BSc (Med) (Hons) Medical Physics at UCT

Postgraduate Programme

BSc (Med) (Hons) in Medical Physics

123 HEQF credits

(Includes a research project of 30 credits)

Plan code: MH001RAY02

January 2017

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1. Introduction

The Department of Medical Physics at the University of Cape Town offers a one-year BSc (Med) (Honours) degree in Medical Physics. Students who wish to complete the programme over two years on a part-time basis may apply to the HOD for case by case evaluation.

Programme convenor: Ms H Burger

Contact Details

The BSc (Med) (Honours) Coordinator

Medical Physics Department

University of Cape Town

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1. Entrance requirements

Entrance requirement is a BSc degree with a major in Physics. Normally the following criteria are used:

> A pass of 60% in PHY3021F (**http://www.phy.uct.ac.za/courses/phy3021f/**) and PHY3022S (**http://www.phy.uct.ac.za/courses/phy3022s/**), or equivalent; and a pass of 50% in MAM2000W or MAM2046W (**http://www.mth.uct.ac.za/Undergrad/**) or equivalent; and in cases where the Head of Department of Medical Physics deems it necessary, favourable referee reports.

Preference may be given to UCT graduates who meet the entrance requirements. Enrolments are limited to an overall total of 5 in any one year. Acceptance will be at the discretion of the Head of Division of Medical Physics who will consult with the BSc (Physics) (Honours) course convener at the Department of Physics.

2. Duration of the course

Dates below are provisional, see the UCT calendar at **http://www.uct.ac.za/calendar/** for more information.

In 2017, registration will take place on Monday 20 February 2017 followed by a compulsory pre-course course offered by the UCT Physics Department. The course acts as refresher and is considered mandatory for all Medical Physics Honours students. Lectures for the first semester will run from 27 February until 23

June 2017, with a mid-term vacation from 29 April to 7 May. Some examinations will take place in the period June and July 2017. Lectures take place on upper campus as well as L-Block, Groote Schuur Hospital.

The second semester will run from 14 August until 10 November, with a mid-term vacation from 26-29 September. Examinations will take place in November. Graduation dates to be confirmed.

3. Application deadlines

We require your application by 30 September 2017.

We require by 15 December 2017 your certified study record from the university at which you obtained your degree.

Students from foreign universities: students who have completed the equivalent of a BSc majoring in Physics are encouraged to apply. We require your SAQA certification by 15 December 2017, and a letter of recommendation of a senior academic staff member of the department at the university at which you obtained your degree(s); and *either* the certified marks and short description of the courses (no. of lectures, content and course reference books) and practical projects taken at the university at which you obtained your degree(s), *or* a copy of your Vordiplom exam certificate.

To speed up the application process please fax (021-404 6269) or email (Hester.Burger@uct.ac.za) your application.

Based on the submitted required information, a decision can be made (often within a few days) whether or not to advise the Health Sciences Faculty that you be accepted to UCT.

4. Programme outline

The Honours programme consists of 10 courses (9 credits per course) and an educational research course counting 30 credits. A course consists of 20 lectures (45 minutes long) or equivalent; reading for each lecture; five tutorial sessions or problem sets (or equivalent). The research course take place in the second semester spread over 10 weeks, including workshops, assignments and tutorials.

The Honours programme in Medical Physics consists of the following courses, all of which are compulsory:

Department of Physics courses

1. Quantum Mechanics 1- Lecturer Dr. A. Hamilton (First semester)
2. Computational Physics - Lecturer Dr. T Dietel (First semester). This course may be replaced by another equivalent course at the discretion of the HoD.
3. Nuclear Physics and the Interactions of Radiation with Matter – Lecturer Dr. T Leadbeater (Second semester)

Department of Medical Physics courses

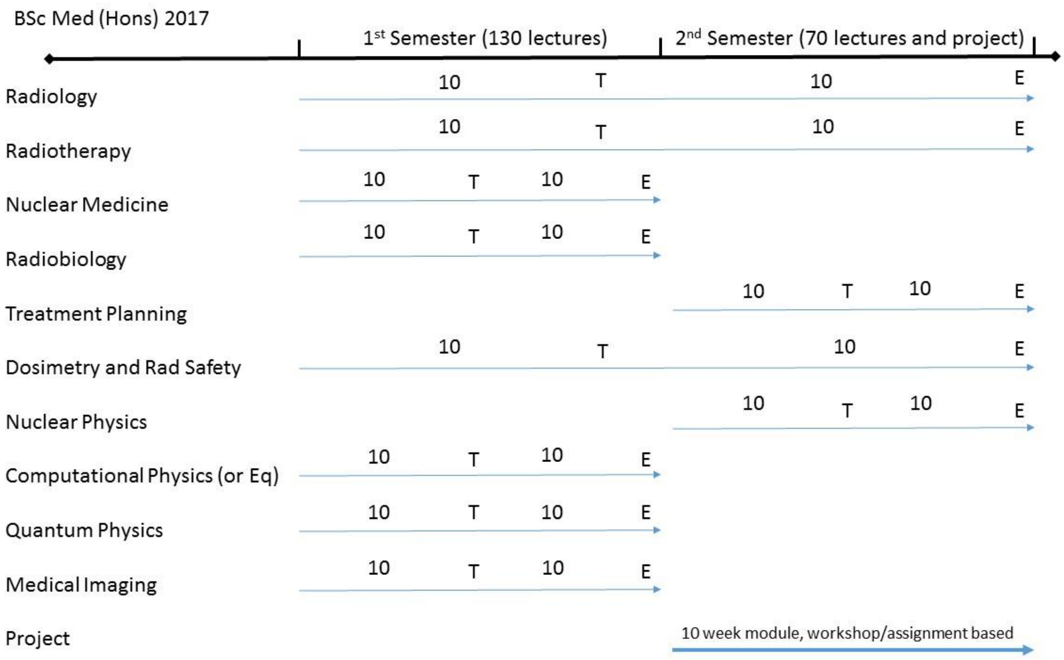
4. The Physics of Diagnostic Radiology – Lecturer Mr V Jonas (Year course)
5. The Physics of Nuclear Medicine – Lecturer Ms N Joubert (First semester)
6. The Physics of Radiotherapy - Lecturer Ms H MacGregor (Year course)
7. Radiation Protection and Dosimetry - Lecturer Ms N Bruwer (Year course)
8. Treatment Planning - Lecturer Ms H Burger (Second semester)
9. Radiobiology and Life Sciences - Lecturer Dr A Hunter (First semester)
10. Research Project – Co-ordinator Ms H Burger (Second semester)

Department of Human Biology – Biomedical Engineering course

11. Introduction to Medical Imaging and Image Processing – Lecturer Dr Marcin Jankiewicz (First semester)

Duly performed (DP) requirements: 30% for class tests and problem sets.

The Department of Medical Physics reserves the right to delete courses, or add courses, or modify the list should staffing or other factors so dictate.



2. General information

1. Standard of the programme

The BSc (Med) (Honours) degree programme is usually undertaken by a student in the 4th year of study, after having graduated with a BSc in Physics at the end of the 3rd year of university study.

The BSc (Med) Honours degree has been accredited by the HPCSA as fulfilling the academic requirement for entry into the two year practical/experiential program required for professional registration as Medical Physicist.

The degree is also a gateway towards further postgraduate study, such as MSc and PhD degrees by dissertation. The content of the programme is comparable to that of senior undergraduate BSc in Medical Physics courses in good UK or USA universities and as such prepares a student for entry into international post-graduate Medical Physics programs, provided the student has done exceptionally well.

2. Workload

The BSc (Med) (Honours) programme is intensive. A rough estimate of the workload (in hours) for a '20-lecture' unit is:

Lectures: 20 @ 45 minutes	15
Reading before and after lecture	20
5 problem sets at 4 hours	20
Independent study	20
Total	75

This totals 75 hours for a nine credit course, and so a course of 120 credits would take about 1000 hours. Divided by 120 days (24 weeks in an academic term) this equates to approximately 8 hours a day. The actual workload, including the research project, and including preparation for examinations, will depend on student preparedness and ability, and may well be 20 percent higher than this, and will fluctuate throughout the year.

3. Programme content

The broad content of a course is decided between the Head of Department of Medical Physics, who bears ultimate responsibility for the academic content of the programme and its courses, the BSc (Physics) (Honours) programme convener at the Department of Physics, and the lecturer concerned. The lecturer enjoys academic freedom to decide the details of content, and the style of teaching of that course. The overall principle of reasonableness applies: the HoD, informed by the views of the BSc (Physics) (Honours) course convener at the Department of Physics, colleagues, the lecturer, external examiners, and the students, decide whether the content of a course is reasonable in quality and quantity for an BSc (Med) (Hons) programme.

4. Duly performed (DP) certificate

Only students who receive a duly performed (DP) certificate, normally issued around 15 October, will be allowed to write the examination.

The DP certificate criteria will be published at the start of the course, and may include, inter alia, satisfactory performance in class tests, examinations written in May/June, problem sets or tutorials, and the project.

5. Examinations of courses

Certain courses will be examined in the May/June examination period. Other courses will be examined in the October/November examination period. Exceptionally, by agreement with students and lecturing staff, the HoD may direct examinations to take place outside these periods.

All core courses (Physics of Radiotherapy, Physics of Nuclear Medicine, Physics of Radiology, Radiation Protection and Treatment Planning), as well as the research course have to be passed with at least 50 % final mark. A minimum final mark of 45% is required for each of the remaining courses, but an average mark of 50% has to be obtained to be able to graduate.

This BSc (Med) (Honours) examination committee is advisory to the HoD, who submits results to the Health Sciences Faculty Examination Committee (FEC) for decision, and ultimate ratification by the University Senate.

A student who fails the BSc (Med) (Honours) course may be prohibited by the HoD from readmission.

3. Description of individual courses

1. Quantum Mechanics I

Lecturer Dr. A. Hamilton, Andrew.Hamilton@uct.ac.za

Tutor S. Bodenstein

20 lectures first semester

5 tutorials counting 20% towards final mark

1 class test counting 30% towards final mark

2 hour exam to take place in May, counting 50% towards final mark.

Outline

Postulates of QM, mathematics of QM: infinitely dimensional vector spaces; functions as vectors; Hermitian vs. self-adjoint operators; spectral decomposition; Lie algebra; generators of transformations; (some) representation theory. |Heisenberg picture, Schroedinger picture. Path integrals; Trotter formula; propagator for a free particle, simple harmonic oscillator, uniform gravity; functional analysis. Perturbation theory: time independent, non-degenerate and degenerate; time dependent, time order exponential, Dyson series; interaction picture. Scattering Theory; Lippman-Schwinger equation; Fermis Golden rule; Born cross section; Optical theorem. Quantum Statistics: Bosons vs. fermions; density matrices. Bells inequality; Einstein-Podolsky-Rosen paradox. Time permitting: WKB approximation, method of steepest descent.

Literature

[1] J.J. Sakurai, Modern Quantum Mechanics, Addison Wesley, 2010.

[2] R. Shankar, Principles of Quantum Mechanics, Springer, 1994.

[3] R.P. Feynman and A. R. Hibbs, Quantum Mechanics and Path Integrals, Dover, 2010.

[4] A. Messiah, Quantum Mechanics, Dover, 1999.

[5] R.L. Liboff, Introductory Quantum Mechanics, Addison Wesley, 2002.

[6] F. Schwabl, Quantum Mechanics, Springer, 2010.

2. Nuclear Physics and Interactions of Radiation with Matter

Lecturer Dr T Leadbeater, tom.leadbeater@uct.ac.za

20 Lectures Second semester

5 Tutorials counting 25% towards final mark

1 Class Test counting 25% towards final mark

Exam to take place in November, counting 50% towards final mark.

Outline

Nuclear properties: Segre plot, binding energies, nuclear shapes and sizes, magnetic moments. Radioactive decay: alpha, beta and gamma decay, fission. Semi-empirical mass formula, the liquid drop model. Cross-sections, nuclear reactions. Acceleration methods, interactions with matter, detectors, counting statistics. Deuteron. Nucleon-nucleon potential. Nuclear structure: Fermi gas, nuclear shell model, collective motion, non-spherical nuclei. Gamma spectroscopy. Nucleosynthesis. Applications: radioactive dating, fission, fusion, biomedical applications. Dosimetry.

Radiation sources, the process of radioactive decay as source of radiation, interaction of photons and neutrons with matter, isotope production with reactors and accelerators, nuclear fission as a source of radiation, lasers and microwaves as sources of radiation.

- Radiation sources: Units and definitions, Fast electron sources, Heavy charged particle sources, Sources of electromagnetic radiation, Neutron sources.
- The process of radioactive decay as source of radiation: Radioactive decay series; Differential equations; "Bateman-equations"; Biological losses and radioactive decay; Effective half-lifes, Production of radioactive isotopes.
- Interaction of photons and neutrons with matter: Emphasis is placed on energy transfer to the matter through which the radiation passes. Gamma-rays, neutrons.
- Isotope production with reactors and accelerators: General equation for production / decay of radioactive isotopes.
- Nuclear fission as a source of radiation: Process applications: Reactors; Criticality accidents
- Lasers and microwaves as sources of radiation.

Outcomes of course

The aim of the course is to indicate useful, purposeful, safe and innovative application of radiation. It is a core course for advanced courses in medical physics and radiation applications in industry.

Literature

[1] B. Martin, Nuclear and Particle Physics, Wiley, 2006.

[2] K.S. Krane, Introductory Nuclear Physics, Wiley, 1988.

[3] N.A. Jelley, Fundamentals of Nuclear Physics, Cambridge University Press, 1990.

[4] Edwin Podgorsak, Radiation Physics for Medical Physicists, 2006

[5] FH Attix, Introduction to Radiological Physics and Radiation Dosimetry.

[6] GF Knoll, Radiation Detection and Measurements.

[7] H Cember, Introduction to Health Physics

[8] CM Lederer et al. Table of Isotopes

3. Computational Physics

Lecturer Dr. T Dietel, thomas.dietel@uct.ac.za

Tutor TBA

20 Lectures first semester

5 Tutorials counting 25% towards final mark

1 Class Test counting 25% towards final mark

Take-home Exam to take place in June, counting 50% towards final mark. Students are expected to be familiar with at least one programming language.

Outline

Undergraduate physics students study simple problems having simple analytical solutions. Real world problems are complex. This course introduces computational methods in the context of simple physical problems which cannot be solved by analytical techniques. These methods form an introduction to problem solving in the real world. Topics to be presented will be drawn from: Motion with nonlinear damping forces (introduction to ODEs); time-independent Schroedinger equation for square well and for arbitrary potentials (roots of equations, Runge-Kutta and Numerov solutions of ODEs); solution of wave equation in periodic potential, band structure (linear algebra, eigenvalues of matrix); electrostatic potential problems (solution of Laplace equation by relaxation techniques); ray tracing in optical systems and charged-particle beam lines (linear algebra); detector response by Monte Carlo techniques (integration, random numbers); the fast Fourier transform; non-linear fitting; symbolic computation.

Literature

[1] R. de Vries, A first course in computational physics, Wiley, 1994.

[2] A.L. Garcia, Numerical methods for physics, Prentice-Hall, 1994.

[3] N.J. Giordano, Computational Physics, Prentice-Hall, 1997.

[4] W.H. Press et al., Numerical recipes, Cambridge University Press (various editions for different programming languages).

4. The Physics of Diagnostic Radiology

Lecturer Mr V Jonas, Vuyi.Jonas@uct.ac.za

20 Lectures first and second semester

5 Tutorials counting 25% towards final mark

1 Class Test counting 25% towards final mark

Exam to take place in November, counting 50% towards final mark.

Outline Physics of Radiology

The objective of the course is to introduce the student to the basic principles of imaging in Diagnostic Radiology. The course covers the following aspects:

- Atomic and Nuclear structure
- Photon and electron interactions with matter
- X-ray production
- Projection radiography and receptors
- Physics of Imaging modalities (i.e. Fluoroscopy, CT, Mammography, Ultrasound and MRI)
- Patient dosimetry
- Justification and optimization in clinical practice

Outcome of the course

A basic understanding of physics principles in diagnostic radiology imaging, as well as the role of medical physicists in radiology imaging.

Literature

[1] The Essential Physics of Medical Imaging, 3rd Edition, 2012, Jerrold T. Bushberg, J. Anthony Seibert, Edwin M. Leidholdt, Jr, John M Boone

[2] Diagnostic Radiology Physics: A Handbook for Teachers and Students, 2014, D.R. Dance, S. Christofides, A.D.A Maidment, I.D. Mclean, K.H Ng, IAEA

5. The Physics of Nuclear Medicine

Lecturer Ms Nanette Joubert, Nanette.Joubert@uct.ac.za

20 Lectures first semester

5 Tutorials counting 25% towards final mark

1 Class Test counting 25% towards final mark

Exam to take place in June, counting 50% towards final mark.

Outline

- Principles of Nuclear Medicine: The role of physics in Nuclear Medicine; Physiology background
- Decay of radioactivity: Definition of activity; the decay constant; Exponential decay; Specific activity; Parent-Daughter decay; modes of radioactive decay
- Radionuclide and radiopharmaceutical production: Reactor-produced radionuclides; Accelerator-produced radionuclides; Radionuclide generators; Radionuclides and radiopharmaceuticals for NM
- Scintillation detectors, energy selective counting and interactions: Passage of high-energy photons through matter; Scintillation detectors working; Spectrometry with NaI(Tl); Attenuation
- The gamma camera: General concepts of radionuclide imaging; Camera components, detector system; Collimators; Event detection

- SPECT: Tomographic Reconstruction; Different reconstruction methods; Attenuation correction; Scatter correction; Partial volume effect, correction; Collimator blurring
- Filters in NM: Different filters; influence of cut-off values; Typical artifacts
- Gamma camera QC, performance characteristics, image quality: General concepts of image quality; Basic performance characteristics; Performance characteristics of different collimators; Measurement of gamma camera performance (NEMA and Tecdoc 602); SPECT performance characteristics and measurements
- Radiation detectors: Gas-filled detectors; Diodes; Dose calibrator vs. well counter; Thyroid probe; Sentinel node probe
- Statistics in NM: Mean; Median; Standard deviation; Chi-squared test; T test
- PET: Annihilation coincidence detection; Time-of-flight; Spatial resolution in PET; PET detectors; Scanner design
- Internal radiation dosimetry: MIRD
- Radiation safety in NM: Safe handling of radioactive materials; Radioactive waste
- Hybrid imaging: Application of SPECT-CT, PET-CT, PET-MRI
- Image processing: Digital images, matrix size, display, ROI, curves, co-registration of images

Outcomes of course

The purpose of the course is to familiarize the student with:

- The theory and principle of operation of all medical nuclear instrumentation.
- The quality control measures of nuclear instrumentation.
- The practical uses of radioactive sources.
- The theoretical principles of common tracer techniques.
- Computer processing techniques of nuclear medicine images.
- The safe use of radioactive substances in Nuclear Medicine

Literature

[1] Physics in Nuclear Medicine, SR Cherry, JA Sorenson, ME Phelps. 4th Edition, 2012

[2] Quality Control of Nuclear Medicine Instruments. IAEA Tecdoc 602, 1991

[3] Quality Assurance for SPECT Systems. IAEA Human Health Series No. 6, 2009

[4] DL Bailey, L Humm, A Todd-Pokropek, A van Aswegen, Nuclear Medicine Physics: A Handbook for Teachers and Students, IAEA 2014.

[5] JT Bushberg, JA Seibert, EM Leidholdt, JM Boone, The Essential Physics of Medical Imaging, 3rd Edition, Lippincott Williams and Wilkens 2012.

6. The Physics of Radiotherapy

Lecturer Ms Hannelie MacGregor, Hannelie.MacGregor@uct.ac.za

20 Lectures first and second semester

3 Practical Assignments counting 25% towards final mark

1 Class Test counting 25% towards final mark

Exam to take place in November, counting 50% towards final mark.

Outline

- Introduction to Dosimetric Principles
- Physical Aspects of External Photon Beams
- Physical and Clinical Aspects of Electron Beams
- Radiation Detectors
- Calibration of Photon & Electron Beams
- Treatment Units for External Beam Radiotherapy
- Acceptance Tests & Commissioning of External Beam Treatment Units
- Physical and Clinical Aspects of Brachytherapy

Outcomes of course

The objective of the course is to introduce the student to the basic principles of dose measurements and dose calculations for teletherapy and brachytherapy. The student should further obtain knowledge on beam shaping, shielding and treatment planning of the radiotherapy patient.

Literature

[1] EB Podgorsak, Radiation Oncology Physics: A Handbook for Teachers and Students, 2005

[2] Faiz M Khan, The Physics of Radiation Therapy, 5th Edition, Williams and Wilkens, 2014.

7. Radiation Protection and Dosimetry

Lecturer: Ms Nanette Bruwer (Nanette.Bruwer@uct.ac.za)

20 Lectures first and second semester

8 Tutorials counting 20% towards final mark

Class Tests counting 30% towards final mark

Exam to take place in November, counting 50% towards final mark.

Outline Dosimetry:

- Stopping power: Interactions of charged particles with matter
- Interactions of charged particles with matter: range, energy and dose
- Mean stopping powers: interactions of charged particles with matter
- Cavity theory

Outcomes of the course

The objective of the course is to introduce the students to the basic principles of dosimetry necessary to scientifically determine the amount, rate and distribution of radiation.

Literature

[1] Introduction to Radiological Physics and Radiation Dosimetry, 2004, Frank Herb Attix

[2] The Physics of Radiology, Fourth addition, Johns and Cunningham. Thomas Books, 1983.

[3] Radiation Oncology Physics: A Handbook for Teachers and Students, 2005, E B Podgorsak, IAEA

Outline Radiation Protection:

- Units and sources of radiation
- Biological effects of exposure to ionizing radiation
- Effects of radiation on humans
- The system of radiation protection
- Structural shielding design
- Radiation safety in diagnostic radiology
- Radiation protection in nuclear medicine
- Radiation protection in external beam radiotherapy
- Radiation protection in brachytherapy

Outcomes of the course

Students are expected to obtain a solid understanding of radiation safety and be able to do structural shielding design calculations of a radiotherapy, nuclear medicine and diagnostic radiology department.

[1] Handout notes

[2] Radiation Oncology Physics: A Handbook for Teachers and Students, 2005, E B Podgorsak, IAEA

[3] Radiation Protection in the Design of Radiotherapy Facilities, Safety Reports Series No. 47, IAEA

[4] James E Martin, Physics for Radiation Protection: A Handbook, 2nd Edition, 2006

8. Radiotherapy Treatment Planning

Lecturer Ms Hester Burger, Hester.Burger@uct.ac.za

15 Lectures second semester

10 Practical planning practical sessions

Two individual planning projects counting 25% towards final mark

1 Class Test counting 25% towards final mark

Exam to take place in November, counting 50% towards final mark. The final exam consists of a theoretical section (60% of exam) and practical exam (40% of exam).

Outline Treatment Planning

The objective of the course is to present a sound foundation in the theory and practice of the radiation treatment planning process. The course covers the following aspects:

- Process overview
- Patient imaging, positioning and immobilization
- Target volume and critical structure definition
- Photon and electron beam characteristics
- Radiotherapy treatment techniques
- Dose calculation algorithms
- Dose verification
- Treatment plan evaluation
- Quality Assurance and Commissioning
- Practical radiotherapy planning

Outcomes of the course

Students are expected to obtain a solid understanding of radiotherapy treatment planning principles, as well as the application of the principles in practical planning. At the end of the course, students are expected to be able to generate clinically acceptable 3DCRT plans for specific lesion sites.

Literature

[1] Treatment Planning in Radiation Oncology, 3rd Edition, 2012, Faiz M Khan, Wolters Kluwer/Lippincott Williams & Wilkens

[2] Radiation Oncology Physics: A Handbook for Teachers and Students, 2005, E B Podgorsak, IAEA

[3] The Physics of Radiation Therapy, 4th Edition, 2010, Faiz M Khan, Wolters Kluwer/Lippincott Williams & Wilkens

9. Radiobiology

Lecturer Dr Alistair Hunter, Alistair.Hunter@uct.ac.za

20 Lectures first semester

1 Class Test counting 30% towards final mark

Exam to take place in June, counting 70% towards final mark.

Outline

This course will provide an introduction to basic radiobiology and radiation pathology of tissues. The course will introduce students to the basic biological interactions of radiation, including cellular radiobiology, tumour radiobiology and radiation effects in normal tissues. An overview of radiobiological modelling of cellular and organ effects will be covered including Tumour Control Probability and Normal Tissue Complication Probability.

Outcomes of the course

A basic understanding of radiobiology as applied to radiation medicine, specifically radiation oncology.

Literature

[1] Hall & Giaccia, Radiobiology for the Radiologist, 7th Edition

[2] Joiner & van der Kogel, Basic clinical radiobiology, 4th edition

10. Research Course

Co-ordinator H Burger, hester.burger@uct.ac.za

The research course will be detailed at the start of the course.

11. Introduction to Medical Imaging and Image Processing

Lecturers from Department of Human Biology – Biomedical Engineering (Dr Marcin Jankiewicz)

20 Lectures First semester

Outline

An introduction to the physics and engineering principles involved in the acquisition and processing of medical images. The contents include mathematical tools of image processing, x-ray imaging, computed tomography, positon emission tomography, ultrasound and magnetic resonance Imaging.

There's no final exam, but a number of assignments, including a literature review.

Outcomes of course

The objective of the course is to provide an introduction to basic concepts and methodologies for image processing and medical imaging modalities.

4. Lecture timetable

Time tables will be supplied at the start of the year.

All Physics courses will be given in the RW James Building, and all Medical Physics courses will be give in the Indaba Lecture Room, Department of Medical Physics, L Block, Groote Schuur Hospital.