



*Department of Medical Physics  
& Clinical Engineering*

**Undergraduate Modules in**

**Medical Physics**

**and**

**Clinical Engineering**

**2011-2012**

**MPY101 :        Physics of Living Systems 2**

**Semester : 2**

**Credits : 10**

**Taught by: Dr A Narracott / Dr J Fenner**

**Prerequisites: None**

**Co-requisites: None**

*Brief Description (including aims of module)*

The aim is to introduce biomechanical descriptions of the human body. We look at its structure and its performance as a physical machine. The structural characteristics of human bones and tissue are investigated, together with the mechanical functions of the skeleton and musculature. Simple fluid dynamic characteristics of the body are introduced, including descriptions of blood-flow in the arteries and veins and air-flow in the lungs.

*Objectives*

At the end of the course the student will:

1. understand the types of loads that are applied to biomechanical structures and understand the principal engineering characteristics of a deformable material;
2. understand the basic structure of bone and tissue and have a feel for their respective strengths and stiffnesses;
3. understand the principles of static equilibrium, and be able to apply them to simple biomechanical analyses;
4. recognise the possibility of structural instabilities in thin or slender members, and be able to perform simple calculations to assess them;
5. recognise the design principles at work in the human skeleton;
6. be aware of the magnitudes of the loads within the skeleton and musculature during everyday tasks such as lifting;
7. understand design methodologies for prosthetic components, including the principles of stress and deflection analyses;
8. understand the engineering effects of physical scale in the animal kingdom;
9. be able to calculate hydrostatic pressure distributions, and their effect on parameters such as blood pressure;
10. recognise the fundamental fluid dynamic parameters of pressure and velocity, and the role of viscosity in fluid flow;
11. be able to identify flow regimes by Reynolds' number and pulsatility parameters, and recognise the flow regime in biofluid mechanical systems, particularly in the cardiovascular system, air flow in the lungs, and the urinary tract;
12. understand the effects of orifices and constrictions, particularly with respect to the performance of components such as natural or prosthetic heart valves.

### *Outline Syllabus*

- Strength of materials: elasticity and viscoelasticity, structure and strength of bone and tissue.
- Equilibrium: forces, moments and couples, applications in biomechanics, energy methods.
- Stress analysis: tension and compression, Engineer's theory of bending, shear and torsion, structural instability of columns (Euler's method).
- Kinetics and kinematics: joint design.
- Hydrostatic pressure distribution: blood pressure.
- Properties of fluids in motion: viscosity, Newtonian models, blood models.
- Fluid dynamics: classification of flow regimes, Navier Stokes equation, Poiseuille equation, Bernoulli equation, Gorlin equation, models of cardiovascular system, haemolysis and thrombosis.
- Special considerations: introduction to methods for dealing with elastic walls of arteries, collapsible veins, Windkessel model, Moens Korteweg wave speed.

### *Mathematics used in the Module*

- Differentiation/Integration of simple functions (polynomial, trigonometric, exponential)
- Solution of simple differential equations, first/second order linear

### *Module Format*

Lectures	20
Tutorial Classes	2
Laboratory work	0
Private study	36

### *Main Text Books*

'Medical Physics and Biomedical Engineering',  
BH Brown, RH Smallwood, DC Barber, PV Lawford, DR Hose,  
IOP Publishing Ltd, 1999. ISBN 0 7503 0368 9 (Paperback)

Comprehensive printed notes are supplied, together with an extensive reading list.

### *Assessment*

Two hour written examination	80 %
Coursework assignments	20 %

## **MPY205: Aspects of Medical Imaging and Technology**

**Semester: 1**

**Credits: 10**

**Taught by: Dr. J.W.Fenner**

**Prerequisites: None**

**Co-requisites: None**

### *Brief Description (including aims of module)*

This module provides an introduction to medical radiation physics (both ionising and non-ionising) and emphasises its diagnostic role in medicine. The course begins with an introduction to the generation and behaviour of electromagnetic waves and proceeds to explore the breadth of their application across the electromagnetic spectrum. This includes magnetic resonance imaging at low energies and X-rays at high energies. The importance of radiation in diagnosis is covered by discussion of imaging theory and primary imaging modalities, such as planar radiography and CT. The therapeutic role involves brief consideration of radiotherapy.

### *Objectives*

At the end of the course the student will:

- be familiar with the differences between electrostatics and electrodynamics
- have an understanding of the structure of atoms and X-ray generation
- be familiar with a physical interpretation of Maxwell's equations
- appreciate the difference between ionising and non-ionising electromagnetic radiation
- be aware of methods of detecting ionising and non-ionising radiation
- have a grasp of the interactions that occur between electromagnetic radiation (ionising and non-ionising) and tissue
- know important SI units and definitions of parameters associated with electromagnetic radiation
- understand the nature of magnetic resonance signal acquisition - how it relates to net magnetisation, simple RF pulse sequences
- understand how RF pulse sequences in combination with gradient fields can lead to MR image production, maps of proton density, T1, T2.
- have a general understanding of the physical principles, construction and function of a diagnostic X-ray unit
- have a general understanding of the physical principles, construction and function of a CT scanner
- have an appreciation of image reconstruction using computed tomography
- have an appreciation of the theoretical description of imaging systems
- appreciate the role of the medical physicist in the management of medical imaging systems, safety aspects and quality assurance

### *Outline Syllabus*

- Atomic structure: the atom, nucleus, X-rays
- Electromagnetic tissue interactions: absorption, resonance,
- Ionising radiation/matter interactions: photoelectric effect, Compton scatter, pair production, dose
- Radiation detection: gas ionisation, solid state, scintillation
- Diagnostic RF radiation: MRI, proton spin, precession, net magnetisation, RF fields, 90 and 180 degree pulse sequences, receiver coils, signal localisation, image production, MRI hardware, safety
- Diagnostic X-rays: tubes, bremsstrahlung, generation, design considerations, film, diagnosis
- Diagnostic X-rays: tomographic technology, reconstruction techniques, noise, dose
- Imaging theory, conjugacy, PSF, MTF, convolution, Fourier decomposition
- Imaging components, transducers, gain, linearity, dynamic range, noise
- Digital acquisition, ADC/DAC, latch, sampling

### *Mathematics used in the Module*

- Differentiation / Integration
- Exponential behaviour
- Convolution and convolution theorem
- Fourier series/transforms and interpretation
- Delta function
- Spatial frequency, point spread function, modulation transfer function
- Simple numerical example of iterative reconstruction

### *Module Format*

Lectures	19
Tutorial Classes	3
Laboratory work	1
Private study	36

### *Main Text Books*

Comprehensive printed notes complement the slides presented in the lectures.  
A reading list is provided.

### *Assessment*

Two hour written examination	80%
Laboratory work/report	10%
Tutorial assignments	10%

**MPY308 : Clinical Engineering and Computational Mechanics**

**Semester : 1**

**Credits : 10**

**Taught by: Dr. A Narracott**

**Prerequisites: Physics, Engineering or Mathematics to level 2**

**Co-requisites: None**

*Brief Description (including aims of module)*

The complexity of the geometry and boundary conditions of structures within the body are such that the physical governing equations rarely have closed-form analytical solutions. This module describes some of the numerical techniques that can be used to explore physical systems, with illustrations from biomechanics, biofluid mechanics, disease treatment and imaging processes. The primary technique that will be used is the finite element method, and the fundamental concepts behind this powerful technique will be described. The lectures will be supported by laboratory sessions in which the student will apply commercial codes to investigate problems in the medical sphere.

*Objectives*

At the end of the course the student will:

- understand the role of numerical methods in the solution of real problems in biophysics and bioengineering;
- be able to construct simple finite difference and finite element schemes for the solution of particular systems of differential equations;
- understand the assumptions in the numerical schemes and the requirements for appropriate boundary conditions, constitutive equations and numerical formulations;
- have experience of the application of world-leading computational analysis software in problems in biomechanics, biofluid mechanics and biomedical applications of electricity and heat;
- understand how numerical solutions can contribute to applications in medical imaging;
- have completed a mini-project using MATLAB, ANSYS or FLOTRAN to investigate a physical system;
- be aware of the requirements for comprehensive verification, validation and reporting of numerical solutions, and recognise these requirements in the production of a mini-project report;
- have a feel for the 'size' of a problem, the requirements for an appropriate numerical scheme, and understand how to go about choosing or developing software;

### *Outline Syllabus*

- Introduction, objectives, history and development, commercial exploitation, typical applications of numerical methods in biomechanics and biofluid mechanics
- Introduction to MATLAB, matrix manipulation. Presentation of results. Exercises.
- One-dimensional heat conduction. Solution by finite difference and finite element schemes. Extension to 2D and 3D. Shape functions. Galerkin weighted residuals.
- Laplace's equation. Numerical solution and practical applications.
- Matrix stiffness methods and applications to truss problems. Symmetry and antisymmetry. Finite element formulation for 1D bar. Principle of virtual displacements.
- Introduction to ANSYS. Pre-processing, solution and post-processing phases.
- Practical aspects of finite element analysis.
- Finite element formulation for a 2D continuum. Completeness and compatibility. Patch test. Parametric element formulations. Jacobian matrix. Computational implementation. Numerical integration.

### *Mathematics used in the Module*

- Differential equations
- Numerical analysis
- Discretisation schemes – finite difference, finite element
- Matrices
- Differential heat equation
- Laplace's equation
- Transformation of coordinate systems, Jacobian

### *Module Format*

Lectures	18
Tutorials	4
Laboratory work	0
Private study	36

### *Main Text Books*

Comprehensive printed notes are supplied, but an important element of this module is the 'hand on' component, learning how to use modern, commercial, engineering analysis software.

### *Assessment*

Mini-project	65%
Assignment 1	10 %
Assignment 2	25%

## **MPY321: Medical Physics Project 1**

**Semester: 1**

**Credits: 10**

**Co-ordinator:** Dr J.W.Fenner / Dr A. J. Narracott  
**Prerequisites:** None  
**Co-requisites:** None  
**Restrictions:** Restricted to students on Physics with Medical Physics Programme

### *Brief Description (including aims of module)*

The aim of the medical physics project is to provide an opportunity for students to develop and apply their skills to a research problem. A range of projects is offered across the spectrum of physics and engineering applications, and many will address current medical or clinical needs. Students are encouraged to work in groups of two or three to develop team skills and to conclude with a formal presentation to graduate staff in the city hospitals.

### *Objectives*

The objective of the project is to give the student the opportunity:

1. to study in depth a particular topic in the medical physics discipline
2. to gain experience of practical application of their knowledge to a real physics problem
3. to understand the importance of planning and project management in a time-critical environment
4. to gain experience in the production of a concise thesis describing a project, and to understand the elements that contribute to effective communication in this context
5. to undertake an oral examination in defence of the thesis, developing the appropriate communication and presentational skills
6. to develop interpersonal skills in working effectively as a member of a small team each making their own contribution towards a larger goal.
7. to gain some appreciation of the day-to-day activities of a researcher in these disciplines

### *Outline Syllabus*

Each project is unique and has its own specific academic and practical targets.

### *Mathematics used in the Module*

Each project is unique and may require a range of mathematical skills, invariably supported by MatLab.

*Module Format*

The project represents ten credits and as such it is expected that the student will devote approximately seventy hours of activity to it. The breakdown of this activity is dependent on the nature of the project.

*Main Text Books*

As appropriate to the project. Will be recommended by the academic supervisor.

*Assessment*

Supervisor Assessment of Progress and Effort	25%
Written Report	50 %
Oral Examination	25 %

## **MPY322: Medical Physics Project 2**

**Semester: 2**

**Credits: 10**

**Co-ordinator: Dr J.W.Fenner / Dr A. J. Narracott**

**Prerequisites: None**

**Co-requisites: None**

**Restrictions: Restricted to students on Physics with Medical Physics Programme**

### *Brief Description (including aims of module)*

The aim of the medical physics project is to provide an opportunity for students to develop and apply their skills to a research problem. A range of projects is offered across the spectrum of physics and engineering applications, and many will address current medical or clinical needs. Students are encouraged to work in groups of two or three to develop team skills and to conclude with a formal presentation to graduate staff in the city hospitals.

### *Objectives*

The objective of the project is to give the student the opportunity:

1. to study in depth a particular topic in the medical physics discipline
2. to gain experience of practical application of their knowledge to a real physics problem
3. to understand the importance of planning and project management in a time-critical environment
4. to gain experience in the production of a concise thesis describing a project, and to understand the elements that contribute to effective communication in this context
5. to undertake an oral examination in defence of the thesis, developing the appropriate communication and presentational skills
6. to develop interpersonal skills in working effectively as a member of a small team each making their own contribution towards a larger goal.
7. to gain some appreciation of the day-to-day activities of a researcher in these disciplines

### *Outline Syllabus*

Each project is unique and has its own specific academic and practical targets.

### *Mathematics used in the Module*

Each project is unique and may require a range of mathematical skills, invariably supported by MatLab.

*Module Format*

The project represents ten credits and as such it is expected that the student will devote approximately seventy hours of activity to it. The breakdown of this activity is dependent on the nature of the project.

*Main Text Books*

As appropriate to the project. Will be recommended by the academic supervisor.

*Assessment*

Supervisor Assessment of Progress and Effort	25 %
Written Report	50 %
Oral Examination	25 %

## **MPY401 : Medical Physics Research Project**

**Semester: 1 & 2**

**Credits: 40**

**Co-ordinator: Dr J. Fenner**

**Prerequisites: None**

**Co-requisites: None**

**Restrictions: Restricted to students on Physics with Medical Physics Programme**

### *Brief Description (including aims of module)*

A research project is offered to students in year four and provides a vehicle for deeper study of a topic of particular interest. The student will work alone or in a small team under academic and/or clinical supervision (students are encouraged to be pro-active in the specification of these projects within the areas of interest of the academic staff). The work of the project will give the students experience and practical laboratory/compute skills in a real research/clinical environment. They will develop hypotheses and ideas linked with a specified research project and undertake in depth experiments and analyses to test the hypothesis, with in depth knowledge of the specific research literature. Insight will be gained into the critical factors involved in developing timelines for research, reading, critical evaluation and writing skills.

### *Objectives*

In this module, students will undertake a defined laboratory or computer-based research project. They will learn essential research techniques, design and perform experiments, undertake computational simulations, record data and critically interpret their findings. Each student will be assigned to an academic supervisor, with whom he/she will meet regularly. Students will be expected to identify a defined published literature on the research topic undertaken and conduct experiments and evaluate their data in light of published findings. This will also be an opportunity to learn about standard operating procedures, safety and appropriate CoSHH regulations. The objectives of this research project go beyond those of a ten credit level three project, with the student expected to take a more active role in the project definition and management. Additional objectives are:

1. to develop the skill of planning achievable objectives in a fixed timescale in a research environment. To this end the student will agree with a supervisor a research topic and programme equivalent to several hundreds of hours of work over the two semesters.
2. to critically evaluate the relevant published research literature, write a substantial dissertation based on this literature in the context of their research project, and critically evaluate their data in light of published findings.
3. to gain experience of discussing their work and subjecting it to the scrutiny of a critical third party

### *Outline Syllabus*

- Each project is unique and has its own specific academic and practical targets.
- The student will need to be in a position to start the research project at the beginning of Semester one. To keep the project under review, formative

assessments will be undertaken, including a comprehensive project plan (to be delivered no later than the end of the fifth week of the Autumn Semester), a literature review (Week12 deadline) and a discussion of progress in the Easter (Spring). Summative assessment will be undertaken in semester two.

### **Summative Assessment**

Assessment will accommodate formative and summative elements. In addition to the formative elements described above, the summative elements will comprise:

- An 8000-15000 word dissertation allowing the student to demonstrate insight into the subject, permitting evaluation of their practical and theoretical understanding. This component is worth up to 50% of the marks for the unit.
- A mark contributing 25% of those for the unit as a whole, awarded by the academic supervisor on skills displayed during the project. This will include assessment of any supporting material (eg. Gantt chart, record of the literature, final/condensed summary report, lab book etc.)
- A viva (incorporating a short presentation) providing an additional means of assessing students' understanding and their ability to construct reasoned arguments. This component is worth up to 25% of the marks for the unit.

### *Mathematics used in the Module*

Each project is unique and may require a range of mathematical skills, invariably supported by MatLab.

### *Module Format*

The breakdown of activity is dependent on the nature of the project.

### *Main Text Books*

As appropriate to the project. Will be recommended by the academic supervisor.

### **In summary....**

Formative assessment:

- Comprehensive project plan delivered by Week 5 of the Autumn semester
- Literature review, placing the work of the project in its wider scientific context, and clarifying the motivation/rationale for the work. This should be fronted by a one page description/abstract of the project and its goals. To be submitted by Week12 of the autumn semester.
- Presentation (round about Easter) discussing project achievements to date and critique of the project abstract delivered in autumn.

Summative assessment:

- Written Thesis 50 %
- Supervisor Assessment of Progress and Effort 25 %
- Oral Examination 25 %

**Note:** Poor performance in formatively assessed content will impact negatively on marks awarded for summative assessment in semester 2.

## **MPY424 : Hospital or Industrial Placement**

**Semester: 1**

**Credits: 20**

**Co-ordinator: Professor W. Tindale / Dr.D.R.Hose / Dr J.W.Fenner**

**Prerequisites: Medical Physics students only**

**Co-requisites: None**

**Restrictions: Restricted to students on Physics with Medical Physics Programme**

### *Brief Description (including aims of module)*

It is recognised that students in year four are keen to experience the working environment to assist in career selection. This module meets this need by providing an opportunity to work with a practising physicist or engineer in an appropriate hospital or industrial environment.

### *Objectives*

The objectives of hospital or industrial placement are:

1. to expose the student to the day-to-day activities of a practising physicist or engineer in the appropriate environment
2. to assist the student in making an informed choice of career
3. to produce a concise training report detailing activities over the placement period

### *Module Format*

The choice of placement will be limited by practical considerations depending on the availability of suitable supervision. Specific activity depends on the nature and location of the placement.

### *Mathematics used in the Module*

Basic mathematics skills required

### *Assessment*

Supervisor Assessment and diary	60 %
Oral presentation	20 %
Essay – ‘The Medical Physicist in Society’	20%