DEPARTMENT OF PHYSICS

The Department is housed in the R W James Building, 9 University Avenue
Telephone (021) 650-3326 Fax (021) 650-3342 Website: www.phy.uct.ac.za

The Departmental abbreviation for Physics is PHY.

Professor and Head of Department:
A Buffler, MSc PhD HDE *Cape Town*
Professor:
A Peshier, MA PhD *Dresden*
Senior Scholars:
J W A Cleymans, MSc D en Sc *Louvain* FRSSAf
C A Dominguez, MSc PhD *Buenos Aires* FRSSAf
Emeritus Professors:
D G Aschman, BSc Hons *Cape Town* DPhil *Oxon*
D T Britton, MSc PhD *London*
R D Viollier, Dipl Phys Dr phil nat *Basel* FRSSAf
Associate Professors:
M S Allie, MSc PhD *Cape Town* (CHED)
M D Blumenthal, BSc *Witwatersrand* Dipl Phys *Bonn* PhD *Cantab*
W A Horowitz, MA MSc PhD *Columbia*
H W G Weigert, Dipl Phys Dr rer nat habil *Regensburg*
Emeritus Associate Professors:
R W Fearick, BSc Hons PhD *Witwatersrand*
M Härting, Dipl Phys *Regensberg* Dr. Ing BW *München*
P E Spargo, BSc (Eng) MSc *Witwatersrand* Cert Ed *Cantab* FRSSAf
G N v d H Robertson, BSc Hons *Cape Town* DPhil *Oxon*
Honorary Professor:
F Azaiez, MSc *Paris* PhD *Orsay*
Senior Lecturers:
T Dietel, Dipl Phys *Heidelberg* Dr phil nat *Frankfurt am Main*
S W Peterson, MA PhD *Wisconsin*
D L Taylor, BSc Hons HDE *UKZN* MSc PhD *Witwatersrand* (CHED)
S M Wheaton, MSc PhD *Cape Town*
S Yacoob, MSc *Cape Town* PhD *Northwestern*
Lecturers:
K E Cole, MSc *Liverpool* PhD *ICL*
D R Geduld, MSc *Cape Town*
J M Keaveney, PhD *Dublin*
T Leadbeater, MSc PhD *Birmingham*
T Salagaram, MSc PhD *UKZN*
Honorary Research Associates:
J A Ayala, PhD *Minnesota*
M Loewe, PhD *Hamburg*
K Schilcher, PhD *Vienna*
M Spiesberger, PhD *Mainz*
Chief Scientific Officer:
N Razak, MSc PhD *Cape Town*
Scientific Officer:
K Maibane, MSc *UWC*

Adjunct Research Officers:
C J Lee
M V Marziani
S Singh
Principal Technical Officers:
J Dickson
G K Fowle
K J Ontong
C J J Sadler
Senior Technical Officer:
M Christians
Department Administrator:
N Lovric
Administrative Assistants:
J Patel

Laboratory Attendant:
R Hansen
Departmental Assistant:
N Mzamo

RESEARCH IN PHYSICS

The Department of Physics is accommodated in the R W James Building, which houses laboratories equipped for nuclear physics, solid state and nanophysics, ultracold physics (8 mK dilution refrigerator), and physics education research. Additional facilities available to the Department are provided by iThemba Laboratories for Accelerator-Based Sciences (200 MeV cyclotron and other particle accelerators).

Major areas of interest at present include:

1. Experimental nuclear physics at iThemba LABS (A Buffler, R W Fearick, T Leadbeater and S W Peterson) comprising: (a) Gamma ray spectroscopy with the AFRODITE array; (b) Giant resonance reactions with the magnetic spectrometer; (c) Fast neutron physics; (d) Radiation detection and measurement.
2. Theoretical Physics (J W A Cleymans, C A Dominguez, W A Horowitz, A Peshier and H W G Weigert), comprising: (a) Research within the Centre for Theoretical and Mathematical Physics; (b) Structure of elementary particles; (c) Neutrino physics and astrophysics; (d) Quantum field theory, quantum electrodynamics and chromodynamics in free space, in the cavity and at extreme temperatures and pressures; (e) Renormalization group equations, both linear and nonlinear (Color Glass Condensate); (f) Nonlinear effects in QCD at high densities; (g) Phenomenology of heavy ion reactions; (h) Quark gluon plasma.
3. Experimental high energy physics (J W A Cleymans, T Dietel, S Yacoob and J M Keaveney), comprising:
(a) Research within the UCT-CERN Research Centre; (b) Relativistic heavy ion collisions within the ALICE collaboration at CERN; (c) High energy proton-proton collisions within the ATLAS collaboration at CERN.
4. Nanophysics and solid state physics (M D Blumenthal and T Salagaram), comprising: (a) Research within the Nanoelectronics Research Laboratory; (b) Structural and electrical properties of nanomaterials; (c) Single electron transport and interactions; (d) Computational studies.
5. Applied Physics (M D Blumenthal, A Buffler, K E Cole, T Leadbeater, S W Peterson, T Salagaram and S M Wheaton), comprising: (a) Research within the Metrological and Applied Sciences University Research Unit (MeASURe). (b) Positron Emission Particle Tracking at PEPT Cape Town, iThemba LABS and the Position Imaging Centre, University of Birmingham, UK; (c) Radiation transport modelling in industrial and medical systems; (d) Applied nuclear physics and engineering; (e) Electrical and radiation measurement standards.

6. Tertiary physics education (M S Allie, A Buffler, T Salagaram, D L Taylor and S M Wheaton), comprising: (a) Curriculum design and evaluation; (b) Role of language; (c) Understanding of measurement and uncertainty; (d) Modelling and visualization; (e) Computational physics education.

Undergraduate Courses

Credit will not be given for both PHY1023H and PHY1031F. Credit can be given for both of PHY1023H and PHY1004W.

First-Year Courses

PHY1004W MATTER & INTERACTIONS

Each student registered for this course is required to have a laptop for use during class sessions as well as after hours. The minimum specifications of the laptop are available at www.phy.uct.ac.za. (A tablet or "netbook" will not be suitable). The course convener will provide details of additional software (open source) required.

36 NQF credits at HEQSF level 5

Convener: Professor A Buffler

Course entry requirements: At least 60% for NSC Physical Science. MAM1000W (or equivalent) must have been passed or be taken concurrently. *Students registered for this course will be assessed in week 5; if it is judged that they are not coping with the level and pace of the course, and would benefit from an opportunity to strengthen foundational concepts and learn new material at a slower pace, they will be required to transfer to PHY1031F or PHY1023H from week 7.*

Course outline:

PHY1004W is an advanced calculus-based introductory course for Science students intending to continue with second-year Physics. It features the modelling of physical systems from fundamental principles, and computational problem solving using VPython. The course includes the following topics: Modern mechanics: Conservation laws, the momentum principle, atomic nature of matter, conservation of energy, energy in macroscopic systems, energy quantization, multi-particle systems, exploring the nucleus, angular momentum, entropy, kinetic theory of gases, efficiency of engines.

Electric and magnetic interactions: Electric fields, electric potential, magnetic fields, electric circuits, capacitance, resistance, magnetic force, Gauss' law, Ampere's law, Faraday's law, induction, electromagnetic radiation, waves and particles.

Lecture times: Monday - Friday, 3rd period

DP requirements: Minimum of 40% in class record, including 50% in laboratory assessment.

Assessment: Class record (weekly problem sets, class tests and laboratory record) counts 50%; one 2-hour examination in June counts 25%; one 2-hour examination in November counts 25%.

PHY1023H PRINCIPLES OF PHYSICS

Students passing PHY1023H may proceed into PHY1032F. Students who pass PHY1023H and then register for and pass PHY1004W will gain credit for both courses.

18 NQF credits at HEQSF level 5

Convener: Dr D L Taylor

Course entry requirements: At least 60% for NSC Physical Science. The permission of the Dean or Head of Department is required prior to registration for this course. *Notes: 1) This course only begins in week 7 and is intended for students who have been advised to transfer to this course after initially registering for PHY1004W or PHY1031F (see entries for these courses). 2) The course places an emphasis on the strengthening of foundational concepts and skills, the carefully-paced introduction of new material, and the development of sound approaches to effective learning.*

Course outline:
PHY1023H is an algebra-based introductory course for Science students. Some calculus may be used. The course includes the following topics: Tools and skills: Essential mathematical, diagrammatic and conceptual tools and skills for Physics, co-ordinate systems, vectors, rates of change, the fundamental forces, mathematical techniques and their relationship with physical phenomena. Mechanics: kinematics, forces, dynamics, momentum, impulse, work, energy, power, collisions, rotation, rotational dynamics, torque, angular momentum, static equilibrium, gravitation. Properties of matter: elasticity, hydrostatics, hydrodynamics. Vibrations and waves: simple harmonic motion, damped oscillations, forced oscillations, resonance, travelling waves, superposition, standing waves, sound waves, sound intensity, Doppler Effect.
Lecture times: Monday - Friday, 3rd period
DP requirements: Minimum of 40% in class record, including 50% in laboratory assessment.
Assessment: Class record (weekly problem sets, class tests and laboratory record) counts 50%; one 2-hour written examination in November counts 50%.

PHY1031F GENERAL PHYSICS A

18 NQF credits at HEQSF level 5
Convener: Dr S W Peterson
Course entry requirements: At least 60% for NSC Physical Science. *Note: Students registered for this course will be assessed in week 5; if it is judged that they are not coping with the level and pace of the course, and would benefit from an opportunity to strengthen foundational concepts and learn new material at a slower pace, they will be required to transfer to PHY1023H from week 7.*
Course outline:
PHY1031F is an algebra-based introductory course for Science students who do not intend proceeding to second-year courses in Physics. Some calculus may be used. The course includes the following topics: Mechanics: vectors, kinematics, forces, dynamics, momentum, impulse, work, energy, power, collisions, rotation, rotational dynamics, torque, angular momentum, static equilibrium, gravitation. Properties of matter: elasticity, hydrostatics, hydrodynamics. Vibrations and waves: simple harmonic motion, damped oscillations, forced oscillations, resonance, travelling waves, superposition, standing waves, sound waves, sound intensity, Doppler Effect.
Lecture times: Monday - Friday, 3rd period
DP requirements: Minimum of 40% in class record; including 50% in laboratory assessment.
Assessment: Class record (weekly problem sets, class tests and laboratory record) counts 50%; one 2-hour written examination in June counts 50%.

PHY1032F GENERAL PHYSICS B

18 NQF credits at HEQSF level 5
Convener: Dr T Salagaram
Course entry requirements: PHY1031F or PHY1023H
Course outline:
PHY1032F is an algebra-based introductory course usually taken by Science students who have completed PHY1023H. Some calculus may be used. The course includes the following topics: Electricity and magnetism: electric charge, electric field, Gauss' law, electric potential, capacitance, current, current density, emf, resistance, resistivity, networks, magnetic field, Biot Savart law, Ampere's law, electromagnetic induction, inductance, alternating currents. Thermal physics: temperature, heat, kinetic theory of gases, first and second laws of thermodynamics. Optics: Geometrical optics, polarization, electromagnetic waves, interference, diffraction. Modern physics: atomic structure, quantum physical phenomena, wave-particle duality, X-rays, elementary nuclear physics, radioactivity.
Lecture times: Monday - Friday, 3rd period
DP requirements: Minimum of 40% in class record, including 50% in laboratory assessment.
Assessment: Class record (weekly problem sets, class tests and laboratory record) counts 50%; one 2-hour written examination in June counts 50%.

PHY1032S GENERAL PHYSICS B
18 NQF credits at HEQSF level 5
Convener: Dr T Dietel
Course entry requirements: PHY1031F or PHY1023H
Course outline:
PHY1032S is an algebra-based introductory course for Science students who do not intend proceeding to second-year courses in Physics. Some calculus may be used. The course includes the following topics: Electricity and magnetism: electric charge, electric field, Gauss' law, electric potential, capacitance, current, current density, emf, resistance, resistivity, networks, magnetic field, Biot Savart law, Ampere's law, electromagnetic induction, inductance, alternating currents. Thermal physics: temperature, heat, kinetic theory of gases, first and second laws of thermodynamics. Optics: Geometrical optics, polarization, electromagnetic waves, interference, diffraction. Modern physics: atomic structure, quantum physical phenomena, wave-particle duality, X-rays, elementary nuclear physics, radioactivity.
Lecture times: Monday - Friday, 3rd period
DP requirements: Minimum of 40% in class record, including 50% in laboratory assessment.
Assessment: Class record (weekly problem sets, class tests and laboratory record) counts 50%; one 2-hour written examination in November counts 50%.

Second-Year Courses

PHY2004W INTERMEDIATE PHYSICS
Each student registered for this course is required to have a laptop for use during class sessions as well as after hours. The minimum specifications of the laptop are available at www.phy.uct.ac.za. (A tablet or "netbook" will not be suitable). The course convenor will provide details of additional software (open source) required.
48 NQF credits at HEQSF level 6
Convener: Associate Professor M D Blumenthal
Course entry requirements: PHY1004W, a full first-year course in Mathematics, and MAM2000W or (MAM2004H and MAM2047H) as co-requisite.
Course outline:
PHY2004W develops the foundations of a major in Physics and allows continuation to third-year Physics. The theory component features a set of intermediate topics, and the laboratory component develops both experimental and computational skills. The course includes the following topics: Mechanics: Review of Newton's laws, inertial and non-inertial frames, transformations, equations of motion for 1D systems, oscillations, resonance, non-linear systems, Euler's equation, Lagrange's equation, generalized co-ordinates and constrained systems, Hamiltonian formalism, phase space and Liouville's theorem, effective potentials, planetary motion, systems of particles, angular momentum, collisions, rigid bodies, simple harmonic motion, resonance, coupled oscillators, wave equation, special relativity, relativistic mechanics.
Electromagnetism: Vector calculus (div, grad, curl), electrostatics, special techniques for potentials, electric fields in matter, magnetostatics, magnetic fields in matter, current, Ohm's law, circuits, electromagnetic induction, electrodynamics, Maxwell's equations.
Quantum mechanics: The basic assumptions of quantum mechanics, solutions of Schrödinger's equation, properties of wave functions and operators, one-dimensional applications, angular momentum in quantum mechanics, three-dimensional applications, the hydrogen atom, approximate methods.
Laboratory: Practical and computational tasks designed to develop advanced skills of experimentation and problem solving within the context of Mechanics, Electromagnetism and Quantum Mechanics.
Lecture times: Monday - Friday, 4th period
DP requirements: Minimum of 40% in class record; completion of all laboratory reports and 75% of tutorial work and problem sets; attendance at all tests.

Assessment: Class record (tests, weekly problem sets and laboratory work) counts 50%; one 2-hour examination in June counts 20%; one 3-hour examination in November counts 30%. A subminimum of 40% is required for the weighted average of the two examinations.

Third-Year Courses

PHY3004W ADVANCED PHYSICS

Each student registered for this course is required to have a laptop for use during class sessions as well as after hours. The minimum specifications of the laptop are available at www.phy.uct.ac.za. (A tablet or "netbook" will not be suitable). The course convenor will provide details of additional software (open source) required.

72 NQF credits at HEQSF level 7

Convener: Dr S M Wheaton

Course entry requirements: PHY2004W, and 40% in MAM2000W or (MAM2004H and MAM2047H).

Course outline:

This course completes the major in Physics. The theory component aims to develop advanced skills in problem solving within physics, and includes the following topics:

Electromagnetism: Maxwell's equations in vacuum and matter, momentum and angular momentum in electromagnetic fields, electromagnetic waves, wave guides, gauge transformations, retarded potentials, electric and magnetic dipole radiation, special relativity, relativistic kinematics and electrodynamics, electromagnetic field tensor.

Thermodynamics and statistical physics: temperature, heat and work, laws of thermodynamics, ensembles and entropy, Boltzmann distribution and Helmholtz free energy, thermal radiation, chemical potential and Gibbs distribution, Fermi-Dirac statistics, electrons in metals, Bose-Einstein statistics, phonons, photons and the black-body distribution, the Bose-Einstein condensate, applications to classical and quantum systems.

Applications of Quantum Mechanics: Atomic physics (atomic structure and spectra, selection rules, spin, fine structure, Zeeman effect, time dependent and independent perturbation theory); nuclear and particle physics (properties of nuclei, nuclear forces, structure, reactions and models, nuclear models, interactions of elementary particles, quarks and leptons, symmetries and the gauge forces); and solid state physics (crystal structure, lattice vibrations, electron states in solids, energy band theory, semiconductor physics and devices).

The laboratory component includes practical and computational tasks to develop advanced skills of experimentation and scientific report writing.

Lecture times: Monday - Friday, 4th period

DP requirements: Minimum of 40% in class record; attendance at all tests; completion of all laboratory reports; completion of the project and completion of 75% of tutorials and problem sets.

Assessment: Class record (tests, weekly problem sets, laboratory work and project) counts 50%; two 2-hour examinations in June counts 25%; two 2-hour examinations in November counts 25%. A subminimum of 40% exists in the weighted average of the four examinations.

Postgraduate Courses

PHY4000W PHYSICS HONOURS

Since the code PHY4000W will not carry a NQF credit value, students will be concurrently registered for PHY4006W (coursework component of 120 NQF credits) and PHY4007W (research project of 40 NQF credits).

160 NQF credits at HEQSF level 8

Convener: Professor A Peshier

Course entry requirements: The entrance requirement is a BSc degree with a major in Physics. Acceptance will be at the discretion of the Head of Department who will consult the Honours course co-ordinator. Criteria for acceptance include a pass of 60% in PHY3004W, or equivalent; and a pass of 60% in MAM2000W or MAM2046W, or equivalent; and in cases where the Head of Department deems it necessary, favourable referee reports. Enrolment is limited to 15 students. Preference may be given to UCT graduates who meet the course entry requirements.

Course outline:

The Honours course in Physics consists of several modules comprising at least 12, but not more than 14 units. The compulsory modules are: Research Project (3 units), Electromagnetism 1, Electromagnetism 2, Quantum Mechanics 1, Quantum Mechanics 2, and Statistical Physics. At least three further modules must be chosen from: Classical Mechanics, Computational Physics, Particle Physics, Nuclear Physics, Relativistic Quantum Mechanics, Quantum Field Theory, and Solid State Physics. The course starts with a compulsory non-credit bearing module dealing with mathematical tools and skills, and aspects of physics education. Furthermore, the course can be complemented by physics-related modules offered by the Departments of Astronomy, and Mathematics and Applied Mathematics. The choice of modules and research project must be approved by the Head of Physics in consultation with the Honours co-ordinator. Details appear on the Physics website: www.phy.uct.ac.za.

DP requirements: 30% for class tests and problem sets, and suitable progress in the Research Project.

Assessment: The pass mark is 50% and is based on an aggregation of the results of all modules, and is further subject to the subminimum criteria of obtaining a minimum mark of 50% in the Research Project, passing two thirds of all modules, and achieving a mark of at least 35% in all but two of the compulsory modules. The Research Project will count 25% of the final mark. These component parts of the course will be combined in a final overall mark which will be reflected against the course code PHY4000W, with PA (pass) entered against the coursework and project codes; each of these components must be passed separately for the award of the degree.

PHY5000W PHYSICS DISSERTATION

180 NQF credits at HEQSF level 9

Course outline:

This course consists of an investigation of an approved topic chosen for intensive study by the candidate (student), culminating in the submission of a dissertation. The dissertation shall demonstrate the successful completion of a programme of training in research methods, a thorough understanding of the scientific principles underlying the research and an appropriate acquaintance with the relevant literature. It must be clearly presented and conform to the standards of the department and faculty. The dissertation will usually consist of a report detailing the conduct, and analysis of the results of, research performed under the close guidance of a suitably qualified supervisor/s. The dissertation should be well-conceived and acknowledge earlier research in the field. It should demonstrate the ability to undertake a substantial and informed piece of research, and to collect, organise and analyse material. General rules for this degree may be found in the front of the handbook.

PHY5001W THEORETICAL PHYSICS DISSERTATION
180 NQF credits at HEQSF level 9
Course outline:
This course consists of an investigation of an approved topic chosen for intensive study by the candidate (student), culminating in the submission of a dissertation. The dissertation shall demonstrate the successful completion of a programme of training in research methods, a thorough understanding of the scientific principles underlying the research and an appropriate acquaintance with the relevant literature. It must be clearly presented and conform to the standards of the department and faculty. The dissertation will usually consist of a report detailing the conduct, and analysis of the results of, research performed under the close guidance of a suitably qualified supervisor/s. The dissertation should be well-conceived and acknowledge earlier research in the field. It should demonstrate the ability to undertake a substantial and informed piece of research, and to collect, organise and analyse material. General rules for this degree may be found in the front of the handbook.

PHY5003W ASTROPHYSICS & SPACE SCIENCE MINOR DISSERTATION
(National Astrophysics & Space Science Programme (NASSP); for further details see entry under Department of Astronomy)
90 NQF credits at HEQSF level 9
Course entry requirements: AST5003F
DP requirements: None.
Assessment: Students will work on an approved research topic on which a minor dissertation must be presented for formal examination.

PHY5006W TERTIARY PHYSICS EDUCATION DISSERTATION
180 NQF credits at HEQSF level 9
Course outline:
This course consists of an investigation of an approved topic chosen for intensive study by the candidate (student), culminating in the submission of a dissertation. The dissertation shall demonstrate the successful completion of a programme of training in research methods, a thorough understanding of the scientific principles underlying the research and an appropriate acquaintance with the relevant literature. It must be clearly presented and conform to the standards of the department and faculty. The dissertation will usually consist of a report detailing the conduct, and analysis of the results of, research performed under the close guidance of a suitably qualified supervisor/s. The dissertation should be well-conceived and acknowledge earlier research in the field. It should demonstrate the ability to undertake a substantial and informed piece of research, and to collect, organise and analyse material. General rules for this degree may be found in the front of the handbook.

PHY5007Z DATA SCIENCE FOR PARTICLE PHYSICS
12 NQF credits at HEQSF level 9
Convener: Dr T Dietel
Course entry requirements: Core modules of the Masters course in Data Science.
Course outline:
This course introduces students to the important computational aspects of high-energy nuclear and particle physics research. Using examples from current research at the European Organization for Nuclear Research (CERN), the students are introduced to: the basic principles of high-energy physics, the Grid computing model employed by the Worldwide LHC Computing Grid (WLCG), the simulation of interactions between subatomic particles and their detection, the ROOT data analysis tool used by all the large high-energy physics collaborations, the signal extraction and significance estimation techniques employed by the most recent particle discoveries including concepts like nuisance parameters and the look-elsewhere effect.
DP requirements: 50% average for the two projects.

Assessment: Two projects: 25% each. Practical 'take-home' Computing examination: 50%. A sub-minimum of 50% for each of the project and examination components will be required.

PHY5008W DATA SCIENCE MINOR DISSERTATION

90 NQF credits at HEQSF level 9

Convener: Dr S Er

Course entry requirements: Successful completion of the coursework component of the Masters course in Data Science.

Course outline:

The research component of the degree is based on a 90 credit dissertation. The topic of the research will be based on an analysis of large data sets from Physics.

PHY6000W PHYSICS THESIS

360 NQF credits at HEQSF level 10

Course outline:

The PhD is a research degree on an advanced topic under supervision which can be taken in any of the departments in the Faculty. Examination is by thesis alone. A candidate shall undertake doctoral research and advanced study under the guidance of a supervisor/s appointed by Senate. The thesis must constitute a substantial contribution to knowledge in the chosen subject, must show evidence of original investigation and give a full statement of the literature on the subject. The PhD degree demands that the candidate is able to conduct independent research on his/her own initiative. Through the thesis the candidate must be able to demonstrate that he/she is at the academic forefront in the topic selected, that the work is original and that it advances our knowledge in the relevant field. Candidates are referred to the rules for this degree as set out in Book 3, General Rules and Policies.

PHY6001W TERTIARY PHYSICS EDUCATION THESIS

360 NQF credits at HEQSF level 10

Course outline:

The PhD is a research degree on an advanced topic under supervision which can be taken in any of the departments in the Faculty. Examination is by thesis alone. A candidate shall undertake doctoral research and advanced study under the guidance of a supervisor/s appointed by Senate. The thesis must constitute a substantial contribution to knowledge in the chosen subject, must show evidence of original investigation and give a full statement of the literature on the subject. The PhD degree demands that the candidate is able to conduct independent research on his/her own initiative. Through the thesis the candidate must be able to demonstrate that he/she is at the academic forefront in the topic selected, that the work is original and that it advances our knowledge in the relevant field. Candidates are referred to the rules for this degree as set out in Book 3, General Rules and Policies.