Configurational states; Copolymers; Molecular Architecture; Effect of Temperature on Structure; Molar Mass; Biological Polymers.

Conformation in polymers: Rotational Isomeric States (RIS): ethane, butane and pentane; RIS in polyethylene; End-to-end distance, radius of gyration, distribution of end-to-end distances; Freely-jointed chain, freely-rotating chain models; Interactions between different parts of chain.

Biomolecules in Life: Introduction: Nucleic acids, proteins and polysaccharides; Bonding in biopolymers; DNA: molecular structure; DNA: replication and molecular mechanisms; Amino Acids; Polypeptide chains: conformation and bonding,  $\alpha$ -helix,  $\beta$ -sheets, Secondary tertiary and quaternary structure and protein function; Synthesis of proteins.

Polymer Solutions and Mixtures: Gibbs free energy of mixing; Regular solutions (small molecules); Modification for polymers in solution; Bimodal and spinodal decomposition; Effect of temperature on mixing; Examples of mixing effects; microphase structure in block copolymers; adhesion; hydrophobic interactions; good and bad solvents; coil-globule transitions ; Protein folding.

Techniques for investigating Polymer Structure: Electron microscopy: Atomic Force Microscopy; Diffraction; Infra-red Spectroscopy.

Project selection:

- Myosins - how do the molecules move along actin filaments?
- Kinesins and Dyneins - how do the molecules move along microtubules?
- Cilia and Flagella - how do bacteria swim?
- ATP-ase - a rotating catalyst that provides energy for all living organisms.
- Semiconducting polymers - will electronics become plastic?
- Stretching molecules - unfolding of proteins by pulling with an AFM.
- X-ray diffraction and NMR studies of protein structure and folding.

### TRANSFERABLE SKILLS:

Investigative skills. Communications skills. Problem solving. Mathematics. Analytical skills.

### READING LIST:

Polymer Physics, U W Gedde (Chapman and Hall, 1996).

Molecular Biology of the Cell, B Alberts et al, 3rd Edn (Garland Press, 1994)

# PX4120 NANOSTRUCTURE OPTOELECTRONICS

## MODULE INFORMATION:

- Autumn semester: 10 credits.
- Module organiser: Prof P Blood.
- Deputy Module Organiser: Prof P M Smowton.
- Teaching and feedback methods: Lectures 22 x 1 hr, Exercises, Case studies.
- Assessment: Examination 100%. [Examination duration: 2 hours]
- Pre-cursors: PX2223.
- Co-requisites: None.
- Pre-requisites: None.

## AIMS OF THE MODULE:

- To provide an understanding of the physics of semiconductor optoelectronic devices which utilise nanostructures and how their performance is shaped by use of wells or dots.
- To give an account of the applications of these devices.
- To give an appreciation of current research issues in the field.

## LEARNING OUTCOMES:

The student will be able to:

- Describe the principles of operation of a laser diode, light emitting diode and solar cell.
- Demonstrate understanding of the double heterostructure and its use for quantum confinement and guiding of light.
- Solve Schrödinger's equation for a finite one dimensional potential well.
- Demonstrate understanding of the quantum mechanical description of optical transitions.
- Explain how gain and recombination in nano-structures are affected by quantum confinement.
- Demonstrate knowledge of non-radiative recombination processes in semiconductors.
- Demonstrate an understanding of the propagation of light in three layer slab waveguide.
- Describe the operation of light emitting diodes and laser diodes, analyse and interpret experimental data on basic device characteristics and describe typical applications.
- Describe processes for formation of nanostructures.

## OUTLINE SYLLABUS:

Background principles: Light emission, Einstein relations, Fermi Dirac statistics, p-n junctions, importance of nanostructures, formation of quantum wells, dots, colloidal systems.

Electronic structure of wells: Schrödinger's equation for a one dimensional potential.

Light emitting diodes: Typical structures, physical principles, materials, "white light" LEDs.

General principles of laser diodes: Typical laser structures, threshold condition, light current curves. Light-matter interaction: time-dependent Schrödinger equation, homogeneous broadening, matrix elements, k-selection, waveguide geometry.

Quantum well lasers: Typical structures and materials. Optical absorption, gain, radiative recombination, threshold, gain-current relations, typical performance figures.

Optical properties of quantum dots: absorption and emission, optical cross section, molar extinction coefficient, localised recombination, inhomogeneous broadening, colloidal dots.

Quantum dot lasers: Typical self-assembled dot laser structures. Advantages of dot systems.

Quantum well photovoltaic devices (Solar cells): match to the solar spectrum: strain-balance wells.

## TRANSFERABLE SKILLS:

Problem solving. Investigative skills. Mathematics. Analytical skills.

## READING LIST:

Solid State Physics, Hook and Hall (essential revision)

Optoelectronics: an introduction, Wilson and Hawkes (basic ideas on LEDs and Lasers)

Optical Properties of Solids, Fox. (an MPhys level textbook)

Quantum Optics, Fox (also an MPhys textbook.)

Laser Physics, Hooker and Webb.

Laser Diodes and Photonic Integrated Circuits, Coldren and Corzine (postgraduate level)

Quantum Dot Heterostructures, Bimberg, Grundmann and Ledentsov (a research monograph)

## PX4215 HIGH-ENERGY ASTROPHYSICS

### MODULE INFORMATION:

- Spring semester: 10 credits.
- Module organiser: Prof W K Gear.
- Deputy Module Organiser: Prof P Coles.
- Teaching and feedback methods: Lectures 20 x 1 hr, Exercises.
- Assessment: Examination 100%. [Examination duration: 2 hours]
- Pre-cursors: PX1207, PX2101 and PX2224.
- Co-requisites: None.
- Pre-requisites: None.

### AIMS OF THE MODULE:

- To introduce the basic physical processes of production of high-energy photons and cosmic rays from astrophysical sources in the Universe.
- To discuss the history and physics of different detection methods.
- To present concepts of relativistic beaming and unified schemes for Active Galaxies.

### LEARNING OUTCOMES:

The student will be able to:

- Recall the basic principles of photon detection at X-ray to Gamma-ray energies, and of cosmic rays.
- Recall the physical principles and basic equations of the common high-energy radiation production processes in the Universe.
- Derive the equations describing the structure of accretion disks.
- Recall the physical principles behind the emission of pulsars.
- Derive the basic equations of relativistic Doppler boosting and demonstrate how these affect the apparent properties of many high-energy astrophysical sources.
- Recall the observational properties and describe basic models for gamma-ray bursters.

### OUTLINE SYLLABUS:

Introduction: Definitions and units. Historical overview.

Detection: Detection techniques for high-energy particles and photons.

Cosmic Rays: Energetics, energy spectrum, models for acceleration. The highest energy cosmic rays and the GZK problem.

Radiation Processes: Photoionization, Photoelectric effect, Pair production, Bremsstrahlung, Compton & Inverse-Compton scattering, Synchrotron Radiation.

Stellar Sources: The Sun, stars and Supernovae.

Pulsars: Observational properties and models. The light cylinder, relativistic beaming, energetics. Accretion disks, binary pulsars.

Accretion Disks: Different types of binary stars, Roche lobe overflow and accretion. The thin-disk approximation. The effects of magnetic fields. Accretion onto supermassive objects.

Active Galactic Nuclei: Observational properties and energy budgets. Radio-loud and radio-quiet objects. Relativistic beaming and superluminal motion. Unified schemes, statistical samples.

Gamma Ray Bursters: Observational properties, distribution on sky, proof of cosmological origin, energetics, models.

### TRANSFERABLE SKILLS:

Mathematics. Problem solving. Investigative skills. Analytical skills.

### READING LIST:

There is no set textbook for this module, however you may find parts of the following books useful for reference (all are available in the library):

High-Energy Astrophysics Vols 1&2, M S Longair.

Astrophysical Techniques, C R Kitchin.

Radiative Processes in Astrophysics, Rybicki and Lightman.

Lecture notes and problem sheets will be provided on the departmental web pages.

**MODULE INFORMATION:**

- Spring semester: 10 credits.
- Module organiser: Prof P D Mauskopf.
- Deputy Module Organiser: Prof B S Sathyaprakash.
- Teaching and feedback methods: Lectures 22 x 1 hr, marked Exercises.
- Assessment: Examination 80%. Coursework 20%. [Examination duration: 2 hours]
- Pre-cursors: PX3211.
- Co-requisites: None.
- Pre-requisites: None.

**AIMS OF THE MODULE:**

- To provide an introductory account of fundamental particles and their interaction.
- To prepare the way for further study in theoretical quantum field theory and/or experimental particle physics.

**LEARNING OUTCOMES:**

The student will be able to:

- Discuss the basic concepts of relativistic quantum mechanics.
- Describe the symmetries in physics and their effects on particle interactions.
- Evaluate the effects of conservation laws on particle interactions.
- Use and interpret qualitatively Feynman diagrams.
- Discuss the general experimental methods used to study fundamental particles.

**OUTLINE SYLLABUS:**

The particle zoo: The basic building blocks, quarks and leptons.

Combinations of particles: Fermions and bosons, spin.

Conservation laws: Energy, momentum, C, P, T, baryons.

Lorentz Transforms: Review of Lorentz transforms, quantum mechanics, relativistic quantum mechanics.

Dirac equation, Klein-Gordon equation

Field quantisation: Hartree-Fock, creation and annihilation operators.

Fermi's golden rule: Phase space and matrix elements.

Particle interactions: Feynman diagrams. QED: Electrodynamics, introduction. QED: 2nd-order scattering (Compton, Thompson scattering). Weak force, discovery of neutrinos, W and Z bosons. Strong force, quarks and gluons.

Experimental Particle Physics: Particle accelerators. Particle detectors and detection methods. Drift chamber, wire chamber, Cerenkov radiation, etc.

The standard model and beyond: CP violation, Higgs, SUSY, gravity, strings.

**TRANSFERABLE SKILLS:**

Mathematics. Problem solving. Investigative skills. Analytical skills.

**READING LIST:**

Quarks and Leptons: An Introductory Course in Modern Particle Physics, Halzen and Martin.

Particle Physics, Martin and Shaw.

## PX4121 QUANTUM FIELD THEORY

### MODULE INFORMATION:

- Autumn semester: 10 credits.
- Module organiser: (From Swansea)
- Deputy Module Organiser: Prof P D Mausekopf
- Teaching and feedback methods: Lectures 22 x 1 hr, marked exercises.
- Assessment: Examination 80%. Course work 20% [Examination duration: 2 hours]
- Pre-cursors: PX3121, PX2206, PX2224.
- Co-requisites: None.
- Pre-requisites: None.

### AIMS OF THE MODULE:

- To provide an understanding of the basics of relativistic quantum field theory, with an emphasis on Quantum Electrodynamics (QED).
- To develop and apply perturbative approaches to the calculation of quantum amplitudes.
- To introduce quantum loop corrections and analyse physical applications.

### LEARNING OUTCOMES:

The student will be able to:

- Describe the classical foundations of relativistic field theory.
- Show an appreciation of the use of creation and annihilation operators in the simple harmonic oscillator problem in the development of a second quantised approach to field theory.
- Demonstrate an understanding of the role of gauge symmetry in the interaction between matter and radiation.
- Perform calculations on some simple physical scattering processes using Feynman diagrams.
- Show insight into the importance of quantum corrections at a basic level.

### OUTLINE SYLLABUS:

**Classical Foundations:** Classical field theory, Lagrangians, Noether theorem.

**Second Quantization:** Canonical quantization of scalar fields.

**Fermions:** Fermions, quantization.

**Gauge Fields:** Gauge fields and their interactions with matter.

**Calculational methods:** Perturbation theory and Feynman graphs.

**Quantum Corrections:** Renormalisation of QED at one loop level, vacuum polarisation, Lamb shift.

### TRANSFERABLE SKILLS:

Mathematical skills. Analytical skills.

### READING LIST:

Gauge Theories in Particle Physics (Volume 1), I J R Aitchison and A J G Hey, (IOP Publishing, Bristol, 2003).

An Introduction to Quantum Field Theory, M E Peskin and D V Schroeder (Addison Wiley 1995).

## PX4122 QUANTUM INFORMATION PROCESSING

### MODULE INFORMATION:

- Autumn semester: 10 credits.
- Module organiser: (From Swansea)
- Deputy Module Organiser: Dr M Elliott
- Teaching and feedback methods: Lectures 22 x 1 hr, marked exercises.
- Assessment: Examination 80%. Coursework 20%. [Examination duration: 2 hours]
- Pre-cursors: None.
- Co-requisites: None.
- Pre-requisites: None.

### AIMS OF THE MODULE:

- To introduce the basic concepts of quantum mechanics and quantum computers.
- To introduce information theory and discuss algorithms which require quantum computers.
- To discuss simple physical realisations of quantum computers.

### LEARNING OUTCOMES:

The student will be able to:

- Demonstrate a knowledge of quantum mechanical principles applicable to quantum computers.
- Show an understanding of and apply basic concepts in information theory.
- Demonstrate an understanding of computer algorithms which require quantum computers.
- Describe and analyse physical realisations of prototype quantum computers.

### OUTLINE SYLLABUS:

**Quantum Foundations:** Two state systems, Hilbert spaces, spins, bras and kets, quantum measurement.

**Quantum Computing Basics:** Bits and qubits, quantum logic gates.

**Applications:** Quantum Fourier transform, Shor's factorization algorithm and RSA encryption, Grover's search algorithm, dense coding, quantum encryption, quantum teleportation.

**Information Theory:** Shannon's entropy, Maxwell's demons.

**Realisations:** Building a quantum computer, decoherence, error correction.

### TRANSFERABLE SKILLS:

Boolean logic, encryption schemes, information theory.

### READING LIST:

Quantum Computation and Quantum Information, Nielsen and Chuang (Cambridge University Press).

Quantum Computer Science, N David Mermin (Cambridge University Press).

## PX4310 PROJECT

### MODULE INFORMATION:

- Autumn and Spring semester: 60 credits.
- Module organiser: Dr B E Richardson.
- Deputy Module Organiser: Prof D Ward-Thompson.
- Teaching and feedback methods: Supervised project work, including structured week at Gregynog Conference Centre. Marked oral and written work.
- Assessment: Continuous assessment, including written reports and oral presentation 100%.
- Pre-cursors: None.
- Co-requisites: None.
- Pre-requisites: None.

### AIMS OF THE MODULE:

- To undertake an extended investigation of a particular aspect of physics, applied physics or astrophysics carried out in a real research environment in the university or industry.
- To undertake independent study in a research-based project with the aim of discovering something new.
- To develop critical thought, theoretical and/or experimental skills, planning and organisation.
- To further enhance written and oral communications skills.
- To undertake group work to make you aware of the issues and planning involved in preparing a research proposal and in assessing such proposals (Gregynog).

### LEARNING OUTCOMES:

The student will be able to:

- Work independently and produce an extended dissertation.
- Plan, organise and conduct a research project.
- Analyse critically data acquired during the course of conducting the project.
- Write an extended dissertation and give a short research seminar on their work.
- Present details of their project in a viva voce examination.
- Appraise health and safety issues connected with their project work.

### OUTLINE SYLLABUS:

The project work extends over two semesters. At the end of the Autumn semester, students submit a fixed-format four-page summary of their work plus a self-assessment. The final dissertation is submitted at the end of the Spring semester and the work is assessed on the basis of this dissertation and performance in an examination (*viva voce*) with the supervisor and an assessor. Students also give a short research seminar on their work.

Projects will be selected from a range of topics mainly in the following general areas:

- Nanometre-scale physics
- Quantum electronics
- Physics near absolute zero
- Acoustics
- Optoelectronics and laser systems
- Chaotic systems
- Galaxies and the Universe
- Astronomical instrumentation
- Formation and evolution of stars and planetary systems
- History of astronomy
- Modelling of astrophysical systems

### TRANSFERABLE SKILLS:

Communications skills. Investigative skills. Personal skills. Analytical skills. Ethical behaviour. They may also include some or all of the following: problem solving; experimental skills; computing skills; mathematics.

### READING LIST:

Directed reading by project supervisor.

## SEMESTER CALENDAR 2011-2012

Week Beginning (Monday)	Semester/Week		Calendar Entries
26 September	<b>Autumn /0</b>	Semester starts Tuesday, 27 September with Year 1 Induction	
03 October	<b>/1</b>	<b>Teaching Week 1</b>	
10 October	<b>/2</b>	<b>Teaching Week 2</b>	
17 October	<b>/3</b>	<b>Teaching Week 3</b>	
24 October	<b>/4</b>	<b>Teaching Week 4</b>	
31 October	<b>/5</b>	<b>Teaching Week 5</b>	
07 November	<b>/6</b>	<b>Teaching Week 6</b>	
14 November	<b>/7</b>	<b>Teaching Week 7</b>	
21 November	<b>/8</b>	<b>Teaching Week 8</b>	
28 November	<b>/9</b>	<b>Teaching Week 9</b>	
05 December	<b>/10</b>	<b>Teaching Week 10</b>	
12 December	<b>/11</b>	<b>Teaching Week 11</b>	
<i>19 December</i>		<i>Recess</i>	
<i>26 December</i>		<i>Recess</i>	
<i>02 January 2011</i>		<i>Recess</i>	
09 January <b>2012</b>	<b>/12</b>	<b>Guided-Study</b>	
16 January	<b>/13</b>	<b>Assessment Week 1</b>	
23 January	<b>/14</b>	<b>Assessment Week 2</b>	
30 January	<b>Spring /1</b>	<b>Teaching Week 1</b>	
06 February	<b>/2</b>	<b>Teaching Week 2</b>	
13 February	<b>/3</b>	<b>Teaching Week 3</b>	
20 February	<b>/4</b>	<b>Teaching Week 4</b>	
27 February	<b>/5</b>	<b>Teaching Week 5</b>	
05 March	<b>/6</b>	<b>Teaching Week 6</b>	
12 March	<b>/7</b>	<b>Teaching Week 7</b>	
19 March	<b>/8</b>	<b>Teaching Week 8</b>	
26 March	<b>/9</b>	<b>Teaching Week 9</b>	
<i>02 April</i>		<i>Recess</i>	
<i>09 April</i>		<i>Recess</i>	
<i>16 April</i>		<i>Recess</i>	
23 April	<b>/10</b>	<b>Teaching Week 10</b>	
30 April	<b>/11</b>	<b>Teaching Week 11</b>	
07 May	<b>/12</b>	<b>Guided-Study</b>	
14 May	<b>/13</b>	<b>Assessment Week 1</b>	
21 May	<b>/14</b>	<b>Assessment Week 2</b>	
28 May	<b>/15</b>	<b>Assessment Week 3</b>	
04 June	<b>/16</b>	<b>Assessment Week 4</b>	
11 June	<b>/17</b>	<b>Assessment Week 5</b>	
<i>18 June</i>		<i>End of teaching year</i>	

Note that summer resit examination (Year 0 and 1 only) are normally held in mid August. Students are advised to check the dates of the resit examination period on the University web site before making summer vacation arrangements.

