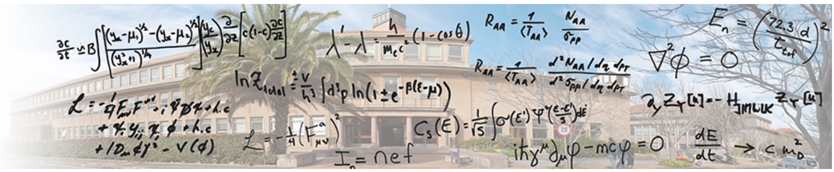
University of Cape Town

DEPARTMENT OF PHYSICS



— 2022 —

Physics Honours

PHY4000W

Official Course Handbook

Department of Physics
University of Cape Town
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Course website
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Contents

1 General information

This handbook contains the academic and logistical details for the one-year BSc Honours degree in physics at UCT with course code PHY4000W: BSc(Hons) in PHYSICS. We recommend this handbook is read through once carefully and is then used as reference manual throughout the year.

This course is usually taken in the fourth year of university study, after having graduated with a BSc. in Physics. The course covers the fundamental aspects of both theoretical and experimental physics at a level similar to the fourth year of an undergraduate degree in physics at any leading international institution. The honours degree is often a gateway towards further postgraduate degrees in physics, such as an MSc. and or a PhD.

The Head of the Phys. Dept (HoD) who bears ultimate responsibility for the course is A/Prof. Steve Peterson. The course convener is Dr. James Keaveney and is responsible for the coordination and day-to-day running of the course. Please direct any queries about the course to the convener at **james.keaveney@uct.ac.za**. Administrative assistance in the physics department in general is provided by Jill Patel **jill.patel@uct.ac.za**. For the benefit of newcomers to the UCT Phys. Dept, you can see photos of Steve, James, and Jill below. The external examiner for the honours course is Dr. H. Kriel (Stellenbosch University).

The course commences with the week-long kick-off module on the 2022, at 9:00, in UCT upper campus. The exact venues and additional details will be communicated by email. Attendance of this module is compulsory.

1.1 The course website

All the information, organisation and communication for the course happens via the Vula course website which can be found at this link **vula site**. This site will only become accessible after 7th Feb 2022 and access requires you to be logged in to UCT Vula. The site should always be the first place you look

Figure 1.1: Left to right: Steve, James, and Jill

when searching for some info related to the course. Separate sections for each physics module will appear there as the modules get started. Each student will be added to the Vula site so you will automatically have appropriate access rights and receive announcements via your UCT email address.

1.2 Restrictions due to the COVID-19 pandemic

Academic life across the globe has been greatly disrupted over the past year due to the ongoing pandemic and the physics honours course at UCT is no different. In spite of these challenges this year we will offer a course that is in no way diminished with respect to the pre-COVID years. The learning activities of this course will take place almost exclusively **in-person** and honours students are expected to be on campus on a daily basis unless no activities are occurring.

The usage of large, ventilated lecture theatres with strict occupancy limits will facilitate adequate social distancing and masks will be required at all time. Project work in research labs will proceed only with strict limits on lab space occupancy. Personal responsibility to adhere to regulations in this regard is the most important factor towards maintaining a safe environment and ensuring an optimal honours experience for all. Further details of the COVID-19 regulations will be communicated via email in the lead up to the start of the course. In order to find out any additional details on the COVID restrictions and regulations, please contact Kerwin Ontong at **kerwin.ontong@uct.ac.za**.

1.3 Structure of the course

The course has four components, each of which corresponds to a certain number of course credits.

- compulsory research project (3 credits)
- three compulsory modules from the Phys. Dept. (1 credit each)
- at least four elective modules from the Phys. Dept. (1 credit each)
- at least two more elective modules either from the Phys. Dept. or *external* modules in a physics-related discipline from another dept. (1 credit each)

Each student must complete at least 12 and not more than 14 credits. The choice of external modules must be approved by the HoD in consultation with the course convener. As electromagnetism and quantum mechanics are among the most fundamental topics in physics, students are encouraged to include Electrodynamics 2 and Quantum Mechanics 2 in their elective modules especially if they intend to undertake a theoretical research project or a further postgraduate degree in theoretical physics. Students are reminded to take into account the semester in which each module takes place to ensure a balanced workload between both semesters. The course starts with a compulsory, zero-credit *Kick-Off* module dealing with fundamental mathematical tools, problem-solving, and aspects of physics education.

In table 1.3, the compulsory and elective modules within physics along with the semester in which the module takes place are shown. Examples of external modules from the Departments of Astronomy (AST), Mathematics and Applied Mathematics (MAM), Medical Physics (MEDPHY), Computer Science (CSC), Centre for Research in Computational and Applied Mechanics (CERECAM) taken by past students are also included. Exhaustive lists of the honours-level modules offered by these departments are available at the following links **MAM modules**, **MEDPHY modules**, **AST modules**, **CSC modules**, **CERECAM modules**. Please note some external modules choices may not be accepted.

The Phys. Dept. reserves the right to modify this list should staffing or other factors dictate. Outlines of each module offered in the Phys. Dept. are given in **Section 2.1**. The content of module is broadly determined by the HoD, the convener, and the module lecturer.

	module	semester	credits
Compulsory	Kick-Off module (KO)	1	–
	Research project (RP)	1+2	3
	Electrodynamics 1 (ED1)	1	1
	Quantum Mechanics 1 (QM1)	1	1
	Statistical Physics (SP)	1	1
Physics Electives	**Electrodynamics 2 (ED2)**	1	1
	Quantum Mechanics 2 (QM2)	1	1
	Classical Mechanics (CM)	1	1
	Computational Physics (CP)	1	1
	Nuclear Physics (NP)	2	1
	Physics Education (PE)	1+2	1
	Particle Physics (PP)	2	1
	Quantum Field Theory (QF)	2	1
	Relativistic Quantum Mechanics (RQ)	2	1
	Solid State Physics (SS)	2	1
Physics-related electives	Data science in High-Energy Physics [PHY]	2	1
	Advanced Math Methods 1+2 [MAM]	1+2	1+1
	Differential Geometry [MAM]	1	1
	Lie Algebras [MAM]	2	1
	General Relativity [MAM]	1	1
	Programming for Scientists/Engineers [CERECAM]	1	1
	Continuum Mechanics [CERECAM]	1	1
	General Astrophysics [AST]	1	1
	Diagnostic Radiology [Med PHY]	1+2	1
	Radiotherapy [Med PHY]	1+2	1
	Nuclear Medicine [Med PHY]	2	1
	...	...	...

Table 1: The compulsory and elective modules expected to be offered by the Phys. Dept. with associated credits and the semester in which the module takes place are listed. Commonly used acronyms for each module, e.g., (PP) are indicated in round brackets. Some examples of physics-related modules from previous years are also included with the department offering module indicated in the square brackets.

1.4 Module choice

A student must declare at the first meeting of class a provisional choice of modules, which may be modified during the first lecture week. Thereafter, a student can change the module package only if the HoD, after consultation with the convener, agrees.

1.5 Research project

The research project (RP) is an essential part of the course and allows the student to greatly deepen their physics knowledge by applying the concepts they learn in the lecture modules to a real-world research problem. Each project is closely supervised by a member of the academic staff of the Phys. Dept. A list of potential research projects, closely-aligned with either, i. e. experimental physics, theoretical physics, or mathematical physics are devised by the physics academic staff in advance of the commencement of the course. Available topics will be listed on the course website **research project list** from the start of the module. Students should examine this list closely and discuss the projects with potential supervisors as early as possible. Novel project proposals from students are welcome including projects in collaboration with co-supervisors from other departments. However all such proposals must include a supervisor from within physics, and must be approved by the HoD, the convener, and the proposed supervisors. Students should look closely at the list of potential project supervisors within UCT physics and their research interests **list of supervisors and research profiles**. Feel free to contact a potential supervisor directly to discuss a potential project if their research looks interesting to you.

A project must be chosen by the end of the second lecture week and communicated to the convener. In both terms 2 and 3, 10-minute presentations to the honours class, course convener and selected academics on the aims and status of of the project is required. These two status presentations cumulatively carry **10 %** of the RP grade. A the start of the second semester, a maximum 10-page literature review and introduction to the RP is to be submitted by the student with the approval of the supervisor. This submission carries **10 %** of the RP grade. If the HoD, after consultation with the convener, feels there has not been sufficient progress, a letter will be sent to the student and the supervisor, warning that the course DP certificate (see **Section 1.8**) may be withheld. On a date specified by the convener (normally a week after the last exam), a final oral presentation of the RP is to be given, which will be assessed by the referee, the convener and the HoD, and which will carry **10%** of the RP grade.

The project report, typically approximately 30 pages,[1] is to be submitted by a date set by the course convener (normally a week before lectures end). otherwise the DP certificate may be withheld. The report should provide a clear introduction to the project undertaken, a thorough description of the work performed by the student with emphasis on any novel problems encountered and a objective appraisal of the strengths and limitations of the project including an outlook on potential future work. The report will be graded by a member of the Phys. Dept. staff appointed by the HoD, the grade provided by the examiner constitutes the remaining **70 %** of the RP grade. A referee, appointed by the HoD, will assess the thesis with regard to the student's ability to conduct (supervised) research including literature review, necessary calculations and/or experimental work, analysis of results, as well as their clear presentation and discussion.

The research project counts 25% towards the final course mark.

1.6 Admission criteria

Admission to the Physics Honours course is at the discretion of the Dean of Science and the HoD, who will consult the course convener. Normally the following criteria are used:

- a pass mark of $\geq 60\%$ in the UCT third year Physics course or equivalent
- a mathematical background strong enough to ensure success in the course, which requires a second year UCT Mathematics or Applied Mathematics course or equivalent.

In exceptional cases a student who does not meet the above criteria may be set reading and study material, and, upon satisfying the HoD that they have mastered this material, may be admitted.

[1] Theses from previous years are available in the WE Frahn library.

1.7 Standard of the course and workload

The UCT Physics Honours course aims at an academic standard commensurate with fourth-year undergraduate physics courses at leading international institutions. A successful UCT physics honours student will be well-prepared for

- a research MSc degree by dissertation
- the GRE examination for US graduate school
- direct entry into a European or US post-graduate degree

A rough estimate of the workload for one typical lecture module is

20 lectures (incl. question time)	20 hours
reading before and after lecture	20 hours
5 problem sets/tutorials	20 hours
independent study	20 hours
total	**80 hours**

Accordingly, the minimum 12 credits would cumulatively take about 960 hours. Divided by 120 days this averages to 8 hours a day. The actual workload, including preparations for tests and examinations, will depend on student preparedness and ability, and may well be somewhat higher than the above estimate. Therefore, effective time management is a crucial skill for a success in the honours course.

1.8 Duly performed (DP) certificate

Only students who receive a duly performed (DP) certificate, normally issued in the last week of lectures, will be allowed to write the October/November examinations. The DP certificate criteria are:

- a class record of at least 30% for all problem sets and class tests
- sufficient progress in the research project, in particular the project report
- attendance of the 'Kick-Off' module

1.9 Examinations

The 1st and 2nd semester modules will be examined in the respective examination period. Exceptionally, by agreement with students and lecturing staff, the HoD may direct examinations to take place outside these periods.

All class tests and examinations will be invigilated and occur in-person on the UCT campus.

Student have to confirm the modules to sit for examination by the beginning of the 3rd last week of lectures or a date set by the HoD.

Results of the examination of all these modules will be used in a final aggregation by the Honours examination committee, a body whose membership is decided by the HoD and will typically include the HoD, the convener, lecturers, project supervisors, and referees as well as the external examiner. This committee advises the HoD, who submits the course results to the Science Faculty Examination Committee (FEC) for decision, and ultimate ratification by the University Senate.

1.10 Aggregation of marks

Passing PHY4000W requires marks of at least 50% for the coursework component (averaged over the lecture modules) and at least 50% for the RP.

The final course mark is the mean of the individual module marks, unless the HoD shows good cause, in writing, for deviating from this. In this average, the RP project is worth 3 credits compared to the lecture modules (each worth one credit). For a module choice with more than the minimum number of 9 lecture modules, the results of the 3 compulsory modules, the 4 best physics-elective modules and the 2 best of the remaining modules enter the average.

The pass/fail decision is based on this final mark exceeding the pass mark of **50%**, and is further subject to the **minimum criteria** of:

- passing six of the lecture modules used to determine the final grade
- achieving a mark of $\geq 35\%$ in all the compulsory lecture modules.

A student who fails PHY4000W may not be re-admitted.

1.11 Resources

The utilisation of these resources depends on the the COVID-19 restrictions that may be increased throughout the year.

An office space honours students to enable quiet study time, interactions and discussion will be provided in the RW James. The usage of these spaces will be subject to COV-19 regulations.

The Department has a **Postgraduate Computer Lab** on Level 4 of the RW James Building which is open to physics honours students. The 8 Quad-Core+GPU PCs run both Windows and Linux; available software includes LaTeX, Open/MS Office, Mathematica and VPython. A printing facility is available (printing abuse will be detected). The usage of this computer lab will be subject to COV-19 regulations. Details of lab and computer usage can be found on posters located around the Lab. For further information contact the lab administrator Kerwin Ontong, **Kerwin.Ontong@uct.ac.za**.

A general guide to new postgrad students is available on the Department website **www.phy.uct.ac.za**.

Last but not least: social interaction between students and staff is something consider an essential part of the physics honours experience. This is not only to give student more chances to discuss physics with their lecturers, but also to cultivate a warm and welcoming atmosphere for all in the department. Obviously this has been almost impossible during the COVID-19 pandemic. However the departmental morning coffee will be restart in the 2022 academic year and Honours students should attend. Details will be communicated via the Vula site.

2 Description of Modules

2.1 Compulsory physics modules

2.1.1 Kick-off module (KO)

Activities in the orientation week involving several lecturers dealing with:

- the nature of Physics and Physics education
- mathematical tools and skills for the Honours course, combined with an introduction to Mathematica
- overview of experimental physics concepts: measurement, data analysis, hardware
- visits and discussions with UCT researchers

No grades or credits are awarded for this module, however full attendance is required for the DP certificate.

Outline

Intro to philosophy and nature of Physics; Role of Mathematics and modeling; Why is Physics hard to learn? (A perspective from cognitive psychology); role of practical work in learning physics; Learning to think computationally. — Introduction to Mathematica; linear algebra and vector calculus; complex analysis; differential equations; Fourier analysis and integral transforms; numerical methods.

2.1.2 Quantum Mechanics 1 (QM1)

Lecturer	Prof A. Peshier, **Andre.Peshier@uct.ac.za**
20 lectures	***First semester, first quarter***
5 tutorials	counting 25% towards module mark
Class test	counting 25% towards module mark
Exam	2 hours, in May/June, counting 50% towards module mark

Outline

Some historical remarks — *Postulates and concepts of Quantum Mechanics*: vectors and operators in Hilbert space and their representation; observables, measurements and uncertainties — *Quantum evolution*: Schrödinger equation, Schrödinger vs. Heisenberg picture, harmonic oscillator, path integrals — *Angular momentum*: rotations and commutation relations, spin and angular momentum eigenstates and eigenvalues, addition of angular momenta, spin correlations and Bell's inequality.

Literature

[1] J. J. Sakurai, *Modern Quantum Mechanics*, Addison Wesley 1993.

[2] N. Zettili, *Quantum Mechanics: Concepts and Applications*, Wiley 2009.

[3] L. D. Landau and E. M. Lifshitz, *Vol. 3: Quantum Mechanics*, Butterworth-Heinemann 1981.

[4] R. Shankar, *Principles of Quantum Mechanics*, Plenum 1994.

2.1.3 Electrodynamics 1 (ED1)

Lecturer	A/Prof H. Weigert, **Heribert.Weigert@uct.ac.za**
20 lectures	***First semester, first quarter***
5 tutorials	counting 25% towards module mark
Class test	counting 25% towards module mark
Exam	2 hours, in May/June, counting 50% towards module mark

Outline

This module aims at redeveloping Maxwell's equations using modern tools to expose the concepts and to demonstrate how fundamental physics observations are encoded in an elegant and flexible mathematical language. The module specifically offers the following topics:

History and perspective — review of Maxwell's equations and their ingredients: vector and pseudo vector fields, associated vector calculus and the symmetries that lead to this classification — basic principles of electrostatics — multipole expansions — solving differential equations: Green's functions, boundary conditions, complete sets of states — electrostatics in media — magneto-statics — magneto-statics in media — synthesis with time dependent phenomena via Maxwell's equations.

Literature

[1] A. Zangwill, *Modern electrodynamics*, Cambridge University Press 2013.

[2] J. D. Jackson, *Classical Electrodynamics*, Wiley 1980.

[3] L. D. Landau and E. M. Lifshitz, *Vol. 2: The Classical Theory of Fields*, Butterworth-Heinemann 1980.

[4] L. D. Landau and E. M. Lifshitz, *Vol. 8: Electrodynamics of Continuous Media*, Butterworth-Heinemann 1984.

[5] All this will be supplemented with extensive lecture notes that will be the main source of material.

2.1.4 Statistical Physics (SP)

Lecturer	Dr. T. Dietel, **Thomas.Dietel@uct.ac.za**
20 lectures	***First semester***
5 tutorials	counting 25% towards module mark
Class test	counting 25% towards module mark
Exam	2 hours, in October/November, counting 50% towards module mark

Outline

Postulates of Statistical Physics: ensembles, thermodynamic potentials, equilibrium conditions – *Non-interacting systems:* ideal gas, speed of sound, harmonic oscillators, Bose and Fermi gases, Bose-Einstein condensation, paramagnetism – *Interacting systems and phase transitions:* Van-der-Waals equation of state, Ising model, ferromagnetism, Einstein and Debye models, phonons

Literature

[1] M. Kardar, *Statistical Physics of Particles*, Cambridge University Press, 2007.

[2] D. V. Schroeder, *An introduction to Thermal Physics*, Pearson 1999.

[3] L. D. Landau and E. M. Lifshitz, *Vol. 5: Statistical Physics Part I*, Butterworth-Heinemann 1981.

2.2 Elective physics modules

2.2.1 Quantum Mechanics 2 (QM2)

Lecturer	Prof A. Peshier, **Andre.Peshier@uct.ac.za**
20 lectures	***First semester, Term 2***
5 tutorials	counting 25% towards module mark
Class test	counting 25% towards module mark
Exam	2 hours, in May/June, counting 50% towards module mark

Outline

Many-particle quantum systems: exchange symmetry, Pauli exclusion principle, spin-statistics theorem — *Approximation methods:* time-independent perturbation theory, Fermi's golden rule, variational methods, WKB approximation — *Scattering theory:* Lippman-Schwinger equation, Born approximation, Optical theorem.

Literature

Same as for QM1.

2.2.2 Electrodynamics 2 (ED2)

Lecturer	A/Prof H. Weigert, **Heribert.Weigert@uct.ac.za**
20 lectures	***First semester, Term 2***
5 tutorials	counting 25% towards module mark
Class Test	counting 25% towards module mark
Exam	2 hours, in May/June, counting 50% towards module mark

Outline

The main goal of this module is a relativistically covariant formulation of electrodynamics and the treatment of (relativistic) time dependent phenomena. This provides a solid foundation for developing quantum field theories (see the RQM and QFT modules). This module offers the following topics:

Special relativity and the Lorentz and Poincaré groups — relativistic classical field theories: actions and symmetries — Noether's theorem for field theories and conservation laws — gauge potentials and a count of degrees of freedom — electrodynamics as a classical field theory — Greens functions revisited: Fourier transforms and the use of residues — moving charges and radiation.

Literature

Same as for module ED1.

2.2.3 Particle Physics (PP)

Lecturer	Dr J. Keaveney, **James.Keaveney@uct.ac.za**
18 lectures	***Second semester, Term 4***
1 data analysis mini-project	15% of module mark
Class presentation	10% of module mark
Class test	counting 25% of module mark
Exam	2 hours, in October/November, 50% of module mark

Outline

The field of experimental particle physics explores nature at the smallest scales by studying the properties and interactions of elementary particles. In this module we will gain a deep understanding not only of the theories that describe these particles but of the vast and complex experiments that test these theories to high precision.

The first three quarters of the module deals with our best theory of elementary particles and their interactions: the *Standard Model*. We will see how imposing basic symmetries on our field theories yields explantation for interactions between electrically- weakly- and color-charged particles. The first half of the module culminates with an exploration of how manually inserting mass terms for elementary particles breaks symmetries in our theories and how the Higgs mechanism can provides mass terms while preserving these symmetries.

The last quarters of the module deals with how the theories are tested with collider experiments. The basic operation of a collider experiment is explored with the Large Hadron Collider as the most relevant example. The module ends with a special topic: "the top quark as a window to new physics", which is a core research interest of the module lecturer in the ATLAS experiment at CERN.

Literature

[1] M. Thomson, *Modern Particle Physics*, Cambridge 2013.

2.2.4 Physics Education (PE)

Lecturer	A/Prof S. Allie, **Saalih.Allie@uct.ac.za**
20 lectures	seminar style format, ***First semester, Terms 1 & 2***
2 essays/projects	counting 50% towards module mark
Exam	Take-home: 2 essays, in October/November, counting 50% towards module mark

Outline

While most of physics involves learning various content areas such as nuclear, particle, solid state etc., physics education deals with how *we learn physics. Although physics education has a long history the area called Physics Education Research (PER) is a more recent addition to the sub-disciplines of physics. For example, since 2005 there is a journal dedicated to PER within the influential Physical Review series, namely Physical Review Special Topics Physics Education Research (PRSTPER). Several North American universities now advertise posts for lecturers in physics departments who have completed PhDs in PER. It is also interesting to note that other disciplines such as Chemistry and more recently Biology are also following this model. This* *discipline focused approach to researching educational issues in science disciplines is referred to as (Science) Discipline Based Education Research (DBER).*

The module is aimed as an introduction to the area of PE and PER with a particular focus on issues pertaining to the teaching and learning of physics at university level. The list below indicates the main themes that will form the basis of the course. Since the themes are inter-linked the order of presentation is not linear but should rather be thought of as 'topic hubs' in a network.

What is Physics? — Exploring the 'nature' of student difficulties — Issues in cognitive science that could inform understanding the learning physics — Teaching physics — Physics Education Research.

Literature will be provided.

2.2.5 Classical Mechanics (CM)

Lecturer	Em. A/Prof R. Fearick, **Roger.Fearick@uct.ac.za**
20 Lectures	***Second semester, Term 3***
5 Tutorials	counting 25% towards module mark
Class Test	counting 25% towards module mark
Exam	2 hours, in May/June, counting 50% towards module mark

Classical mechanics is the basis for all further developments in physics. While the Newtonian formulation seems simple enough, the Lagrange and Hamilton formulations reveal a deep connection with modern ideas of geometry and the mathematics of differentiable manifolds. This course introduces you to these ideas.

Outline

Newtonian mechanics: space and time, Newton's laws, systems with one degree of freedom, central forces, non-inertial frames — *Lagrange formalism:* the route to Lagrange's equations, calculus of variations, Hamilton's principle of least action, conserved quantities, transformations of the Lagrangian — *Hamilton formalism:* the Hamiltonian, phase space, Poisson brackets, canonical transformations — *Advanced topics:* approximate methods, rigid bodies.

Literature

[1] F. Scheck, *Mechanics: From Newton's laws to deterministic chaos*, Springer 2005.

[2] J. V. Jose and E. J. Saletan, *Classical Dynamics: A Contemporary Approach*, Cambridge 1998.

2.2.6 Computational Physics (CP)

Lecturer	Dr S. Wheaton, **spencer.wheaton@uct.ac.za**
20 Lectures	***First semester, Term 2***
5 Tutorials	counting 25% towards module mark
Test	Take-home, counting 25% towards module mark
Exam	Take-home, in May/June, counting 50% towards module mark

Students are expected to be familiar with at least one programming language.

Outline

In the real world, very few deterministic problems can be solved analytically. Furthermore, many physical processes are stochastic. Finally, data analysis is required for the interpretation of most experiments. In all of these cases, physicists look to computers to shed light on the physics. In this module, several of the more ubiquitous numerical and computational methods will be introduced that form part of most physicists' toolkits.

Foundations: computational efficiency, root finding, matrix operations — *Numerical calculus:* differentiation, integration, optimization and fitting — *Monte Carlo techniques:* sampling, integration and simulation — *Ordinary and partial differential equations*: initial value problems, Runge-Kutta integration, eigenvalue problems, discretisation, relaxation method

Literature

[1] T. Pang, *An introduction to computational physics*, Cambridge 2006.

[2] H. Gould, et al., *An Introduction to Computer Simulation Methods*, Pearson Addison Wesley, 2007.

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

2.2.7 Nuclear Physics (NP)

Lecturer	Dr T. Leadbeater, **Tom.Leadbeater@uct.ac.za**
20 lectures	***Second semester, Term 3***
5 problem sets	counting 25% towards module mark
4 practicals	counting 25% towards module mark
Exam	in October/November, counting 50% towards module mark

Outline

This module will feature the fundamental aspects of ionising radiation detection and measurement; including spectroscopy, particle identification, and advanced analysis techniques. The first part of the course will cover the classification of radiation fields, interactions of heavy charged particles and fast electrons (including the Bethe equation and Bragg peak), interactions of high energy photons (photoelectric effect, Compton scatter, pair production), and interactions of neutrons with matter. The second part of the course will cover detector response functions and electronics requirements for the three main types of radiation detector (gas filled, scintillator, semiconductor), and will detail considerations of advanced signal analysis techniques and spectroscopic measurements. The final section will extend these concepts to high energy, such as seen at particle collider facilities (e.g. LHC), and will cover tracking detectors, electromagnetic and hadronic calorimeters, and particle identification techniques.

Practicals: Introduction to nuclear electronics, high resolution gamma spectroscopy, neutron detection using gas filled detectors, particle transport modelling.

Literature

[1] G. F. Knoll, *Radiation Detection and Measurement*, Wiley 2010.

[2] W. R. Leo, *Techniques for Nuclear and Particle Physics Experiments*, Springer 1994

[3] M. Tanabashi et al. (Particle Data Group), Review of Particle Physics, Phys. Rev. D'98, 030001 (2018).

[4] C. Grupen, *Particle Detectors*, Cambridge 2009.

2.2.8 Quantum Field Theory (QF)

NB: *module can only be taken in conjunction with Rel. Quantum Mechanics*

Lecturer	A/Prof W.A. Horowitz, **WA.Horowitz@uct.ac.za**
10 lectures + self study (equivalent to 20 lectures)	***Second semester, Term 4***
Some 5 tutorials	counting 50% towards module mark
1 project	counting 50% towards module mark

Outline

Quantizing gauge fields — BRST gauge fixing — Non-abelian fields — Tree level calculations — Renormalization.

Literature

[1] M. E. Peskin and D. V. Schroeder, *An introduction to Quantum Field Theory*, Addison Wesley 1995.

[2] G. Sterman, *An Introduction to Quantum Field Theory*, Cambridge 1993.

[3] L. H. Ryder, *Quantum Field Theory*, Cambridge 1996.

[4] M. Srednicki, *Quantum Field Theory*, Cambridge 2007.

2.2.9 Relativistic Quantum Mechanics (RQ)

Lecturer	A/Prof W. A. Horowitz, **WA.Horowitz@uct.ac.za**
20 lectures	***Second semester, Term 3***
Tutorials	counting 50% towards module mark
Exam	2 hours, in October/November, counting 50% towards module mark

Outline

Relativistic invariance, equations and Lagrange densities for Klein-Gordon and Dirac and vector fields — Elements of a quantum theory of fields: scalar, vector and spinor fields — Particle interactions, simple Feynman diagrams and scattering matrix; cross sections and decay rates; phase space.

Literature

[1] M. E. Peskin and D. V. Schroeder, *An introduction to Quantum Field Theory*, Addison Wesley 1995.

[2] G. Sterman, *An Introduction to Quantum Field Theory*, Cambridge 1993.

[3] C. Itzykson and J.-B. Zuber, *Quantum Field Theory*, McGraw Hill 1980.

[4] M. D. Schwartz, *Quantum Field Theory and the Standard Model*, Cambridge 2014.

[5] L. H. Ryder, *Quantum Field Theory*, Cambridge 1996.

[6] M. Srednicki, *Quantum Field Theory*, Cambridge 2007.

[7] L. S. Brown, *Quantum Field Theory*, Cambridge 1994.

[8] J. D. Bjorken and S. D. Drell, *Relativistic Quantum Mechanics*, McGraw Hill 1963.

2.2.10 Solid State Physics (SS)

As the module lecturer is on sabbatical in 2022, this module will only run if there is significant student demand and will be conducted entirely in online mode.

Lecturer	A/Prof M. Blumenthal, **Mark.Blumenthal@uct.ac.za**
20 Lectures	***Second semester***
5 tutorials	counting 25% towards module mark
2 paper reviews	counting 10% towards module mark
Class test	counting 15% towards module mark
Exam	2 hours, in October/November, counting 50% towards module mark

Outline

Review of Bulk Semiconductors: Crystal structure, energy band structure, doping — *Introduction to Low Dimensional Systems*: Length and energy scales, overview of fabrication techniques and possibilities in nano-physics, applications of low-dimensional physics — *Electron Properties in Low Dimensional Systems*:

Band engineering, heterostructures, free electron gas, 2D electron gas, 1D electron gas, 0D electron gas, density of states — *Quantum Transport*: 1D wires, 0D quantum dots, Coulomb blockade, resonant tunnelling, charge detection, single-electron dots, electron pumps and turnstiles, surface-acoustic-wave current source — *Electrons in magnetic fields*: Landau levels, Shubnikov-De Haas effect, integer quantum Hall effect, edge states, Aharonov-Bohm effect.

Literature

[1] C. Kittel, *Introduction to Solid State Physics*, Wiley 1996.

[2] N. W. Aschcroft and N. D. Mermin, *Solid State Physics*, Holt, Rinehard and Winston 1976.

[3] M. J. Kelly, *Low-dimensional Semiconductors: Materials, Physics, Technology, Devices*, Clarendon Press 1996.

[4] J. H. Davies, *The Physics of Low-Dimensional Semiconductors: An introduction*, Cambridge 1997.

[5] E. L. Wolf, *Nanophysics and Nanotechnology*, Wiley 2007.