# 10674-755(16) Relativistic Quantum Mechanics & Quantum Field Theory (3l, 3p)

## 2018

### Course summary:

Module introduces concepts from relativistic quantum mechanics and field theory.
Dispersion relations and quantum mechanics. Klein-Gordon, Dirac and Maxwell equations, free-particle solutions, non-relativistic limit. Covariance of the Dirac equation, chirality. Lagrange formalism in field theory, Noether currents. Gauge symmetries and electromagnetic interactions. Relativistic treatment of hydrogen atom. Quantisation of Klein-Gordon, Dirac and Maxwell fields. Particle interpretation, spin and statistics. Perturbation theory and Feynman rules. Cross-sections and decay widths in particle physics. Further alternatives in response to student demand: Higgs mechanism and standard model or renormalisation.

## Module relevance in programme:

Physics 755 is an advanced fourth year module. In the first part the students learn about the linkage of special relativity and quantum mechanics. In the current curriculum these two topics are taught in the third year. This linkage explains, among others, the spin as an internal property of elementary particles. In the second part a fully new concept, that of quantized fields, is introduced. Within that framework the particle-wave dualism is fully resolved (which is not possible in standard quantum mechanics) and the origin of Bose-Einstein and Fermi-Dirac statistics is described. These are fundamental entries of statistical physics. The use of quantum field theory for modern particle physics is comprehensively discussed for quantum electrodynamics. Occasionally, P755 is also taken by MSc students.

### Outcomes of course:

The student is skilled in the relativistic covariant formulation of quantum mechanics, particularly the Klein-Gordon and Dirac equations, their interpretations and applications. The student is also skilled in the basic techniques of quantum field theory, particularly how the concept of quantised fields embodies a particle interpretation that leads to the perturbation theory of interacting systems. Finally the student is introduced to the field theory description of processes in particle physics. The course serves as a basis for any more advanced course in quantum field theory.

### Lecturer:

Prof H Weigel
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Office: Room number 1025 in the Merensky Physics Building.

### Mentor:

The Department of Physics has appointed a staff member as mentor for each year of its physics programme to be available to students for consultation. Students should feel free to discuss general issues related to the physics programme or specific modules in the programme with the relevant mentor, in addition to usual consultations with their individual lecturers of modules.

The mentor for the Honours programme and its modules is Prof KK Müller-Nedebock kkmn@physics.sun.ac.za.

## Course content:

***Formal lectures***

Klein-Gordon and Dirac equations; interpretation of solutions with negative energies; covariant notation. Symmetries of the Klein-Gordon and Dirac equations and their non-relativistic limits. Relativistic description of the hydrogen atom. Spontaneous symmetry breaking, Higgs mechanism, Quantization of the Klein-Gordon, Dirac and Maxwell fields. Particle interpretation. Perturbation and scattering theory for quantum electrodynamics.

***Laboratory work***

## Practical (Tutorials):

Tutorials (3h/week) enable the student to cope with exercises and standard problems.

## Study material:

**Recommended textbooks:**
**Relativistic Quantum Mechanics and Field Theory**, F Gross, Wiley, 1993.
Quarks and Leptons, F. Halzen and A. D. Martin, Wiley, 1984.

Textbooks whose content goes beyond these lectures to be used as reference:
Quantum Field Theory, C. Itzykson and J.-B. Zuber, Mc Graw Hill, 1980.
Introduction to Quantum Field Theory, M. E. Peskin and D. V. Schroeder, Perseus Books, 1995.

## Learning opportunities:

Lectures as indicated on time table
Further information can be traced at http://www.physics.sun.ac.za/~weigel/teach/qftdownload.html

## Assessment:

***Methods of Assessments***
Evaluated on a continuous basis.

***Venue and time of assessment opportunities***
Set in consultation with the lecturers.

***Availability of marks:***
*As soon as possible*

***Calculation of final mark for the module:***
Test 1 – 25% (3rd quarter)
Test 2 – 25% (4th quarter)
In each quarter  homework assignments and self-studies will contribute 25% to the final mark.

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