Faculty of Science

Prospectus 2009 - 2010

Physics and Astronomy

Master

Radboud University Nijmegen

Preface

This booklet is the prospectus for the masters programme of Physics and Astronomy. It contains information about the objectives, the goals and the contents of the programme. Furthermore a lot of practical information is given.
A small part of this prospectus is written in Dutch. This applies to the description of the courses of the C- and MT-variant in chapter 4 and to the chapters on the examinational systems and the student activities.

P.S. *This prospectus has been made with great care. However the authors are not responsible for inaccuracies. If you have comments or proposals for improvements don't hesitate to contact them.*

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Contents

1 Introduction

The Radboud University Nijmegen offers a Master of Science programme in Physics and Astronomy. This programme forms the connection between the Bachelors programme, taught in Dutch, and the state-of-the-art research that is being pursued at the different departments in the faculty. This Masters programme is of international standards and compatible with, e.g., the German Masters programme. It is therefore of particular appeal to students of any nationality who qualify in terms of their preceding studies and want to graduate as a Master of Science at the highest standards.

The Radboud University Nijmegen is a general university, offering almost all possible academic Programmes, ranging from Arts and Law, to Medicine and Science. This Masters programme allows a substantial choice of topics from all these areas, thereby offering the possibility to combine Physics and Astronomy with other studies.

A large part of the Masters programme is in the form of one or more traineeships, either in Physics and Astronomy departments at the Radboud University Nijmegen, or at an external institution, university or company. In this traineeship the student is confronted with current research and, moreover, actively takes part in ongoing frontier research. One of these traineeships results in a Masters thesis.

1.1 Admittance

The programme requires a Bachelors degree in Physics or Astronomy from the University of Nijmegen, or an equivalent degree. A Bachelors degree in Physics and/or Astronomy from any Dutch (technical) university qualifies. By exception, bachelor students with a maximum deficiency of 18 ec in the bachelor education, may already register for the Master Education (for students who started their education before September 1, 2002, this deficiency is 30 ec). In case of a deficiency, it is obligatory to complete the bachelor education in Physics & Astronomy within one year from the date of registration. In case of failure, students will be exluded from further participation to master course exams.

1.2 Structure of the Masters programme

The Masters programme at the Science Faculty of the University of Nijmegen is offered in four variants: a research (O) variant, a communication (C) variant, an education (E) variant, and a business and management (MT) variant. At this moment, only the research variant has a complete programme in the English language. The other variants are primarily aimed at the Dutch market and the Dutch educational system, and are therefore taught in Dutch.
The O-variant is intended as a preparation for admission as a research PhD Student in Physics and Astronomy. The other variants are not intended as such.

The O-variant of the Masters programme has 4 specializations:

- Biophysics and Neuroscience
- High Energy Physics
- Astrophysics
- Molecules and Functional Materials

These specializations are directly related with the pillars of research in Nijmegen, organized in the institutes: Donders Centre for Neuroscience (DCN), Institute for Mathematics, Astrophysics and Particle Physics (IMAPP), and Institute for Molecules and Materials (IMM).

Each specialization will be composed out of 4 elements:

- Common compulsory subjects for all physics students
- Specialization specific basic subjects
- Electives, specialization related and free
- Master's thesis

The master's thesis will be the reflection of a traineeship at one of the research departments.

Our research departments are specialized in the following fields:

- Theoretical Solid State Physics, notably band structure calculations where Nijmegen is the home of a national facility
- Theoretical Elementary Particle Physics, notably Standard Model and Minimal Supersymmetric Standard Model phenomenology
- Mathematical Physics (in association with the Mathematics department), notably diagrammatica and quantum probability theory
- Experimental Solid State Physics, notably in the areas of high magnetic fields (the High Field Magnet Laboratory, an international facility), scanning tunneling microscopy and spectroscopy, material surface spectroscopy and materials engineering
- Experimental Molecular Physics, notably in the areas of molecular dynamics and (bio)molecular structure trace gas facility based at the department
- Experimental Elementary Particle Physics, notably on experiments conducted at the leading facilities in the world, CERN and Fermilab, and a local facility for highest energy cosmic ray research
- Applied Molecular Physics, notably in diesel combustion research, materials science, neuro-imaging and turbulence
- Astro-(Particle) Physics, notably gamma ray bursts and the highest energy cosmic rays and
- Biophysics and Neuroscience, notably the biophysics of brain and behaviour and the study of artificial neural nets

The courses that are needed to prepare for the Masters thesis work are determined by the Masters thesis supervisor and the student together. It is therefore advisable to contact the prospective Masters thesis adviser(s) to discuss the content of these courses. These courses are deemed electives and are tailored to the needs and wishes of the student. To select a prospective Masters thesis adviser, please look at the descriptions of the different departments. The contact persons of the departments can be approached at any stage for information or to set up a programme in the electives section. In the last year of the bachelor programme, tours of the departments are organized for groups of students. This is a good occasion to visit all our departments and find out in detail what your possibilities are to do your Masters thesis work there.

Students may at any time enroll in supplementary courses and exceed the minimum of 120 study points (ec = european credits) required for the Masters degree.

2 Aims and Attainment targets

2.1 Aims of the Master's programme

The aims of the Master's (or doctoraal) programme in Physics and Astronomy have been laid down as follows in the Education and Examination Regulations (Art. 1.3):
The aims of the study programme are:

1. *To provide students with the knowledge, skills and insights pertaining to the fields of physics and astronomy that will enable them to practise their future professions independently, and to become eligible for the advanced programmes for scientific researchers or designers (O-variant), communication experts (C-variant),teachers (E-variant) or research managers in business organizations (MT-variant).*
2. *Academic education.*

Naturally, this description refers to professions for which a scientific education in physics and astronomy is either required or useful. This general aim is concretized in a number of detailed objectives.

Basically, prospective students are expected to possess all the knowledge, skills and insights mentioned in the attainment targets of the Bachelor's programme. Consequently, additional requirements may be set with regard to previous education, in individual cases, with regard to entrants from other institutions. Furthermore, the Master's programme pursues the following specific additional aims:

- Students acquire more specialized knowledge and insights pertaining to one or more sub-areas of physics and astronomy
- Students become acquainted with one or more disciplines outside the fields of physics and astronomy or with one or more sub-areas in physics and astronomy, other than the sub-area of specialization mentioned above
- Students learn how to analyse complex problems independently and how to formulate standard and innovative solutions
- Students learn how to test theories using concrete questions which they will have developed themselves
- Students who wish to obtain the Master's title in the Communication or Education variant will further deepen their knowledge of and insight into teaching and communication theories respectively, and will be able to apply this knowledge and these insights during practical training in the fields of communication or education
- Students in the Master's phase of the Management variant will further deepen their knowledge of and insight into management and organizational aspects, and will subsequently apply this knowledge and these insights during practical training in a business environment

2.2 Attainment targets of the Master's programme

The attainment targets of the Master's programme consist of:

General cognitive skills

1. Graduates will have acquired a way of thinking that will enable them to penetrate and solve problems, while maintaining a critical stance towards established scientific insights
2. Graduates will be able to formulate and analyse scientific problems at an abstract level by dividing them into testable sub-problems, differentiating between major and minor aspects
3. Graduates will be able to synthesize solutions to subproblems within a scientific framework and thus contribute to the formulation of general theories
4. Graduates will possess mathematical knowledge insofar as relevant in physics and astronomy at the Master's level
5. Graduates will possess sufficient skills in the fields of computing and computer science, which will enable them to design and implement computer programs and use current application programs

Skills based on knowledge and insights pertaining to the fields of physics and astronomy

6. Graduates will have gained adequate knowledge and insights pertaining to the basic sub-areas of physics and astronomy. The scope of this basic knowledge will be sufficient to allow them to do practical training in one of the research groups
7. Graduates will possess sufficient skills in at least one sub-area of physics and astronomy to conduct scientific research under supervision
8. Graduates will be able to understand scientific articles on the chosen specialization. Furthermore, they will be able to follow the developments in the chosen specialization (level: Physical Review)
9. Graduates will be able to assimilate newly acquired knowledge of physics and astronomy and to integrate this knowledge with the knowledge they already possess. In addition, they will be able to orient themselves at specialist level in a sub-area of physics and astronomy that lies outside the chosen specialization

Research methods in physics and astronomy

10. Graduates will be able to find relevant scientific sources relating to physical or astronomical problems that need to be solved
11. Graduates will be able to formulate new questions and hypotheses in the fields of physics and astronomy, and to select the appropriate pathways and research methods for solving these questions, taking into account the services and means available
12. Graduates will be able to set up and perform experimental or theoretical scientific research, to systematically process and critically interpret the research results, and to formulate conclusions

General communication skills

13. Graduates will be able to communicate with colleagues in the same discipline about scientific knowledge, both at basic and specialist levels. They will be able to report orally and in writing, and to discuss a scientific topic, in Dutch as well as in English

14. Graduates will be able to hold an oral presentation and to write a lucid article on the research conducted and modern concepts in physics and astronomy for a general, non-specialist public

Reflection on society and societal problems

15. Graduates will have gained sufficient knowledge of and insights into the role of physics and astronomy in society in order to function adequately in their future professions and reflect on societal problems

Specific skills to be acquired in the C variant

16. Graduates will have sufficient knowledge of various theories of communication that will enable them to reflect critically on the literature in the field of communication
17. Graduates will have gained insight into theories of communication and will be able to put a number of them into practice
18. Graduates will be able to reflect on the ways in which they put their communication skills into practice, efficiently applying communicative concepts
19. Graduates will have gained insight into factors that have a positive or negative effect on communication, and will have acquired the skills to identify and influence these factors in concrete communicative situations
20. Graduates will possess skills in the fields of scientific journalism and technical communication, and knowledge of recent developments in these fields

Specific skills to be acquired in the E variant

21. Graduates will have sufficient knowledge of various theories of education that will enable them to reflect critically on the literature in the field of educational counselling
22. Graduates will have gained insight into theories of education and will be able to put a number of them into practice
23. Graduates will be able to reflect on the ways in which they put their teaching skills into practice, efficiently applying educational concepts
24. Graduates will be able to indicate how scientific analyses and solutions to questions should be applied in concrete curricular and extra-curricular settings
25. Graduates will be able to guide non-colleagues in mastering and practising the teaching profession

Specific skills to be acquired in the MT variant

26. Graduates will have gained an overview of and insight into the various theories in the fields of management science and business administration
27. Graduates will have sufficient knowledge of these theories to reflect critically on the literature on counselling in these fields
28. Graduates will have gained insight into the various tools and strategies relating to the diagnosis and analysis of various types of complex management questions in science-related, knowledge-intensive organizations
29. Graduates will be able to use these tools and strategies in practice and to report on them orally and in writing, effectively applying theoretical concepts from management science and business administration

The above-mentioned attainment targets resulted in the Master's programme as described in Chapter 3.

3 Programme

3.1 Research variant (O variant)

The programme for the O-variant will be composed of 4 elements:

- Common compulsary subjects with a total of 7 ec
- Specialization specific basic subjects
- Free electives
- Master's thesis of 60 ec

The specialization specific basic subjects are chosen by mutual agreement with the master's thesis supervisor. In table 1 the subjects which are highly recommended for the various specializations are listed. There are 4 specializations. Two of the specializations have a theoretical and an experimental stream. The amount of ec points is given between parentheses.

Master of Science in Physics and Astronomy		
Astrophysics[a]	**High Energy Physics**	
	Theoretical	**Experimental**
Mandatory		
Electrodynamics 1 (3) Prof. Preparation (1) Philosophy (3)	Electrodynamics 1 (3) Prof. Preparation (1) Philosophy(3) Electrodynamics 2 (3) Quantum Field Theory (6)	Electrodynamics 1 (3) Prof. Preparation (1) Philosophy (3) Particle Physics Phenomenology (6)
Strongly recommended		
Compact Binaries(6) Black Holes (6) Telescope Observing (2) Astrophysics Seminar (3)		
Electives (36)[d]	Electives (44)[d]	Electives (47)[d]
Master thesis (60)[e]	Master thesis (60)[e]	Master thesis (60)[e]
Biophysics	**Molecules and Functional Materials**[b]	
	Theoretical	**Experimental**
Mandatory		
Electrodynamics 1 (3) Prof. Preparation (1) Philosophy (3)	Electrodynamics 1 (3) Prof. Preparation (1) Philosophy (3)	Electrodynamics 1 (3) Prof. Preparation (1) Philosophy (3)
Strongly recommended		
Research Labs (6) Exp.Techniques (3) Comp.Neuroscience (6) Data Analysis (3) Machine Learning (6) or Brain and Behaviour 2 (6)	Group Theory I (3)[c] Adv.Statistical Phys. (6) Condensed Matter Theory (6) Numerical Methods (3)	Exp. Techniques (3) Numerical Methods (3) Data Analysis (3) Adv.Statistical Phys. (6) Int. Light w. Mol. & Mat. (6) or Material Science (6)
Electives (32)[d]	Electives (29)[d]	Electives (32)[d]
Master thesis (60)[e]	Master thesis (60)[e]	Master thesis (60)[e]

Remarks:

(a) Within the Dutch Astronomy Programme, the Nijmegen specialization is High Energy Astrophysics.

(b) The track Nanoscience and Nanotechnology is one of the possibilities within the specialization Molecules and Functional Materials. The Nanoscience and Technology track will be part of the common Master's programme of the Radboud University Nijmegen and the Eindhoven University of Thechnology. This framework provides a number of courses (of a total of 12 ec over the two years) as an integrative element for all students of Physics and Chemistry within the common Master's programme.

(c) Group Theory 1 (3) is the first part of group Theory (9)

(d) An approval by the examination committee is required.

(e) Within the Master thesis an additional industrial project (or comparable) can be incorporated. Within the Nijmegen-Eindhoven Nano-programme, a joint Research School (3) will be organized in the final year.

At the start of the Master's programme, the student is expected to contact one or more prospective Masters thesis supervisors to discuss a programme, after which a choice is made. The individual programme is administered by the Masters thesis supervisor and the student using a form, of which the student, Masters thesis adviser and Examination Committee will all get a copy. This individual programme constitutes a commitment from both the student and Masters thesis adviser. Of course, it can be changed by mutual agreement between the student and the Masters thesis adviser. The Examination Committee provides a marginal check on the individual programme, and will contact student and Masters Thesis adviser within three weeks after receiving the individual programme if a problem should occur.

In the first half year the student is expected to follow courses to prepare for the traineeship(s). After that, he can start with the traineeship(s).

While the Masters thesis work or another traineeship is being done, the student still takes courses, usually the most advanced ones. Students are in particular encouraged to also have discussions about this material with the members of the department in which they are doing their Master thesis work. Of course, students may also approach any member of the faculty at any time with questions about any of the courses.
It is possible to take 30 ec C, E or M components as electives. If necessary the excess number of ec may be deducted from the Masters thesis project. For theoretical physics, time can be taken from the Masters thesis project for one or more courses to prepare for the Masters thesis work.
In general, by agreement of the Masters thesis supervisor, up to 12 ec of the time reserved for the Masters thesis project can be traded for electives.

The electives need approval by the examination committee. Normally the student will contact a thesis supervisor before starting the Masters programme. The course programme and Masters thesis subject are transmitted on paper or by email to the examination committee. Without a notification of the examination committee within three weeks the course programme and Masters thesis subject are approved.

3.2 Communication variant (C variant)

C-variant	
Internship and Essay Master Communication	(30)
C-package*	(27)
Masters thesisproject	(30)
Electrodynamics 1	(3)
Professional Preparation	(1)
Philosophy	(3)
Physics or Astrophysics Electives	(20)
Electives	(6)

If you are interested in the interaction between science and the society, science communication might be an interesting way to go. Science communication is one of the graduation variants on the beta-faculty in Nijmegen. Among other things, it deals with perceptions, participation processes, knowledge production, interdisciplinarity and risks and uncertainties in science. Moreover, much attention is paid to writing skills (essay, columns), presentation skills and research methods. During your graduation project (30 ECTS), you link up theory from the courses with your beta background.

The job profile entails three fields: intermediary organisations between science and society (advisory bodies, interest groups and gouvernements), science communication research and science journalism. The Science Communication graduation variant is not only a very interesting new field of study for which there is a need on the labour market, it provides you with knowledge that may come in handy in every speciality!

* C-package includes: Framing Knowledge (3), Knowledge Society (3), Science & Media: strategies and trends (only in Dutch) (3), Introduction Science Communication (3), Science & Societal interaction (3), Risk Communication (3), Boundary-Work: The Tension between Diversity and Sustainability (3), Visible Scientists (3), Elective (3). More information can be obtained at: http://studiegids.science.ru.nl/2008/en/science/prospectus/ects_science/contents/

and from:
Prof. dr H. Zwart
Room: HG 02.808
Tel. 3652038
E-mail: h.zwart@science.ru.nl

3.3 Education variant (E variant)

E-variant	
E-traineeships	(57)
Masters thesis project	(30)
Electrodynamics 1	(3)
Professional Preparation	(1)
Philosophy	(3)
Physics or Astrophysics Electives	(20)
Electives	(6)

This variant is intended as a preparation for a job in education. It gives admission to the postdoctoral Teacher Education of the ILS. Orientation on education at a Dutch High School during some weeks (3 ec) is possible. More information:
http://www.ru.nl/ils/onderwijs/masteropleiding

This variant is not intended as a preparation for admission as a research PhD student in physics or astronomy. More information can be obtained from:
Edith Verbeet - ILS (Instituut voor Leraar en School)
Rob van Haren - ILS (Instituut voor Leraar en School)

Erasmusgebouw, kamer 20.18
tel.: (024)3615573
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3.4 Business & Management variant (MT variant)

MT-variant	
MT-traineeship	(27)
MT-package*	(30)
Masters thesis programme	(30)
Electrodynamics 1	(3)
Professional Preparation	(1)
Philosophy	(3)
Physics or Astrophysics Electives	(20)
Electives	(6)

This variant is intended as a preparation for jobs in the field of management. It is not intended as a preparation for admission as a research PhD student in physics or astronomy.

* MT-package includes: Business & Society (5 ec), Finance & Accounting (5 ec), Innovation management (5 ec), Organization Theory (5 ec), Strategy & Marketing (5 ec) and one optional subject for example: Research Strategy and Management (3 ec), Science and Entrepreneurship (3 ec).

More information can be obtained at:
studiegids.science.ru.nl/2008/en/science/prospectus/ects_science/contents

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4 Description of the Courses

Advanced Spectroscopy

Course ID: **NM075B** *6 ec* first semester prof. dr. T.H.M. Rasing

Teaching methods

- 28 hrs lecture
- 28 hrs problem session

Prerequisites

Bachelor Physics, Natural Science or Chemistry

Objectives

- The student is familiar with state of the art spectroscopic tools (radiation sources and external parameters like pressure, temperature and magnetic fields)
- The student knows about their possibilities, limitations (ground state properties and excited state properties) and fields of application
- The student knows what kind of experimental tool to use to addess a specific research problem

Contents

In this course students will learn about state of the art spectroscopic techniques to study the properties of molecules and materials. In particular, the spectroscopic tools within the Nijmegen Centre for Advanced Spectroscopy will be treated, covering Laser spectroscopy, Nuclear Magnetic Resonance, Spectroscopy in High Magnetic Fields and Nano/Single Molecule Spectroscopy.

Literature

Will be announced during the course

Advanced Statistical Physics

Course ID: **NM029B** *6 ec* first semester prof. dr. M.I. Katsnelson

Website
www.theorphys.science.ru.nl/people/katsnelson

Teaching methods
- 30 hrs lecture
- 30 hrs problem session

Prerequisites
Bachelor Course 'Statistical Physics'

Objectives
The course is focused on the concepts of order parameter, broken symmetry and scaling, with applications to solid state and soft condensed matter physics. General methods of theoretical physics such as path integrals and renormalization group are considered in a context of statistical physics.

Contents

Subjects
- Landau theory of phase transitions and the concept of order parameter. Examples: structural phase transitions, magnetism, liquid crystals, superconductivity, superfluidity
- Ginzburg-Landau theory; the role of fluctuations. Correlation length
- Concepts of scaling for the second-order phase transitions and its qualitative justification ("Kadanoff decimation")
- Wilson theory of the phase transitions: renormalization group and ε-expansion
- Order parameter, broken symmetry and topological defects
- Fluctuations in low-dimensional systems and Mermin-Wagner theorem. Berezinski-Kosterlitz-Thouless transition
- Scaling concepts in polymer physics. Scaling properties of a single polymer chain
- Introduction to the statistical physics of membranes
- Percolation theory

Literature
- Shang-Keng Ma. *Modern theory of critical phenomena,* Perseus Books Group, ISBN 0738203017
- Gilles de Gennes. *Scaling concepts in polymer physics,* Cornell University Press, ISBN 080141203X

Examination
Oral exam

Astroparticle Physics

Course ID: **NM076B** *6 ec* second semester dr. J.R. Hörandel

Teaching methods

- 32 hrs lecture
- 32 hrs problem session

Prerequisites

Bachelor degree in (astro)physics with Observational techniques (e.g. 'Radioastronomy or Observational Astrophysics')

Objectives

- The student will master the physics behind ultra-high energy particles from space, especially their acceleration and propagation through interstellar space
- The student will master the physics behind collisional interactions of ultra-high energy particles, especially with atmospheric atoms and molecules
- The student will master the electromagnetic radiation properties emitted by accelarated elementary particles, especially low-frequency synchroton radiation
- The student will master the (astro)physics of possible sources of ultra-high energy particles, including supernova remnants, compact binaries and massive black holes
- The student will understand the observational techniques used to detect ultra-high energy astroparticles and ultra-high energy gamma-rays
- The student will familiarize him/herself with the newest observatories connected with astroparticle physics

Contents

Astroparticle physics is a quickly growing field, where charged particles (cosmic rays), neutrinos, and very high energy gamma-rays (> 100 GeV) are used to probe the Universe. An overview will be given of the current state of the field, on the current views of accelerating particles to energies in excess of 10^19 eV, on the physics of the propagation of these particles through interstellar space and the interactions these particles will have with the Earth's atmosphere and magnetosphere. A particular focus will be put on the observations of ultra-high energy cosmic rays with LOFAR and the Pierre Auger Observatory.

Literature

- T. Stanev, *High Energy Cosmic Rays*, Springer
- T.K. Gaisser, *Cosmic Rays and Particle Physics*, Cambridge University Press
- M.S. Longair, *High Energy Astrophysics, (Volume 1+2)* , Cambridge University Press
- V.S. Berezinsky, *Astrophysics of Cosmic Rays*, Elsevier Science, North-Holland

Examination

Written examination

Extra information

This course will be given biannually.

Astrophysics Seminar

Course ID: **NM072B** *3 ec* first semester prof. dr. H.D.E. Falcke

Website
http://www.astro.ru.nl/wiki/news/seminars

Teaching methods
Colloquia and student seminars are held on Tuesday afternoon 4-5 pm.

Objectives
- The students can critically read scientific articles and present them

Contents
Astrophysics is an international discipline. It is important to know what research is done in other places. Therefore regular talks (Colloquia) are held by Astronomers from all over the world.
In addition masters students will give student seminars in which they critically discuss a recent article, present the results and lead a discussion on the topic of the paper.
See Prof. Falcke at the start of the academic year to choose an article and get a data assigned.

Extra information
Compulsory for masters students Astrophysics

Beyond the Standard Model

Course ID: **NM022B** *6 ec* This course is given bi-annualy prof. dr. A.N.J.J. Schellekens

Website
http://www.nikhef.nl/~t58/lectures.html

Teaching methods
- 40 hrs lecture

Prerequisites
Theoretical Foundations of Elementary Particle Physics

Objectives
- The student understands the main outstanding problems of the Standard Model and some possible solutions

Contents
In this course a selection of new ideas for extending and improving the Standard Model of particle physics will be discussed. Depending on the theoretical and experimental status of these ideas and the interest of the students, topics may include neutrino masses and oscillations, supersymmetry, Grand Unification, composite quarks and/or leptons, extra dimensions and 'brane worlds' and others.

Literature
Necessary:
- Lecture notes 'Beyond the Standard model' available at the web

Examination
Oral examination

Extra information
This course will be given biannually. Next occasion in 2010/2011.

Black Holes in Active Galactic Nuclei

Course ID: **NM018B** *6 ec* first semester prof. dr. H.D.E. Falcke

Website
mpifr-bonn.mpg.de/staff/hfalcke

Teaching methods
- 16 hrs lecture
- 16 hrs problem session

Prerequisites
Bachelors in Physics and Astronomy

Objectives
- The student masters methodes from high-energy astrophysics and is able to apply these to Active Galactic Nuclei and Black Holes
- The student is able to model these processes numerically in a simplified setting

Contents
The course addresses the astrophysics of Active Galactic Nuclei (AGN) and the processes which occur near the central black holes, their accretion discs and jets. After a general introduction to AGN, we focus on relativistic jets and compact radio sources, synchrotron radiation, shock acceleration, black hole basics, standard accretion discs, advection-dominated accretion flows, the emission-line region of AGN and a unified view of AGN. Students will be trained in modelling some of these phenomena with relevant physics on the computer.

Literature
- Lecture notes

Examination
Grading wil be based on presentation and assignments

Extra information
This course will be given biannually. Next occasion in 2010/2011

Brain and Behaviour 2

Course ID: **NM050B** *6 ec* second semester prof. dr. C.C.A.M. Gielen

Website
www.mbfys.ru.nl/~stan/

Teaching methods
- 28 hrs lecture

Prerequisites
Brain and Behaviour 1

Objectives
- The student is familiar with the main problems in the field of visual perception and motor control
- The student is familair with Information Theory (Mutual information and maximum log likelyhood estimator) to estimate information transfer
- The student can apply deterministic optional control (including Hamilton-Jacobi-Bellman equation and Pontryagin Maximum Principle)
- The student has the mathematical skills to develop advanced models to explain recent experimental data in a unified conceptual frame work

Contents
This course will present general principles of neuronal information processing. These principles are illustrated by discussing the functional characteristics of the visual system and motor system in man.

Subjects
- Control Theory
  - Conditions of stability of nonlinear systems
  - Conditions for stable control
  - Algorithms for optimal control
- Information Theory
  - Entropy; mutual information
  - Efficiency of information coding
  - Parameter estimation principles
- The visual system
  - Organisation of the visual system
  - Efficiency of visual information processing

- The motor system
  - Organisation of the motor system
  - Optimal control of the motor system
  - Control of redundant manipulators

Literature
Necessary:
- Lecture notes (For sale at secretary's office of Biofysica room 0.20 M244, Geert Groteplein-Noord 21)

Examination
Written examination

Compact Binaries: Physics and Evolution

Course ID: **NM024C** *6 ec* This course is given bi-annualy prof. dr. P.J. Groot

Website
www.astro.ru.nl

Teaching methods
- 30 hours lecture
- 30 hours tutorial

Prerequisites
Bachelor degree in (astro)physics with Stellar evolution ('sterevolutie').

Objectives
- The student will be have a working knowledge of the equation of state of compact objects
- The student will be able to explain the formation of compact binaries
- The student will master the physics of accretion and be able to relate this to observed phenomena.

Contents
Binary stellar systems containing at least one compact object (a white dwarf, neutron star or black hole) are ideal place to study physics under extreme conditions: strong gravity, high energy, supranuclear densities, strong radiation fields, 'naked' fusion. Compact binaries host most of the observed high energy physics phenomena as observed in the X-ray and gamma-ray sky: X-ray bursts, X-ray pulsars, novae, Supernovae Type Ia, radio and X-ray jets, accretion disks and perhaps even gamma-ray bursts. The course will give an overview of the formation of the compact binary. The (interior) physics of compact objects will be explained (supranuclear densities, degenerate matter, quark-gluon plasmas, superfluidity and superconductivity). In most systems accretion of matter is reponsible for the observed phenomena. The physics of accretion will be detailed and a relation will be made with the observed phenomena.

Literature
Recommended:
- Lewin & Van der Klis, *Compact Stellar X-ray Sources*

Examination
Exercises and a presentation on a relevant topic in a concluding 'mini-symposium'

Extra information
This course is given biannually

Computational Neuroscience

Course ID: **NM047B** *6 ec* first semester prof. dr. C.C.A.M. Gielen
prof. dr. H.J. Kappen

Website
www.mbfys.ru.nl/~stan

Teaching methods
- 30 hrs lecture
- 30 hrs problem session

Prerequisites
Course Inleiding Biofysica

Objectives
This course deals with the mechanisms underlying the communication by and between cells in the central nervous system. It begins with the dynamics of changes in the configuration of proteins that are responsible for the transport of ions (sodium, potassium, chloride, etc.) through the outer cell membrane, and a biophysical model of the nerve cell is developed. Then, neuronal information processing and information storage within the CNS is treated, and how self organisation of the CNS can be understood from basic principles about development and learning.
After successful completion of the course
- the student is able to calculate the response of a neuron or of a network of neurons to various inputs, both analytically and by computer simulations
- the student should be able to apply basic principles from Information Theory and Non-linear Systems analysis to quanitfy information processing by networks of neurons and to determine the attraction domain and stable states of a network of neurons.

Contents
The aim of this course is to give a theoretical description of the neuronal dynamics at the level of a single neuron and at the population level. The theoretical model will be used to explain the information processing and the storage and retrieval of information by populations of neurons.

Subjects
- Structure, function and properties of ion channels. This part is a further elaboration on the Hodgkin-Huxley model as dealt with in the Introduction to Biophysics course (Bachelors program).
- Biophysical models of the neuron:
  - Integrate-and-fire model
  - Fitz Hugh-Nagumo model
  - First passage time model
  - McCullock Pitts model

- Phase-space analysis of neuron dynamics: stable states and convergence criteria
- Information coding by firing rates (Poisson model) and coincidence detection
- Physical properties of synapses; the inhibitory and excitatory synapse
- Feedforward and recurrent neurale networks
- Markov processes for binary neural networks and ergodicity
- Learning and memory within recurrent neural networks
- Selforganisation in neural networks

Literature
Necessary:
- Reader with chapters from *Handbook of Biological Physics*, Vol.4: Neuro-Informatics and Neural Modeling. Editors: Gielen and Kappen, Elsevier, 2001 (For sale at secretary's office of Biofysica, room 020 M244, Geert Grooteplein-Noord 21)

Recommended:
- Theoretical Neuroscience, Computational and Mathematical Modeling of Neural Systems, by Dayan and Abbott, MIT Press, paperback version, (2005) is highly recommended.

Examination
Written exam

Computational Physics

Course ID: **NM015B** *6 ec* second semester prof. dr. A. Fasolino
prof. dr. H.J. Kappen

Teaching methods
- 60 hrs lecture

Prerequisites
Knowledge of a programming language and the course numerical methods

Objectives
- The student can use computer simulations to address a variety of problems in physics. This ability makes possible either to gain a deeper understanding of physics already studied in other courses or to address a broader class of problems than traditionally studied in undergraduate courses
- In the module on Artificial Intelligence the student has learned that for a class of artificial intelligence problems, the required computations are similar to problems in statistical mechanics. Therefore, similar approximation techniques can be used. The student is able to apply these techniques on actual expert systems that are built at the RU

Contents
This course introduces prototypical models and computational methods developed to deal with complex physical systems and phenomena, particularly in statistical mechanics and artificial intelligence.

Subjects
- Review of Statistical physics:
  - Relation between microstates and observables
  - Deterministic and stochastic simulations
- Random processes:
  - Random walk, percolation
  - Critical exponents, finite size scaling
- Monte Carlo simulations:
  - Crude and importance sampling, Metropolis algorithm, non-Boltzmann sampling
  - Ising model
- Molecular dynamics:
  - Description of interatomic forces, integration of equations of motion
  - Microcanonical, constant temperature simulations
  - Simulated annealing
- Artificial intelligence:
  - graphical probability models for expert systems
  - approximate inference with MCMC and belief propagation
  - combinatoric optimization with simulated annealing and belief propagation

Literature

Relevant books are present in the library and do not have to be bought. For the AI part, the book by David Mackay: Information theory, inference and learning algorithms (see www.inference.phy.cam.ac.uk/mackay/itila/ for online version) will be used as background material.

Examination

For each topic students carry out a computer project which is then summarized in a short report. A final task is chosen in agreement with the teacher, either on one of the course topics or in other relevant fields.

Extra information

This course will be given biannually

Condensed Matter Theory

Course ID: **NM068B** *6 ec* second semester prof. dr. M.I. Katsnelson

Website
www.theorphys.science.ru.nl/people/katsnelson

Teaching methods
- 30 hrs lecture
- 30 hrs problem session

Prerequisites
Bachelor Courses 'Quantum Mechanics' and 'Statistical Physics'

Objectives
The course is focused on the concept of quasiparticles and many-body effects in condensed matter theory (including magnetism, superconductivity, superfluidity, metal-insulator transitions, etc.)

Subjects
- Types of condensed matter. General quantum-mechanical problem of a crystal. Adiabatic approximation
- Lattice dynamics. Phonons as prototype quasiparticles. Scattering by the lattice and correlation functions. Anharmonic phenomena
- Conduction electrons in solids. The effect of external electric and magnetic fields on the Bloch states. Zener breakdown. Quantum oscillation phenomena (de Haas-van Alphen, Shubnikov-de Haas effects). Quantum Hall effect
- Plasma phenomena in solids. Plasmons as an example of collective excitations. Landau theory of Fermi liquids. Mott transitions and the restrictions of the band theory of crystals
- Magnetism, exchange interactions, spin waves. Types of magnetic ordering, quantum theory of ferro- and antiferromagnets. Interaction of conduction electrons with spins. Kondo effect
- Superconductivity. Phenomenological theory of superconductivity. Flux quantization. Josephson effect. Cooper pairing and the BCS theory
- Bose-Einstein condensation and superfluidity. The model of nonideal Bose gas. Feynman variational approach to the superfluidity of He^4

Literature
Recommended:
- S.V. Vonsovsky and M.I.Katsnelson, *Quantum solid state physics*
- C. Kittel, *Quantum theory of solids*

Examination
Oral examination

Cosmology

Course ID: **NM026C** *6 ec* first semester

dr. G.A. Nelemans
prof. dr. P.J. Groot
dr. W.J.P. Beenakker
prof. dr. N. de Groot
M.T.B. Nielsen

Website
http://www.astro.ru.nl -> studiemateriaal

Teaching methods
- 32 hrs lecture
- 32 hrs problem session

Objectives
The students masters the most important methodes in non-electromagnetic and emerging fields of astrophysics, in particular:
- The student understands the physics of gravitational radiation
- The student understands the measurements, implications and physical settings the Cosmic Microwave background, in particular in the context of general relativity
- The student understands the physics of gravitational lensing, both in the case of microlensing, as well as on galaxy cluster scales

Contents
The early Universe is, par excellence, the area where astrophysics and high energy physics come together. Relevant topics that find their origin in this overlap regions are:
- The formation of elementary particles,
- the origin of density variations as seen in the micro-wave background,
- the nature and evidence for dark matter,
- the nature and evidence for dark energy
- observations of distant supernovae Type Ia
- the theory and use of gravitational lensing (strong, weak and microlensing)

Literature
Recommended:
- Peacock, *Cosmological Physics*, Cambridge University Press, ISBN 0-521-42270-1

Examination
Grading will be based on the assignments and a presentation

Extra information
This course will be given biannually.

Data Analysis

Course ID: **NM067B** *3 ec* fourth quarter dr. A.V. Kimel

Teaching methods

- 16 hrs lecture

Prerequisites

Numerical Methods. The basics of MATLAB

Objectives

The student is able to analyse experimental using both statistical methods and Fourier transformation

Contents

The course will introduce the main approaches for analysis and interpretation of experimental data

Subjects

The course will cover the following topics:

- Basics of probability theory(Conditional probability and multiplication law, Law of tota probability, Bayes' rule, Bayesian approach to probability)
- Discrete random variable(Probability mass function, Cumulative distribution function, Expected value, Variance and standard deviation, Bernoulli random variable and binomial distribution, Poisson distribution)
- Continuous random variable(Expected value and variance of a continuous random variable, Uniform distribution, Exponential distribution, Normal distribution, Central limit theorem, Law of large numbers)
- Parameter estimation(Criteria of quality of parameter estimation, Estimation of expected value and variance from experimental data (direct and indirect measurements), Moments of probability law and sample moments, Method of moments, Maximum likelihood)
- Fit of experimental data(Least squares and linear least squares, Assessing quality of fit and χ^2-distribution)
- Testing hypothesis(Probability plots, Null hypothesis, Comparison of two normally distributed samples, Student's t-distribution)
- Signal processing(Fourier transformation, Spectra of periodic and pulsed signals, Fourier transformation of discrete (experimental) data, Sampling, Temporal profile of signals with bandwidth limited spectra (sampling theorem))

Literature

- Lecture notes

Recommended:

- R.J. Barlow, *Statistics: A guide to the Use of Statistical Methods on the Physical Sciences* (John Wiley & Sons, Chichester, 1989)
- F. James, *Statistical Methods in Experimental Physics* (World Scientific, Singapore, 2006) 2nd edition

- J.A. Rice, *Mathematical Statistics and Data Analysis* (Belmont, CA: Thomson Brooks/Cole, 2006) 3rd edition

Examination

- The judgement of the reports of the tutor are the basis of the examination
- An oral exam completes the examination

Electrodynamics 1

Course ID: **NM001B** *3 ec* first quarter dr. ir. G.A. de Wijs

Teaching methods
- 14 hrs lecture
- 14 hrs problem session

Prerequisites
Bachelors course electromagnetism or equivalent.

Objectives
- The student has a thorough understanding of classical radiation theory
- The student is capable to solve the exercises of the treated subjects at the level of Jackson's 'Classical Electrodynamics'

Contents
The subject of this course is electromagnetic radiation. The course opens with short review of Maxwell's equations and the potentials, followed by the conservations laws for energy, momentum and angular momentum and a derivation of the retarded Green function from Maxwell’s equations. This Green function is the basis for the treatment of radiation, starting with the radiation of an oscillating charge distribution in the multipole expansion up to and including the quadrupole term. A further application is Rayleigh scattering and the structure function of a material. This Green function is also used to derive the potential (Lienard-Wiechert) and radiation from an accelerated charge. The special case of a constant velocity larger than the speed of light in a medium leads to a qualitative description of Cerenkov radiation. The case of uniform circular motion is worked out to the point of a qualitative treatment of the power spectrum of cyclotron and synchrotron radiation. Other important examples that are treated in the course are radiation from scattering of light to a free electron. (Thomson and Compton scattering) and radiation from a collision of two charges (Bremsstrahlung). Level: Introduction to Jackson: 'Electrodynamics'

Literature
Necessary:
- J.D. Jackson, *Classical Electrodynamics,* 1998, ISBN 0-4713-0932-X
- A syllabus will be distributed during the course.

Examination
Written examination

Electrodynamics 2

Course ID: **NM002B** *3 ec* second quarter dr. ir. G.A. de Wijs

Teaching methods
- 16 hrs lecture
- 16 hrs problem session

Prerequisites
Electrodynamics 1

Objectives
The student is capable to solve and answer the exercises and questions concerning the treated subjects at the level of Jackon's '*Classical Electrodynamics*'.

Contents
The topics covered in this course are (a) the Lagrange and Hamilton formalism for a charged particle in an electromagnetic field, both non-relativistically and relativistically, (b) a complete but concise treatment of multipole radiation, (c) the classical connection between macroscopic fields D and H and the macroscopic fields E and B, (d) birefringence, (e) (model) dielectric functions of metals and non-metals and their role in, e.g., optical response and EELS, and (f) the Kramers-Kronig relations. (c-e) all relate to electro-magnetic phenomena in matter. Also a quantum excursion into (c) is made, where the connection between polarisation/magnetization of crystals and the microscopic Bloch functions becomes apparent in the so-called ``modern theory of polarisation and (orbital) magnetization", dating from respectively the 1990s and the current decade.

Literature
Necessary:
J.D. Jackson, *Classical Electrodynamics,* 1998, ISBN 0-4713-0932-X
Additional syllabus (will be made available during the course)

Examination
Written examination

Electronic Structure of Materials

Course ID: **NM038B** *6 ec* second semester prof. dr. R.A. de Groot

Teaching methods

- 32 hrs lecture

Objectives

This course gives insight in the (im)possibilities of calculating electron structure in solid states

Contents

Tutorials involve the calculation of electron structure of:

- Simple metals
- Magnetic metals
- A semiconductor
- A relativistic material

all with the use of existing computer programs.

Subjects

- Reciprocal space, Brilliouin zones and group theory associated to electron structure calculations
- Basic sets, pro's and con's
- Density functional theory
- APW, ASW and LSW methods in some detail

Literature

- Lecture notes and references given during the lectures

Examination

Oral exam

Experimental Foundations of Elementary Particle Physics

Course ID: **NM011B** *9 ec* first semester dr. A.C. König

Website
www.hef.ru.nl/~filthaut/teach/expt

Teaching methods
- 50 hrs lecture
- 2 hrs laboratory course
- 8 hrs student presentation

Prerequisites
Bachelor courses 'Quantum Mechanica II' and 'Inleiding subatomaire fysica' or equivalent

Objectives
- The student is aware of the physical principles used in the detection, measurement, and identification of high energy particles, as well as of the most important aspects of data handling in large experiments
- The student is knowledgeable about the basics of accelerator techniques and properties
- The student is aware of the important developments in experimental particle physics
- The student is able to participate in research activities, without further general prior knowledge

Subjects
- Concepts: cross sections, decay rates and lifetimes
- Accelerators:
  - history of particle accelerators
  - acccelerator physics: focusing, acceleration, cooling
- Detection principles and their applications
  - the shell model of modern particle detectors
  - interactions of charged particles
  - charged particle tracking
  - scintillation
  - Cherenkov radiation
  - calorimetry
  - triggering and data acquisition
  - reconstruction of physics objects
- Weak interactions
  - the weak structure of the Standard Model
  - electroweak physics at LEP
- Strong interactions
  - from hadrons to quarks
  - structure functions
  - QCD at LEP

- Mixing and CP violation
  - the neutral kaon system
  - the CKM matrix
  - the neutral B meson system
  - neutrino oscillations

Literature

Strongly recommendable:

- M.Conte and W.MacKay, *An Introduction to the Physics of Particle Accelerators*, World Scientific Publishing Co., ISBN 981-02-0813-8
- R. Fernow, *Introduction to experimental particle physics*, Cambridge University Press, ISBN 0-521-37940-7
- D. Griffiths, *Introduction to Elementary Particles*, J. Wiley & Sons, ISBN 0-471-60386-4
- Lecture notes

Examination

Oral examination

Experimental Techniques

Course ID: **NM004B** *3 ec* first semester dr. S.A.J. Wiegers

Teaching methods
- 12 hrs lecture
- 12 hrs problem session

Prerequisites
- Bachelor Program Laboratory Courses

Objectives
- The student understands the experimental and physical background of achieving high vacuum, of operating lasers, achieving low temperaturs and using electronic lock-in signal techniques
- The student is able to translate a scientific question into an experimental design/realisation

Contents
Modern physics depends heavily on advanced experimental techniques. The technological fields of vacuum technology, laser technology, cryogenic technology and electronics are essential when translating a scientific question into an instrument including the collection and use of the observations. In this course, we want to stay close to the technology, pumps, lasers, coolers, lock-in amplifiers explaining their physical and practical operating principes. Next to making series of problem sets on the different topics, a self-chosen scientific problem and its experimental solution will be described and presented.

Literature
- Lecture notes

Examination
- Take home experimental construction problem
- Oral presentation

Health physicists and radiation protection

Course ID: **INDD** *5 ec* first semester drs. P.A.J. Jonkergouw

Teaching methods
- 110 hrs lecture
- 30 hrs laboratory course

Prerequisites
Science, mathematics

Objectives
This 19-day course (given in dutch) is intended for health physicists and radiation protection technologists who may be called upon to respond to emergencies involving radioactive materials and injury to personnel. After following the course and passing the national exam you will receive a legal permit to supervise and work with radioactive materials and X-ray apparatuses. The course is designed to train health physicists in the use of radioactive materials and radiation-producing devices such as those used in hospitals and related medical facilities, colleges and universities, industry, public health services and nuclear power installations. Demonstrations, laboratory exercises, group problem solving sessions will complement the didactic presentations.

Contents
An intensive course (200 hours) of lectures and laboratory exercises dealing with almost every aspect of radiation safety, radiation protection or health physics, whichever term you prefer to use. Participants spend approximately 20% of their time performing laboratory exercises using radiation detection and measurement equipment. Laboratory exercises complement the health physics principles covered in lectures. Topics include:
- Radiation Physics
- Radiation Detection and Measurement Techniques
- Radiation Dosimetry
- Radiation Biology
- Assay Techniques
- Shielding and Facility Design
- Health Physics Principles
- Radioactive Materials and Control Techniques
- Environmental Monitoring

The course is not only open to students, most of the members are from hospitals and companies.

Literature
Necessary: (by way of AMD)
- Bos A.J.J., Draaisma F.S., Okx W.J.C., *Inleiding tot de Stralingshygiëne*, Sdu Uitgevers Den Haag 2007, ISBN 978 90 12 11 905 4
- Bos A.J.J., Uitwerkingen van de vraagstukken uit het boek *Inleiding tot de Stralingshygiëne*, IRI Delft

- Keverling Buisman A.S., *Handboek Radionucliden*, Betatext, Bergen N.H. 2007, ISBN 978 90 75541 10 6
- Magill J., Pfennig G., Galy J., Karlsruher Nuklidkarte, European Communities 2006, ISBN 92 79021753

Examination

National exam, MC and open questions

Extra information

The course will be given in Dutch, on Monday and Friday, 09:00 - 17:00, total course is 19 days.

Interacademic Course Astrophysics

Course ID: **NM063B** *6 ec* second semester prof. dr. P.J. Groot

Website

www.uu.nl/uupublish/homeuu/deuniversiteit/wiewatwaar/1137main.html

Teaching methods

- 32 hours lecture
- variable hours (group)assignments

Contents

In the framework of a Dutch national astrophysics master at least one course a year will be given nationally, at the Utrecht University. The topic of each year's course is changing, and will mostly cover topics outside of the Nijmegen astrophysics Masters curriculum. The topic of the year 2009/2010 will be announced as soon as it is known.

Extra information

The course will be given in Utrecht on Wednesdays from 11h to 16h.
Morning (11 am-13 pm) lectures will be followed by practical work, tutorials, and guest lectures on specific topics in the afternoon.
The morning lectures will be held in the Minnaert building.
You can reach the Uithof from Utrecht CS with bus 11 or 12, leaving the station every 3-5 min. Allow for about 25 min to reach the Minnaert building from the station. Maps and directions can be found at the the university webpage. In case of major group delays (trains or weather) you are asked to inform the lecturer. Coffee, tea and lunch are available in the Minnaert canteen (chipcard required). A prepaid card can be bought at the entrance hall.

Interaction of Light with Molecules and Materials

Course ID: **NM074B** *6 ec* second semester dr. A.V. Kimel
prof. dr. M.J.J. Vrakking
prof. dr. W.J. van der Zande

Teaching methods
- 24 hrs lecture
- 16 hrs problem session

Prerequisites
Inleiding Vaste Stof Fysica, Inleiding Atoom- en Molecuulfysica, Quantummechanica 1a,1b

Objectives
Bridging the gap between Bachelor Courses and Specialized Capita Courses, Broad Introduction to Optical Techniques in Research

Contents
We will present the quantum mechanical description of the interaction of light with quantum systems, introducing incoherent and coherent interactions and their non-intuitive consequences. Where abstract quantum systems are isotropic, solids and interfaces are not. The optical response of these systems requires vector and tensor descriptions. The course will explain why different solids (insulators, semiconductors, metals, super-conductors) have different optical responses. A special attention will be paid to non-linear optical processes, which allow changing the colour of light, ultrasensitive diagnostic of surfaces and interfaces. It will be shown that at the shortest most intense pulses, processes change. The special position of NMR (or MRI) will be explained.

Subjects
At the end of the course the student is expected to obtain knowledge on the following issues:

Interaction of Light with Matter
- Quantum treatment of atom-radiation interaction
- Two-level and few-level systems
- Rabi frequency
- Bloch vector, optical Bloch equations
- Principles of Coherent control
- Introduction to quantization of the optical field
- Excitation by intense laser fields (guest speaker)

Optics of Molecules and Atoms
- Linear optics (line shapes, the role of collisions)
- Non-linear optics in atoms and molecules (multi-photon excitation, (stimulated) Raman scattering, AC Stark shifts)
- Ultra fast spectroscopy
- Examples of coherent control
- The few level system, description of NMR/MRI

Optics of Materials
• Linear optics (approximations, dielectric permittivity, magneto-optical effects)
• Tensor representation of optical phenomena
• Nonlinear optics (approximations, optical rectification, second harmonic generation, photo-refraction, stimulated Raman scattering)
• Ultra-fast optics of solids (optical Bloch equation, semiconductor Bloch equations, ultra-fast transient processes in solids)
• Optics of dielectrics and semiconductors (approximations, specific spectral features and their correlation with transport properties)
• Optics of metals and superconductors (approximations, specific spectral features and their correlation with transport properties)
• Optics of superconductors (approximations, specific spectral features and their correlation with transport properties)
• Optics of strongly correlated systems (guest speaker)

Literature

- Lecture notes

Recommended:

- R. Loudon, *The Quantum Theory of Light* (Oxford University Press, USA, 2000).
- L. D. Landau, E. M. Lifshitz, *Electrodynamics of Continuous Media.* (Pergamon, Oxford, 1984).
- Y. R. Shen, *The Principles of Nonlinear Optics* (John Wiley & Sons, 2003).

Introduction to C++

Course ID: **NM073B** *3 ec* second semester dr. F. Filthaut

Teaching methods
- 14 hrs lecture

Prerequisites
Basic programming skills (*e.g.*, experience with C or Fortran)

Objectives
- knowledge of basic C++ syntax
- knowledge of object orientation using C++
- ability to code algorithms using C++

Contents
C++ has become the *lingua franca* of modern computer programming, especially where large software projects are involved and efficiency is an issue.
The aim of this course is to provide students with sufficient basic skills for them to be able to participate in such projects. The course is slightly biased (in its examples and exercises) towards high-energy physics but is meant to be accessible to others, too.

Subjects
1. basic language features
2. modularity and structured programming
3. basics of classes
4. design features of classes
5. I/O using the Standard Library
6. templates
7. the Standard Template Library
8. inheritance and polymorphism
9. exception handling

Literature
Lecture notes will be available
Recommended literature:
- B. Stroustrup, *The C++ Programming Language*, 3rd edition, Addison Wesley, ISBN 0-201-88954-4. This book by the creator of C++ contains a wealth of information, which makes it worth having for everyone dealing with C++ on a regular basis. However, it is not very suitable as a tutorial
- J.J. Barton and L.R. Nackman, *Scientific and Engineering C++: An Introduction with Advanced Techniques and Examples*, Addison Wesley, ISBN 0-201-53393-6
  Though slightly outdated, this book provides one of the best tutorial introductions to C++

Examination
Through exercises

Extra information
Computer access is essential

Introduction to Computer Graphics

Course ID: **NM058B** *6 ec* Fall semester drs. P.F. Klok

Website
http://www.hef.ru.nl/~pfk/education/icg/

Teaching methods
- 40 hrs computer course

Prerequisites
Required is programming experience at the level of Programmeren (NB021B) or equivalent

Objectives
Familiarize with basic terms and techniques of computer graphics and image processing and implement various techniques in both fields. Through the knowledge and the practical experience of this course, well-funded judgement on graphics matters and quick mastering of graphics software should be obtained.

Contents
During the lectures the basics of computer graphics and image processing are covered. The assignments of the practical course follow the topics of the lecture text. A written examination about the topics of the lecture text concludes the course.

Subjects
- **General:**
  basic notions, synthetic camera, windows, viewports, clipping, coordinate systems, graphical standards
- **Interactive Graphics:**
  windows, graphical objects, input classes, user interface
- **2D and 3D Graphics:**
  transformations, projections, graphics pipeline, hidden-line and hidden-surface removal
- **Raster Graphics:**
  frame buffers, scan conversion, colour models
- **Rendering:**
  ray tracing and ray casting, reflections, shading, splines
- **Image Reconstruction**:
  fourier transforms, backprojections
- **Image Enhancement:**
  filtering, histogramming
- **Visualization:**
  pseudo colour, lookup tables

Literature
Necessary:
- Website http://www.hef.ru.nl/~pfk/education/icg/

Strongly recommended:

- Foley, van Dam, Feiner, Hughes, Phillips, *Introduction to Computer Graphics*, Addison Wesley, 1993, ISBN 0-201-60921-5.

Examination
Exercises and preliminary examination.

Extra information
Lectures followed by practical work to elaborate on lecture topics
The graphical package OpenGL is used with programs written in the C programming language

Introduction to Partial Differential Equations

Course ID: **WB046B** *6 ec* second semester prof. dr. H.T. Koelink

Teaching methods
- 32 hrs lecture
- 32 hrs problem session

Prerequisites
Calculus 1-4, Analysis 1-2, Ordinary Differential Equations (or Applied Mathematics 1)

Objectives
Te student is to able to work with partial differential equations, as well as to distinguish between various classes of pde's. For such classes the student is able to discuss solution methods as well as theoretical considerations.

Contents
A partial differential equation describes a relation between the partial derivatives of an unknown function and given data. Such equations appear in all areas of physicsan engineering. More recently the use of PDEs in models in biology, pharmacy, imageprocessing, finance etc. have increased strongly. Since the origin of these models is very diverse and the results should be applicationdriven, the analysis of PDEs has many facets. The classical approach focused on finding explicit solutions. Since numerical methods and fast computers became available, the modern approach is more oriented to the application of functional analytic methods in order to find existence and uniqueness results and to show that solutions depend continuouslyon the given data. Having existence, uniqueness and stability under perturbations, a numerical method may be implemented to find an approximation of the solution one is interested in. The present course will be an introduction to the field. The elementary classical results will be explained and we will touch some of the more modern aspects.

Subjects
- Introduction: some elementary models will be explained and different types of PDEs will be classified.
- First order equations: the method of characteristics, conservation laws and shock waves.
- Linear second order equations: the heat equation, the laplace equation and the wave equation are classical second order models.
- The wave equation for one space dimension: The Cauchy problem and d'Alembert's solution.
- Seperation of variables. For special domains and special PDEs one may split the problem into a set of ODEs.
- Sturm-Liouville equations. Parameter dependent boundary value problems for ODEs.
- Elliptic equations. The maximum principle and uniqueness.
- Integral representations. For some special cases Green functions give an almost explicit solution.

- Equations in higher dimensions: the classification in parabolic, elliptic and hyperbolic equations. Some explicit solutions.
- Variational methods. Introducing the weak formulation

Literature
Lecture notes, which will be made available via Blackboard.
Secundary literature 'An Introduction to Partial Differential Equations' by Y.Pinchover, J. Rubinstein, Cambridge University Press.

Examination
Schriftelijk tentamen.

Introduction to String Theory

Course ID: **NM059B** *6 ec* prof. dr. A.N.J.J. Schellekens

Website
http://www.nikhef.nl/~t58/lectures.html

Teaching methods
- 32 hrs lecture

Prerequisites
Theoretical Foundations of Elementary Particle Physics

Objectives
Student understands main goals of Superstring Theory and the present status

Contents
In this course an introduction to string theory will be given. At this moment string theory is the most important candidate for a quantum theory of gravitation, describing at the same time strong, weak and electromagnetic interactions as we know them. Over the past thirty years string theory developed to an extended web of new ideas in theoretical and mathematical physics.
In this course a number of basic concepts are treated. In addition a not too detailed overview of the field is given addressing also recent developments.

Literature
Necessary:
- Lecture notes

Background material:
- B. Zwiebach, *A first course in String Theory*

Advanced:
- M. Green, J. Schwartz and E. Witten, *Superstring Theory (I+ll)*, Cambridge University Press, 1987
- J. Polchinski, *String Theory (I+II)*, Cambridge University Press, 1998

Examination
Oral exam

Extra information
This course is given biannually.

Lasers and Electro-Optics

Course ID: **NM008B** *6 ec* second semester dr. F.J.M. Harren

Teaching methods
- 30 hrs lecture
- 30 hrs problem session

Prerequisites
Completed B.Sc. programme

Objectives
The student is able to describe the physics and engineering aspects of lasers as well as optical systems and electro-optical devices.

Contents
This course provides a detailed introduction to the basic physics and engineering aspects of lasers, as well as to the design and operational principles of a wide range of optical systems and electro-optic devices. Throughout, important derivations and results are given, as are many practical examples of the design, construction and performance characteristics of different types of lasers and electro-optical devices. The lecture deals with the fundamentals of laser physics, the characteristics of laser radiation, and discusses individual types of laser, including optically pumped insulating crystal lasers, atomic gas lasers, molecular gas lasers and semiconductor lasers. The electro-optic part deals with topics such as fundamentals of non-linear optics, parametric processes and electro-optic and acousto-optic devices.

Literature
Necessary:
- Davis, *Lasers and Electro-optics, Fundamentals of Engineering,*, Cambridge Univ. Press 2002, ISBN 0-521-48403-0

Examination
Open book examination

Particle Physics Phenomenology

Course ID: **NM010C** *6 ec* first semester prof. dr. N. de Groot

Teaching methods
- 30 hrs lecture
- 30 hrs problem session

Prerequisites
Bachelor courses 'Kwantum Mechanica 2' and ´Structuur der Materie´
'Inl. Subatomaire Fysica' or ´Kwantum Mechanica´ 3 are a bonus.

Objectives
- The student will be able to describe the production and detection methods of elementary particles
- The student will be able to name the elementary particles, their properties and describe the history of their discovery
- The student will be able to apply Feynman diagrams to fundamental processes
- The student will be able to apply symmetries and conservation laws
- The student will be able to describe the Standard Model

Contents
Introduction to the elements of the Standard Model of elementary particle physics

Subjects
- Introduction to the production and detection of elementary particles
- Historical introduction to the elementary particles: featuring leptons, quarks and gauge bosons
- Feynman diagrams: fundamental interactions in pictures
- Symmetries and conservation laws
- The Standard Model of Elementary Particle Physics

Literature
- David Griffiths, *Introduction to Elementary Particles*, John Wiley & Sons Inc., 2008 (new edition), ISBN: 978-3-527-40601-2

Examination
Oral exam

Lie Algebras

Course ID: **NM028C** *9 ec* first semester prof. dr. G.J. Heckman

Teaching methods
- 42 hrs lecture
- 14 hrs problem session

Prerequisites
One of the bachelor course Symmetry (for mathematicians) or Introduction to Group Theory (for physicists)

Objectives
The student becomes familiar with the following subjects:
- Poisson algebras
- Universal enveloping algebras
- The representation theory of SL(2)
- Representations via constructions of linear algebra
- Reductive Lie algebras
- Verma representations
- Physical application: The Kepler problem
- The representation theory of SL(3)
- Physical applications: Spin and quarks
- The Weyl character formula
- Spherical harmonics, and SO(n)
- Lorentz group
- Poincare group

Contents
In this course we discuss the mathematics of Lie algebras and their representations. The basic examples are the Heisenberg algebra, the special linear algebra SL(n) and the orthogonal algebra SO(n). For each of these algebras we discuss the physical relevance which lie mainly in the realm of particle physics. We also discuss the link with invariant theory, an important subject in geometry. The course is interesting for students in both physics and mathematics, and standard for students in mathematical physics. The material of the course is useful for the courses "Beyond the Standard Model" and "Introduction to String Theory" of Prof. dr. B. Schellekens.

Literature
There are written lecture notes of the course

Examination
Oral examination

Machine Learning

Course ID: **NM048B** *6 ec* first semester prof. dr. H.J. Kappen
dr. W.A.J.J. Wiegerinck

Website
http://www.snn.ru.nl/~wimw/collegeML.html

Teaching methods
- 40 hrs lecture

Prerequisites
- Neural Networks and information theory

The following courses are useful but nor required: Voortgezette Kansrekening , Markov ketens, Toegepaste wiskunde 1

Contents
This course is an advanced course on machine learning and neural networks from a probabilistic point of view. In 2009/2010, the course will be given as previous years. See http://www.snn.ru.nl/~bertk/machinelearning/ for last years course.
Starting in 2010/2011, the course is a continuation of the course Neural Networks and information theory and will contain more advanced topics. The course is intended for master students in physics and mathematics. Students with a background in computer science, AI or cognitive science are recommended to follow the course Introduction to Pattern Recognition instead.
The course provides a good preparation for a Masters' specialisation in Theoretical Neuroscience or Machine Learning.

Subjects
- Short recapitulation of probabilities (MK Ch. 2, 3)
- Bayesian posterior estimate for Gaussian distribution (MK Ch. 24)
- Graphical models (MK Ch. 21.1, 16, 26, Bishop Ch 8)
- Examples of useful probability distributions (MK Ch. 23)
- Laplace method (MK Ch. 27)
- Variational methods (MK Ch. 33)
- Model comparison (MK Ch. 28 + ev. illustratie MLPs MK Ch. 44)
- Monte Carlo methods (MK Ch. 29, 30)
- Binary netwerken, Markov processen, ergodiciteit (diktaat)
- Ising model (MK Ch. 31)
- Boltzmann Machines, mean field theorie (MK Ch. 43, diktaat)
- Independent component analysis (MK Ch. 34)
- Gaussian processes (MK Ch. 45)

See also the course website: http://www.snn.ru.nl/~bertk/machinelearning/

Literature

- David MacKay, *Information Theory, Inference and Learning Algorithms*, Cambridge University press. The entire book can be viewed on-screen at http://www.inference.phy.cam.ac.uk/mackay/itila/book.html
- several handouts will be distributed during the course

Examination

Written exam

Materials Science

Course ID: **NM020B** *6 ec* second semester dr. P.R. Hageman

Teaching methods
- 30 hrs lecture
- 30 hrs problem session

Prerequisites
This course aims at master students physics, chemistry or natural sciences

Objectives
- The student has knowledge of the concepts and theory from material science as presented in the course
- The student can apply the presented concepts and theory in order to interpreted correctly scientific literature in the area of material science
- The student is capable to reduce the information from the scientific literature to the core problems
- The student is capable to solve these core problems using the presented theory and concepts or can present a different solution method

Contents
Understanding of the fundamental nature of materials during the last century has led to the development of materials science and engineering. Within this field traditionally the relation between the microscopic structure and macroscopic properties of bulk materials such as metals, semiconductors, ceramics and polymers is studied. Recent developments concentrate on the processing and performance of materials in the form of thin films, as these have become increasingly important in our daily life.
This material science course handles the relationship between material structure and the resulting mechanical, electrical, chemical, optical and magnetic properties of materials in general and thin films in particular. Enveloping this relation special emphasize is given to methods for thin film deposition (MOCVD, MBE, Sputtering) and their final performance. The processing -> structure -> properties -> performance interactions will be illustrated by the discussion of recently developed materials such as gallium-nitride and synthetic diamond coatings as well as specialized applications such as high efficiency solar cells and magnetic multi-layers.

Literature
Hand outs will be distributed during the course. No specific book is required.

Examination
The students write independently a paper about a subject dealing with materials science on basis of distributed scientific literature. In this paper the student has to apply the knowledge learned in the course.

Monte Carlo Techniques

Course ID: **NM042B** *6 ec* second semester prof. dr. R.H.P. Kleiss

Website
www.hef.ru.nl/~kleiss/

Teaching methods
- 40 hrs lecture

Prerequisites
Theory of probability, some programming experience

Objectives
The student can perform Monte Carlo computations and simulations and discuss their results.

Contents
The course is an introduction to solving problems using random numbers. As primary example, the problem of multi-dimensional integration is treated. This course is mainly intended for people confronted with numerical integration and Monte Carlo simulation, such as in the phenomenology of elementary particle physics.

Subjects
- Theory of Monte Carlo integration: probability calculations and the construction of estimators
- Techniques of variance reduction: stratification, importance sampling, multichanneling
- Algorithms for the generation of (pseudo)random numbers
- Tests of randomness of number series
- Algorithms for the generation of non-uniform number sets
- Discrepancies and Koksma-Hlawka type inequalities
- The Wozniakowski theorem
- Principles of quasi-Monte Carlo
- Generating quasi-random number sets
- The problem of many-particle phase space integration: RAMBO, MAMBO and SARGE algorithms

Literature
Announced during the course

Examination
By arrangement

MRI techniques in the Life Sciences

Course ID: **NM049B** *6 ec* second semester prof. dr. D.G. Norris

Website
http://www.ru.nl/fcdonders/

Teaching methods
- 18 hrs lecture
- 12 hrs problem session
- 10 hrs individual study period

Prerequisites
Basic electromagnetic theory, quantum mechanics, Fourier transforms

Objectives
Students will gain understanding of how Magnetic Resonance Imaging functions and some insight into applications in brain imaging.

Subjects
1. Basics
   - Basic NMR Experiment
   - Classical MR Experiments and relaxation mechanismes
   - MR system hardware and construction principles
   - Coursework 1
2. Imaging
   - Slice selective excitation, essentials of Fourier imaging
   - K-space formalism. Echo planar imaging
   - Fast spin echo and fast gradient echo sequences
   - Coursework 2
3. Applications
   - Diffusion weighted imaging
   - Perfusion imaging methods
   - Functional magnetic resonance
   - Coursework 3

Literature
Heighly recommended (can be borrowed from D. Norris)
- M.Bernstein, *Handbook of MRI pulse sequences*
- Paul T. Callaghan, *Principles of Nuclear Resonance Spectroscopy*
- E. Mark Haacke, *Magnetic Resonance Imaging, Physical Principles and Sequence Design*

Examination
- 70% of the marks are awarded for the exam which is closed book and lasts 3 hours
- 10% is awarded for each of the coursework sessions which last 1.5 hours and are open book

Nano Magnetism

Course ID: **NM044B** *6 ec* second semester dr. A.I. Kiriliouk

Teaching methods
- 28 hrs lecture

Prerequisites
Quantum mechanics; Introduction to Solid State Physics

Objectives
- The student should be able to understand the recent discoveries in the area of magnetism
- The student is able to read and understand the articles in leading scientific journals

Contents
Magnetism is a phenomenon that has intrigued mankind since millennia and has found a large variety of applications ranging from the compass to hard disks. Modern preparation techniques have allowed the fabrication of magnetic structures with typical dimensions that are small compared to fundamental **length scales** such as exchange length, mean free paths or spin diffusion length, which have led to exciting new effects like giant magneto-resistance and spin injection. The importance of such phenomena has been recognized in the Nobel prize 2007.
This course will cover several topics of magnetism in **nano dimensions**, starting from basics. Special attention will be on the formation of the magnetic moments as well as on various aspects of magnetization dynamics. It will also include a review of experimental approaches.

Subjects
- quantum mechanics: spin-spin and spin-orbit interactions
- exchange and anisotropy
- magnetic order: ferro-, ferri, and antiferromagnets - dimension dependence
- superparamagnetism
- spin waves in nanoelements
- magnetization dynamics: domain wall, spin precession, spin heating, etc.
- magnetic quantum phenomena
- preparation and magnetic and structural characterization techniques
- magneto-optics as important tool for ultrafast dynamics studies
- utilization: are we going to have a magnetic computer?

Literature
Lecture notes are handed out at every lecture; blackboard will also be used for the lecture notes and extra material
As extra reading:
- S.V. Vonsovskii, *Magnetism,* John Wiley & Sons, New York, 1974
- S. Chikazumi, *Physics of Ferromagnetism,* Clarendon Press, Oxford, 1997
- D. Craik, *Magnetism: Principles and Applications,* John Wiley & Sons, New York, 1995

- D.C. Mattis, *The theory of magnetism,* Harper & Row, New York, 1965
- J. Stöhr and H.C. Siegmann, MAgnetism: from fundamentals to nanoscale dynamics, Springer, 2006

Examination

Combination of a written short report, 15 minutes oral presentation on a selected subject, and the work during the semester

NIKHEF Topical Lectures

Course ID: **INDC** *1 ec* 3 times per year prof. dr. S.J. de Jong

Website
www.nikhef.nl/pub/onderzoekschool/

Teaching methods
- 24 hours lecture

Contents
These topical lectures typically comprise three full days and need some preparation. Participation in the NIKHEF topical lectures should be reported a priori to the IMAPP secretariat (HG 03.380, tel: 52099, email: secr@hef.ru.nl) or to Prof.dr. S.J. de Jong. For dates and topics of upcoming NIKHEF topical lectures, please consult the web-site.

Examination
Aanwezigheidsplicht

Nuclear Physics

Course ID: **NM016B** *6 ec* first semester dr. A.C. König

Teaching methods
- 40 hrs lecture

Prerequisites
Quantum Mechanics 1a, 1b en 2

Objectives
Thorough knowledge of:
- Nuclear structure
- Nuclear instability
- Nuclear reactions
- Interaction of radiation with matter
- Detectors and instrumentation
- Biological effects of radiation
- Nuclear medicine
- Nuclear power

Subjects
- The nuclear force: nuclear size, deuteron and tensor force
- Shell model, Woods-Saxon potential, correction terms, allowed orbits
- Spherical even-even nuclei, pairing, energy-gap, ground states, excited states, collective vibrations
- Semi-empirical mass formula
- Decay laws
- Nucleon emission, neutron emission, angular momentum barrier, Coulomb barrier, *alpha*-emission, nuclear fission
- *Beta*-decay and electron capture, energy spectrum, angular momentum, selection rules, decay forces
- *Gamma*-emission, electrical and magnetic multipole radiation
- Nuclear reactions, compound nucleus reactions, the imaginary potential, resonances, strength function, thermal neutrons, direct reactions, angular distributions, planewave Born approximation, distorted-wave Born approximation

Literature
Necessary:
- John Lilley, *Nuclear Physics, Princples and Applications*, John Wiley & Sons Ltd.

Examination
Written examination

Extra information
This course will be given biannually

Numerical Methods

Course ID: **NM066C** *3 ec* first quarter Dr. W. Hundsdorfer

Teaching methods
- 14 hrs lecture
- 14 hrs problem session

Prerequisites
Basic knowledge Linear Algebra and Calculus

Objectives
- The student will become femiliar with properties of some numerical methods and their implementations

Contents
Theoretical properties and practical aspects of basic numerical methods for
Linear and nonlinear algebraic equations
Polynomial interpolation and approximation
Numerical integration
Ordinary differential equations

Subjects
- Root finding: bisection, Newton-Raphson
- Numerical diffentiation
- Numerical integration: trapezoid, Simpson, Monte Carlo
- Ordinary differential equations: Euler, Runge-Kutta, Verlet
- Interpolationand polynomial approximation; special functions

Literature
Lecture notes, can be downloaded from Blackboard

Examination
Programming tasks with written exam

Extra information
This course is given at master-physics and bachelor-mathematics by prof.dr W. Hundsdorfer

Oriëntatiestage E-variant

Course ID: **NM061B** *3 ec*

Teaching methods

- 60 uur stage in het voortgezet onderwijs
- 20 uur voorbereiding / stage-opdrachten / verslag

Prerequisites

- CEM-cursus
- **Alleen toegankelijk voor Nederlands sprekende studenten**

Objectives

De Oriëntatiestage E-variant biedt studenten de mogelijkheid om (na de CEM-cursus in de bachelorfase) zich tijdens de masterfase verder te oriënteren op de Educatieve variant. Deze snuffelstage is niet verplicht maar zeer aan te raden voor iedereen die de eerstegraads bevoegdheid leraar wil halen. De stage kan flexibel worden ingeroosterd.

Contents

De scholen bieden twee mogelijke periodes voor de snuffelstage, te weten van 1 oktober tot 1 december of van 1 februari tot 1 april. Deze periodes zijn ruim genomen om de student en de school de gelegenheid te geven om de stage flexibel in te roosteren in het vierde studiejaar. De schoolstage bestaat niet alleen uit meelopen en observeren, maar ook uit zelf lesgeven (8 lesuren) en de eigen lessen nabespreken met de begeleidende schooldocent. De ervaring leert dat men 4 à 5 weken lang 2 dagen per week op school aanwezig moet zijn om de verlangde hoeveelheid ervaring op te doen. Het staat de student echter vrij om in overleg met de stageschool een ander rooster te maken.

Begeleiding

De begeleiding vanuit de universiteit wordt verzorgd door een vakdidacticus van het Instituut voor Leraar en School (ILS). Deze instituutsdocent verzorgt een inleidende bijeenkomst, onderhoudt de contacten met de scholen, levert literatuur en opdrachten, en beoordeelt het verslag. De instituutsdocent komt in principe één keer naar de stageschool voor overleg ter plekke, al dan niet aangevuld met een lesobservatie.

Informatie en aanmelding

Stageplaatsen worden geregeld door het stagebureau van het ILS op basis van inschrijvingen voor de cursus. Houd er rekening mee dat het gebruik van een OV-weekkaart nodig kan zijn. Neem voor verdere informatie contact op met het Secretariaat Instituut voor Leraar en School, Gymnasion, tel. 024-3530093 of 3530094.

Particle Physics Experiment Analysis

Course ID: **NM077B** *6 ec* second semester prof. dr. S.J. de Jong

Website
blackboard

Teaching methods
- 32 hrs lecture
- 32 hrs problem session

Prerequisites
Particle Physics Experiments

Objectives
After the course the student should be able to analyze data from high energy physics experiments under supervision of a senior physicist.

Contents
The analysis of data for particle physics experiments is explained.
Special emphasis lies on the statistical treatment of the data, fitting techniques, event classification, significance, exclusion limits, and systematic uncertainty treatment.

Literature
To be decided

Examination
By arrangement

Philosophy 2 (for Physicists)

Course ID: **FFIL211A** *3 ec* third quarter dr. M.A.M. Drenthen
S.A.J. Segers

Teaching methods
- 20 hrs lecture
- 2 hrs personal study counseling
- 58 hrs individual study period

Prerequisites
students are expected to have completed the bachelor course 'Inleiding in de filosofie'

Objectives
After this course the student:
- is able to read and analyze a philosphical text, to present a text, to lead a group discussion
- understands the epistemological shift from classical physics to quantumphysics and is familiar with the major positions in the debate between scientific idealism, realism, instrumentalism and positivism
- is aware of the specific nature of the scientific appraoch, and is able to demarcate the boundaries between physics and other fields of intellectual activity

Contents
The development of quantum mechanics has given rise to a number of epistemological, cultural historical, and philosophical debates. In this course, we will read some texts from the founding fathers of quantum mechanics. The main focus is on the relation between physical models and reality. What is the status of physical knowledge? What is the role of aesthetic judgments in the development of theoretical physics? What are the boundaries of the scientific approach? What can a theory of everything imply? What is the relation between scientific insights and religious or ideological outlooks on life?

This course will be taught in English. However, if there are less then 2 foreign students, it will be held in Dutch. In that case, non-dutch speaking students will get an alternative assignment.

Students who wish to follow this course have to **sign up at least 4 weeks before the start of the course**. Please conform your subscription in Blackboard by pressing the 'group activation' button.

Students who do not speak Dutch are requested to make themselves known as such, by sending an e-mail to: m.drenthen@science.ru.nl**.** This way, that the lecturer can decide in time if the course will be held in Dutch, or if it has to be taught in English.

Literature
Papers will be distributed.

Examination

During this course, student will have to read and analyze, present and discuss philosophical texts.
Students will be assessed on their home assigments, their presentation and their contributions to the discussions in class. There will be no final exam.
Attendance is mandatory.

Extra information

College: thursday 13.30-15.30

Professional Preparation

Course ID: **NM019B** *1 ec* second semester prof. dr. S.J. de Jong

Website
Blackboard

Teaching methods
- 16 hrs problem session

Prerequisites
Bachelor exam Physics and/or Astronomy

Objectives
The student will be able to:
- reflect on her/his professional abilities
- reflect on her/his preferences for employment
- compose her/his CV
- write a letter to apply for a professional position
- present her-/himself to a selection board

Contents
This course prepares for the transition from being a student to physicist or astronomer on the job.
It comprises four half-day sessions in which the student is trained to reflect on her/his own abilities, preferences for employment and on matching these. Under the guidance of the trainer a CV and a letter of application will be composed and commented on in a group process. Presentation as a job candidate to a selection board will be practised with students both in the role of the applicant and member of the selection board.
The course will be lead by a professional trainer from the RU Student Affairs Office.

Examination
Presence and active participation is required for all four lectures

Extra information
This course will occupy four half-day (3,5 - 4 hour) session at dates that will be announced by email in early 2010

Quantum Field Theory

Course ID: **NM040B** *6 ec* first semester dr. W.J.P. Beenakker

Teaching methods
- 30 hrs lecture
- 30 hrs problem session

Prerequisites
Bachelor courses on Quantum Mechanics

Objectives
- The student has a good understanding of the fundamental aspects of quantum field theory in the canonical formulation
- The student is able to derive and use Feynman rules
- The student is familiar with the salient details of calculating radiative corrections within perturbation theory
- The student knows the fundamental differences between Abelian and non-Abelian gauge theories
- The student is able to construct theoretical models on the basis of symmetry arguments and conservation laws

Contents
This course provides an introduction to the modern concepts of quantum field theory, formulated in the canonical framework. A further aim of the course is to introduce the concept of gauge symmetries, which plays a crucial role in the description of the interactions between fundamental particles. By means of Abelian, non-Abelian, as well as spontaneously-broken symmetries it is possible to adequately describe electromagnetic, strong and weak interactions. As a particular application it will be shown how the Standard Model of electroweak interactions can be constructed from basic experimental observations and basic physical requirements (like unitarity and predictability).

Subjects
- Klein-Gordon and Dirac equations, Lagrangian formalism, quantum fields, canonical quantisation
- Quantum electrodynamics (QED), conserved currents, minimal substitution, gauge fixing
- Perturbation theory, Green's functions, Wick's theorem, Feynman diagrams; scattering theory, S-matrix, LSZ reduction; derivation of the Feynman rules for φ^4 theory, Yukawa theory and QED
- Radiative corrections, Källén-Lehmann representation, Feynman parameters, Wick rotation, optical theorem, unstable particles; specific topics for QED: Ward-Takahashi identity, running coupling, regularization of ultraviolet divergences, renormalization
- Global gauge symmetries and conservation laws, gauge principle, Abelian and non-Abelian local gauge symmetries, discrete symmetries
- Constructing new theories on the basis of unitarity, charge-algebra and anomaly arguments; symmetry breaking and mass generation

Literature

Necessary:

- Michael E. Peskin and Daniel V. Schroeder, *An introduction to Quantum Field Theory* (Westview Press, 1995)

Recommended (not mandatory):

- Claude Itzykson and Jean-Bernard Zuber, *Quantum Field Theory*, Dover Edition (Dover Publications, 2006)

Examination

Written exam

Research Labs

Course ID: **NM003B** *6 ec* first semester ir. R.A.H.M. van Haren

Teaching methods
- 3,5 days laboratory work per experiment

Prerequisites
Bachelor lab classes

Objectives
- The student can perform experiments independently
- The student can work out problems and have malfunctioning apparatus repaired
- The student can analyse the obtained data and give a concise oral and written presentation of the work

Contents
This course is the final preparation before working in a real experimental environment. 'Research Labs' tries to simulate the environment which students will experience in a real Research Laboratory.
Up to 3 experiments can be chosen from a list of available subjects. Each experiment brings 3.0 ec. The experiments are located in the experimental researchgroups of the faculty. The following experiments are available (with some restrictions):
- A3:Laser Induced Fluorescence (Harren)
- B2: De Haas van Alphen Effect (Zeitler)
- B3: Femtoseconde spectroscopie (Van Etteger)
- B4: Magneto-optica (Kirilyuk)
- B5: 2D Electron Gas (Zeitler)
- B6: Scanning Probe Microscopy (Gerritsen)
- C1: Radio Interferometer (Groot)
- D1: Biofysica (Gielen)
- E1: Muondetection (Timmermans)
- E2: Dradenkamer (Timmermans)
- T2: Photo Acoustic Detection (Harren)
- T3: Molecular Light Scattering (Dam)
- T4: Chemical Vapour Deposition of Diamond (Schermer)

The student him/herself should be mainly responsible for the proper execution of the work. There is enough time available for working out eventual problems and debugging. The analysis of the obtained data plays an important role, as well as concise presentation.
More general information on the objectives and the organization of this course is available from the coordinator.

Examination
Oral and written presentation

Scanning Probe Microscopy

Course ID: **NM070C** *3 ec* first semester prof. dr. S.E. Speller

Teaching methods

- 30 hrs lecture

Prerequisites

Solid State Physics

Objectives

- The student knows differences of physics and chemistry when reducing dimensions to nanoscale and the number of atoms/molecules to a few
- The student knows how physical and chemical concepts on nanoscale are employed to device dedicated scanning probe microscopy modes
- The student can follow and participate discussions on nanoscience and can relate results obtained by local methods with more conventional spectroscopic methods

Contents

Nanosystems are aperiodic and inhomogeneous and require local visualization and manipulation in real space on nanoscale, which is provided exclusively by Scanning probe microscopy (SPM) so far. The nanoprobe usually does not physically touch the surface. This is managed by mounting the probe on actuators, capable of nanometric precision. These are adjusted according to a signal stemming from a local interaction between tip and sample. The nanoprobe is scanned over the surface and the signal is maintained constant by means of a feedback circle. In this way, surface characteristics, for instance, the topography of a surface is mapped showing terraces steps, and atoms. Probes can be rendered specific for a wealth of interaction types, and several nanomanipulation modes have been developed. This course is an introduction to:

- Scanning Tunneling microscopy
- Atomic Force microscopy
- Nano-Optical microscopy

The methods are illustrated and discussed by means of example objects from solid state surfaces, molecular layers, and bio-molecular systems.
Nijmegen has a long tradition in the development of Advanced Scanning Probe Microscopy and spectroscopy modes. For some of the more specific modes under development like Magnetic Resonance Force Microscpy (MRFM), a combination of Atomic force microscopy and Nuclear Magnetic Resonance, the lectures will be given by a docent of the resepective research group of the Institute for Molecules and Materials (Prof APM Kentgens, a.o.).

Literature

On website during the course

Examination

Oral presentation on a dedicated scanning probe microscopy mode. A support package is provided.

Solid State Physics

Course ID: **NM009B** *6 ec* first semester prof. dr. ir. J.C. Maan

Teaching methods
- 30 hrs lecture
- 30 hrs problem session

Prerequisites
Inleiding in de Vaste Stof Fysica en/of Structuur der Materie

Objectives
- The student will have an understanding of formal transport theory
- The student will have an understanding of mesoscopic phenomena
- The student will have an understanding of semiconductor and heterojunctions
- The student will have an understanding of superconductiviy
- The student will have an understanding of magnetism in solids
- The student will have an understanding of important quantum phenomena of solids in magnetic fields

Contents
This course assumes a working knowledge of key concepts and methods in solid state physics: the consequences of crystal symmetry, the notion of quasi-particles and the Fermi-particle character of the electrons, as obtained in a course like 'Inleiding Vaste Stof Fysica', and/or 'Structuur der Materie' and the student should have cursory understanding of energy bands and Fermi surfaces, and the consequences of band filling for metals, semiconductors and insulators.
The importance electron-electron interaction and the concept of quasiparticles to describe important phenomena like superconductivity and magnetism will be emphasized. Furthermore the effect of the discrete electron charge and wave character electron for small systems (mesoscopic physics) will be treated. The course aims at building a bridge bridge between the basis concept developed in the last fifty years to understand solid state physics and the new phenomena discovered in the last decades which are based upon this understanding. The course material roughly covers chapters 8-13, 17 and 18 from Kittels book.

Subjects
- Formal transport theory in bulk and low dimensional (semiconductor) systems where mesoscopic phenomena play a role. Semiconductors and heterostructures will be treated more thoroughly than in the introductory course
- Superconductivity which from a phenomenological point of view while also an introduction to the BCS theory is given
- Magnetism (paramagnetism, diamagnetism and ferromagnetism) both from an experimental as a theoretical point of view
- Important quantum effects in magnetic fields, like the Shubnikov-deHaas, deHaas van Alphen, Magnetic resonances, Quantum Hall effect and fractional quantum Hall effect will be presented

Literature

Necessary:

- Charles Kittel, *Introduction to Solid State Physics*, Wiley 2005, ISBN 0-471-680057-5, (8th edition or later)

Recommended:

- Luth and Ibach, *Solid State physics*, 2nd edition, Springer Verlag

Examination

Written exam and 1 point credits by joining the tutorial

Telescope Observing

Course ID: **NM027C** *2 ec* Throughout the year, on individual basis prof. dr. P.J. Groot

Website
www.astro.ru.nl/studiemateriaal

Teaching methods
- 100 hrs laboratory course

Prerequisites
Astronomisch Practicum I and/or II.

Objectives
- Gaining insight into the working of professional observatories
- Gaining knowledge on the preparation, execution and analysis of observing runs
- Gaining deeper insight into the working of spectrographs, wide field camera's or radio interferometers

Contents
Astronomical observations are obtained on large scale international observing facilities. The student will spend a number of nights at an observatory obtaining observations and doing first line data reductions. The data will be obtained as part of running observing programs of the staff of the Department of Astrophysics. Possible observatories where the observations will be conducted include the Westerbork Synthesis Radio Telescope, the optical telescopes at the Anglo-Dutch Isaac Newton Group of Telescopes at La Palma and the telescopes of the European Southern Observatory (ESO) in Chile. In preparation for these observing trips, students will be required to operate the optical and radio telescopes at the University of Nijmegen.
This course is only open to students of the masters track 'Astrophysics', and who have started their Masters Research project. Contact prof.dr. P.J. Groot to start the project.

Literature
Depends on the project and will be handed out during the course

Examination
Essay on the basis of an observing run.

Extra information
Only open for Master students in Astrophysics. The course will be done during the Masters thesis research project.

Theoretical Foundations of Elementary Particle Physics

Course ID: **NM014B** *9 ec* first semester prof. dr. R.H.P. Kleiss

Website
http://www.hef.ru.nl/~kleiss

Teaching methods
- 60 hrs lecture

Prerequisites
Bachelor course 'Kwantummechanica 2' and 'Inleiding subatomaire fysica' or equivalent

Objectives
- Working knowledge of the priciples and methods of perturbative quantum field theory
- The capability of computing simple phenomenological predictions by diagrammatic means

Contents
For a complete overview of particle physics, this course can be combined with the course 'Experimental Foundations of Elementary Particle Physics'.

Subjects
- Diagrammatica: the art of Feynman diagrams
- Particle scattering theory predicting interaction rates and lifetimes
- Particle spin: making the world turn
- Gauge invariance and its profound implications
- The Standard Model of elementary particle physics

Literature
Discussed during the course

Examination
By arrangement

Lie algebras

Course ID: **WM062B** *9 ec* first semester prof. dr. G.J. Heckman

Teaching methods
- 42 hours lecture
- 14 hours tutorial

Prerequisites
Symmetry or Introduction Group Theory

Objectives
The student becomes familiar with the following subjects:
- Poisson algebras
- Universal enveloping algebras
- The representation theory of SL(2)
- Representations via constructions of linear algebra
- Reductive Lie algebras.
- Verma representations
- The representation theory of SL(3)
- Physical applications: Spin and quarks
- The Weyl character formula Spherical harmonics, and SO(n)
- Physical application: The Kepler problem.

Contents
In this course we discuss the mathematics of Lie algebras and their representations. The basic examples are the Heisenberg algebra, the special linear algebra SL(n) and the orthogonal algebra SO(n). For each of these algebras we discuss the physical relevance which lie mainly in the realm of particle physics. We also discuss the link with invariant theory, an important subject in geometry. The course is interesting for students in both physics and mathematics, and standard for students in mathematical physics. The material of the course is useful for the courses "Beyond the Standard Model" and "Introduction to String Theory" of Prof. dr. B. Schellekens.

Literature
is given in the class

Examination
Oral exam

5 Institutes for Education and Research

Research is an integral part of the master education. Faculty staff members are generally appointed in a research institute. Giving lectures is one of their tasks. Research in the Faculty of Science occurs in 6 multidisciplinary research institutes. Faculty involved in master education of Mathematics, Physics and Astronomy are recruited from 3 different research institutes:

- Institute for Mathematics, Astrophysics and Particle Physics (IMAPP)
- Institute for Molecules and Materials (IMM)
- Donders Centre for Neuroscience (DCN)

The educational institute for Mathematics, Physics and Astronomy (WiNSt) is responsible for the coordination and organization of the master education.

5.1 The Educational Department for Mathematics, Physics and Astronomy

Head:	Dr G.W.M. Swart
Staff	Dr T. Smits, Dr Ing. M.G.M. van Doorn, Ms M. Dekkers Msc, Ir R. van Haren, Ing. P. van Rijsingen, Ir W. Szweryn, Drs T. Asselbergs
Secretariat	Ms J.Th.M. Vos - van der Lugt (secrons@science.ru.nl), Ms M. van Megen (m.vanmegen@science.ru.nl) room HG 01.831; tel.: (36)52739;
Website:	www.ru.nl/winst

The Educational Department 'WiNSt' is responsible for the coordination and organisation of education in the discipline of Physics and Astronomy. The implementation of improvements and innovations is also part of the job, as is the managing of the Student Laboratories. Besides, the department informs and recruits future students. Finally the department keeps in contact with high-school teachers in order to improve the relation between secondary and tertiary education.
The tasks of the department are partly executive, partly initiating and preparatory. There is a strong interaction between the education-committee, the exam-committee and the PR-committee.

5.2 Institute for Mathematics, Astrophysics and Particle Physics (IMAPP)

5.2.1 Institute for Mathematics, Astrophysics and Particle Physics (IMAPP)

The Research Institute for Mathematics, Astrophysics and Particle Physics (IMAPP) comprises research in the areas of mathematics, astrophysics and elementary particle physics.

In addition to research in the disciplinary areas, the institute fosters research that connects these areas, such as mathematical physics and astroparticle physics. Research at the institute also connects to research areas outside the IMAPP domain, such as computer science via algebra and logic, neuroscience via stochastics and solid state physics via semiconductor detector R&D.

To summarise the mission of the institute: it performs research on the fundaments of mathematics and (astro)particle physics to push the boundaries of the known, where e.g. the question of the origin and evolution of the universe is central

5.2.2 Astrophysics (IMAPP)

Chair:	Prof. Dr P. Groot
Scientific staff:	Prof. Dr H. Falcke, Dr J. Hörandel, Dr G. Nelemans, Prof. Dr J. Kuijpers, Ms Prof. Dr C. Aerts, Prof. Dr C. Dominik
Secretariat:	Mrs C. Custers, Mrs E. Gebhardt, Mrs. D.Maurits (secr@astro.ru.nl) room: HG 03.720, tel. (36)52804
Website:	http://www.astro.ru.nl

Research:

- Detection of ultra-high energy cosmic rays
- Physics and populations of (ultra)compact binaries in our Galaxy
- Cosmic magnetohydrodynamics, extremely relativistic plasmas and astroparticle physics
- Asteroseismology
- Formation of planetesimals in proto-planetary disks

The Master's programme focuses on high-energy astrophysics and particle astrophysics. Core subjects are the physics of compact objects (white dwarfs, neutron stars, radio pulsars, and black holes), the origin of our universe and nucleosynthesis in the context of the Big Bang and the Standard Model, and the development of new observational methods (neutrino, gravitational and cosmic ray detectors). These areas are at the forefront of physics and the students will be given the opportunity to explore (and extend) these frontiers. The student is expected to go on at least one observing trip either to the Westerbork Synthesis Radio Telescope, the new radio telescope array LOFAR, to the optical telescopes at La Palma or at ESO, Chile, or to the Pierre Auger Observatory in Argentina. The Department of Astrophysics participates in the Netherlands' School for Research in Astronomy (NOVA), a collaboration of the astronomical institutes of the Universities of Amsterdam, Leiden, Utrecht, Groningen and Nijmegen which constitute one of the six national 'topscholen'. The Department participates in the Institute for Mathematics, Astrophysics, and Particle Physics (IMAPP).

Description of research:

Detection of ultra-high energy cosmic rays

The research of the Department is focused on theoretical and observational high-energy and particle astrophysics. The research in the group of Prof.dr. Heino Falcke and Dr. Jörg Hörandel is focused on astroparticle physics, in particular the detection of ultra-high energy cosmic rays through their low- frequency radio emission that can be detected with telescope arrays such as LOFAR and Auger. Prof.dr. Falcke is furthermore interested in jets from black holes, in particular the supermassive black hole in the center of our own Galaxy.

Population of (ultra)compact binaries in our Galaxy
The group of Prof.dr. Paul Groot and Dr. Gijs Nelemans focuses on the population of (ultra)compact binaries in our Galaxy. In these binaries a stellar remnant (white dwarf, neutron star or black hole) accretes matter from a companion, which, in the ultracompact binary setting, is also an evolved object. Determining space densities from massive wide field surveys, understanding the physical characteristics of known systems, combining observations with theory in population synthesis techniques and determining the strongest sources of low-frequency gravitational wave radiation are some of the aims of the research group.

Cosmic magnetohydrodynamics, extremely relativistic plasmas and astroparticle physics
The adjunct professors Kuijpers, Aerts and Dominik spend part of their research time in the Department. Their specialisations are cosmic magnetohydrodynamics, extremely relativistic plasmas and astroparticle physics (Kuijpers), asteroseismology of single and binary (subdwarf) B stars (Aerts) and the formation of planetesimals in proto-planetary disks (Dominik).

Opportunities for students:
For student training and research, the Department owns an extensive suite of telescopes: a 20 cm optical refractor, a 35 cm optical reflector, a two disk radio interferometer and a few LOFAR antennae. The Department also participates in the HISPARC detector for cosmic rays. Students are encouraged to use these facilities for their own research. The research of the Department is focused on theoretical and observational high-energy and particle astrophysics. Usage is made of optical telescopes worldwide (in particular the ING telescopes on La Palma and the ESO telescopes), the Hubble Space Telescope, the LOFAR array and its predecessors and the Pierre Auger Observatory in Argentina. The research is done in close collaboration with researchers within and outside of the Netherlands.

Location:
The departement of Astrophysics is located in the Huygens building, on the third floor in wing seven. This is the top-floor of the north-western wing (above the crossing of the Heyendaalseweg & the Kapittelweg).

Websites:

- **http://www.astro.ru.nl/: Nijmegen Department of Astrophysics**
- http://www.astronomy.nl/: Dutch School for Astrophysical Research (NOVA)
- http://www.astron.nl/: Westerbork Synthese Radio Telescoop
- http://www.eso.org/: European Southern Observatory
- http://www.ru.nl/IMAPP: IMAPP
- http://www.ing.iac.es/: Isaac Newton Group of Telescopes, La Palma
- http://www.lofar.org/: LOFAR
- http://www.stsci.edu/: Hubble Space Telescope Science Institute

5.2.3 Experimental High Energy Physics (IMAPP)

Head:	Prof. Dr N. de Groot
Scientific staff:	Prof. Dr S.J. de Jong, Prof. Dr D. Froidevaux, Dr F. Filthaut, Drs P.F. Klok, Dr A.C. König, Dr Ch. Timmermans
Secretaries:	Ms M. van Wees-Mobertz, Ms G. Koppers-Janssen (secr@hef.ru.nl) room: HG 03.830; tel. (36)52099
Website:	www.hef.run.nl/ehef

Research:
- The search for the Higgs particle
- New phenomena beyond the Standard Model
- High energy cosmic rays
- Detector development

The department performs experimental research in the fields of elementary particle physics and astroparticle physics.

Description of research:
The search for Higgs particle.
The Standard Model (SM) is a very succesful quantum field theory of leptons and quarks as the most fundamental building blocks of matter. The interactions between these building blocks are described in terms of an exchange of quanta of the electro-weak and colour forces. Besides the quarks, leptons and field quanta, which have all been discovered by now, the SM predicts the existence of a so-called Higgs particle, with gives mass to all the other particles in the model. This Higgs particle, sometimes described as the holy grail of particle physics, has not yet been observed.

The DØ detector at the Tevatron proton-antiproton collider at Fermilab is recording data since 2001. The accelerator is currently the most powerful in the world, and if the Higgs particle is light enough, it can be observed at Tevatron. Our group is focusing on the Higgs search in this experiment. If the Higgs is heavier, the ATLAS detector at the LHC at CERN, which will become operational in 2009, will be able to find this. We are currently participating in the commissioning of the detector and are preparing the analysis of the data.

The phenomena beyond the Standard Model
Even though the Standard Model agrees extremely well with the experimental results, a number of observations is not explained by this model. For example the number of different species of quarks and leptons and their masses cannot be predicted by the SM. We expect that a high enough energy, the Standard Model gets superseded by another model. This could manifest itself in the production of new particles. Because of the high energy of the LHC collider, the ATLAS detector, will be an excellent place to look for signatures of 'new physics'. We are preparing for this analysis.

High energy cosmic rays
Together with the astrophysics department we investigate various aspects of high energy cosmic rays. The NAHSA initiative (Nijmegen Area High School Array) has been followed nationally as HiSPARC. In this experiment high-school students install, maintain and analyze

data from cosmic ray detectors at their own school, with the aim to observe extremely high energy cosmic rays (with an energy of more than 0.01 J). The origin of such radiation is unknown and the observed rate worldwide is higher than expected.
We have joined the Pierre Auger observatory in Argentina. We investigate the origin of the cosmic rays with the highest energies that can be measured on earth. The LOFAR project (Low Frequency Array of Radio telescopes) uses radiowaves to detect cosmic airshowers. We plan to use LOFAR-like detectors at Auger to improve the energy measurement and pointing resolution of cosmic rays.

Detector and accelerator development
Although the start of data taking for the ATLAS experiment is about to begin, people are already planning the next generation of accelerators and their detectors. One idea is to increase the number of particles and therefore the number of collisions in the LHC. Another is to have a linear collider of electrons and positrons. We are involved in the development of precision tracking detectors for both accelerator technologies.

Opportunities for students:
Within the topics and experiments described above and supervised by staff and PhD students returning from CERN and FNAL, students can do excellent work on topics like:

- Experimental physics analysis and theoretical interpretation:
  - analysis of the DØ data (QCD, Higgs, cosmic muons etc)
  - analysis of the first ATLAS data
  - analysis of HiSPARC data
- Numerical physics:
  - physics and detector simulation with Monte-Carlo techniques
  - software for the reconstruction of particle collisions and their graphical reproduction
  - neural network techniques for particle reconstruction
- Applied physics:
  - development of semiconductor detectors
  - development of fast read-out electronics
  - development of cosmic radiation detectors for high school application

The research is carried out in teamwork with PhD students, post-docs and staff, but on an individual topic. It is expected to lead to a masters thesis.

In principle, students can be sent for short periodes to CERN (Geneva) or Fermilab (Chicago). Furthermore, the Department can help with applications for summer student fellowships at CERN or Fermilab.

5.2.4 Theoretical High Energy Physics (IMAPP)

Head:	Prof. Dr R.H.P. Kleiss
Scientific staff:	Prof. Dr A.N.J. Schellekens, Dr T.A. Rijken, Dr W.J.P. Beenakker
Secretariat:	Ms A.M.J. van Wees-Mobertz and Ms G. Koppers-Janssen (secr@hef.ru.nl) room: HG 03.830; tel. (36)52099
Website:	www.ru.nl/thef/

Research:
- Phenomenology of electron-positron and hadron-hadron collisions
- Monte Carlo techniques
- Baryon-(anti)baryon interactions
- The landscape of string vacua

Description of research:
Phenomenology of electron-positron and hadron-hadron collisions
The goal of the research is to work out precise theoretical predictions for experimentally measured observables at existing and future collider experiments. Examples are:

- Production and decay of Higgs particles at the hadron colliders Tevatron (Fermilab, Chicago) and LHC (CERN, Geneva), aimed at studying the mechanism by which particles acquire mass
- Production and decay of supersymmetric particles at the hadron colliders Tevatron and LHC, aimed at studying the theoretical idea of unifying the fundamental forces in nature
- The study of scattering processes at a future linear electron-positron collider, aimed at gathering information on the physics that governs the ultra-high energy scales where gravity starts to play a prominent role

In this work, heavy reliance is put upon perturbative techniques in quantum field theories, embodied in Feynman diagrams.

Monte Carlo techniques
The previously mentioned research strongly involves algebraic and numerical techniques. The results often appear as Monte Carlo codes suitable for use by the experimental community. The Monte Carlo method enables the calculation of complex multi-dimensional integrals as well as the simulation of very nontrivial processes. This is made possible by the use of computer-generated sequences of (pseudo)random numbers. Generating sequences of such numbers is a fundamental and challenging field of both pure and applied mathematics. The possible use of different, quasi-random number sequences, which give numbers that are distributed more uniformly than (pseudo)random ones, poses a host of fundamental as well as practical questions.

Baryon-(anti)baryon interactions
Baryons are fermionic particles composed of three light quarks. In addition to the common nucleons proton and neutron, which consist of up and down quarks, the baryon family also contains the more exotic hyperons, which consist of at least one strange quark. When these particles are collided they all interact with each other via the strong nuclear force. The research programme aims at describing and elucidating the present and future experimental baryonic data. This involves partial-wave analysis of nucleon-(anti)nucleon scattering data and the construction of nucleon-nucleon, nucleon-hyperon and hyperon-hyperon potentials, using theoretical concepts such as chiral symmetry and effective Lagrangians. A spin-off of this programme is the study of nuclear and hyperonic matter in the context of neutron stars.

The landscape of string vacua
String theory is a model of fundamental physics whose building blocks are one-dimensional extended objects called strings, rather than the zero-dimensional point-particles that form the basis for the Standard Model of particle physics. The goal of the research is to find among all the possible string vacua the ones that incorporate the known laws of physics. The idea of the landscape of string vacua is based on the anthropic principle, which states that fundamental constants may have the values they have not for fundamental physical reasons, but rather because such values are necessary for life to exist. The research has a strong mathematical component, involving conformal field theory and topology.

Opportunities for students:
The department of Theoretical High Energy Physics offers several theoretical research projects at the Bachelor and Master level. Students are advised to contact the head of the department or one of the members of the scientific staff for more details. In addition, the department can help students with applications for summer-student fellowships at CERN.

5.3 Institute for Molecules and Materials (IMM)

5.3.1 Institute for Molecules and Materials (IMM)

The Institute for Molecules and Materials (IMM) is the largest of the research institutes of the Faculty of Science and contains nearly all chemistry and a large fraction of the physics research groups. The aim of the IMM is to conduct research and train undergraduate and graduate students in the field of functional molecular structures and materials. This research area can roughly be divided into two main themes: bio-inspired systems and nano/mesoscopic structures. The IMM strongly encourages collaborations between it research groups, which leads to many interdisciplinary projects in which both theoretical and experimental expertise may be combined. The IMM hosts several state-of-the-art experimental facilities, including the High Field Magnet Laboratory (HFML), solution and solid-state NMR, the Nanolab for scanning probe experiments, and Molecular and Laser spectroscopy. The facilities will be extended by a Free Electron Laser (FEL) in the coming years.

The IMM offers a stimulating research environment for graduate students, who can select a research project from a very broad range of activities with a chemical, biological or physical emphasis, with options for both experimental or theoretical work and with a goal varying from fundamental to applied. A significant fraction of the graduate research projects leads to a (co-)authorship of a publication in an international science journal. Details about the various research groups can be found elsewhere or on the IMM website www.ru.nl/imm

5.3.2 Applied Materials Science (IMM)

Head:	Prof. Dr E. Vlieg
Scientific staff:	Dr P.R. Hageman, Dr Ir J.J. Schermer
Secretariat:	Ms A.L.A.M. Hendriks (ams-secr@science.ru.nl) room: HG 03.527; tel. (36)53353
Website:	www.ru.nl/ams

Research:
- Solar cells
- Wide bandgap semiconductors

Research is aimed at the formation (growth and processing) and the study of thin-film materials and devices. For this purpose the AMS department has a state of the art clean room facility with all the required equipment for the deposition, processing and analyses of the thin-films. Of particular interest are the so-called III-V and III-nitride semiconductors. These are compound materials based on elements from the third (Al, Ga, In) and fifth (N, P, As) group of the periodic table. The physical and chemical properties of these materials can be tuned at will by variation of the element composition. Therefore, these materials are used to produce opto-electronic components of extremely high quality. Related to this, the research is generally conducted in close cooperation with companies, large institutes and other universities such as Philips, NXP, ESA, Dutch Space, ECN and the Technical University Eindhoven.

Description of research:
Solar cells
The III-V materials GaAs and InGaP are applied for the production of high efficiency solar cells. These cells are produced at crystal wafers. Due to the high cost of these wafers, the III-V solar cells are presently only utilised for spacecraft. At the AMS department an Epitaxial Lift-Off (ELO) technique is being developed by which the solar cell layer with a thickness of about 2 μm can be released from the wafer on which it was formed. In this way the wafer can be reused, resulting in a large reduction of costs so that the cells can also be utilised for the generation of electric energy on Earth. Single junction solar cells produced with the ELO technique have already reached a world record efficiency of 24.5% and approach their theoretical maximum. Further developments aim for multi-junction solar cells and the use of lenses and mirrors to concentrate the light before it is converted into electricity. In this way theoretically efficiencies above 50% can be achieved.

Wide bandgap semiconductors
The recently developed group III-nitride materials (AlN, GaN and InN) have ideal properties (wide bandgap, high break-down voltage and electron mobility, etc.) to be used in high power opto-electronic components. As a result the application of these materials in e.g. LED-lamps and multi-media lasers increases rapidly. Because presently there are no wafers with a 'matching' crystal structure, the nitrides are produced on 'non-matching' wafers of sapphire. As a result of this, the nitride layers contain many defects which have a large influence on the performance of the electronic components made from these materials. At the department the formation and behaviour of these defects are studied with the aim to minimise their concentration. This has resulted in the realisation of High Electron Mobility Transistors with a European record power density. On the other hand the possibility to develop matching wafers is being investigated. Application of such wafers would reduce the defect density of the nitride layers with several orders of magnitude and further boost up the efficiency of the components produced from these materials.

Opportunities for students:
The department offers many possibilities for students to conduct scientific research. Together with a supervisor the student defines a project assignment that he/she can conduct

independently after a short introduction period. The research is completed with a colloquium at the department and a final report (master thesis). Dependent on the result the project can lead to a publication in a scientific journal.

5.3.3 Applied Molecular Physics (IMM)

Head:	Prof. Dr J.J. ter Meulen
Scientific staff:	Prof. Dr W. van de Water (TU/e), Dr N. Dam
Secretariat:	Ms E.A.M.L. Meijer (ine.meijer@science.ru.nl) room HG01.721, tel. (36)52339
Website:	www.ru.nl/appliedmolecularphysics/

Research:
- Molecular collisions
- Deposition of ultra hard diamond films
- A black box: what happens inside a diesel engine?
- Molecules in flames
- Writing in air and the mystery of turbulence

The Applied Molecular Physics group focuses on the development and application of sensitive laser diagnostics for fundamental and applied research with the aim to study physical and chemical processes involving molecular dynamics. In addition, the group is involved in solid state research. There are several research projects where students can take part for their masters thesis work.

Description of research:
Molecular collisions:
In the European network "Molecular Universe" we investigate collisions of interstellar molecules by the use of laser techniques. Collaboration with Molecular and Laser Physics - IMM (Prof.dr. D. Parker).

Deposition of ultra hard diamond films
Investigation of the deposition of diamond with direct applications as ultra hard or heat conducting layers. Collaboration with Applied Materials Science - IMM (Dr. J. Schermer) and Solid State Chemistry - IMM (Dr. W. van Enckevort).

A black box: what happens inside a diesel engine?
Study of the formation of (nano)particles and nitric oxide inside a transparent diesel engine. Collaboration with TU/e and DAF

Molecules in flames
Nitric oxide influences the formation of ozone and causes smog and acid rain. Can we reduce its formation by adding hydrogen? Collaboration with Prof.dr.L. de Goeij (TU/e).

Writing in air and the mystery of turbulence
Investigation of turbulent gas flows by the use of laser detection techniques. Collaboration with Prof.dr. W. van de Water (TU/e).

Opportunities for students:
Suitable for Physics, Chemistry and Natural Science students.

5.3.4 Condensed Matter Science and HFML (IMM)

Head:	Prof. Dr Ir J.C. Maan
Scientific staff:	Dr J.A.A.J. Perenboom, Dr P.C.M. Christianen,Dr S.A.J. Wiegers, Dr U. Zeitler, Dr H. Engelkamp
Secretariat:	Ms H.E.M. Verhaegh-Peeters (hfmlsecr@science.ru.nl) room: HFML 02.15; tel. (36)52087;
Website:	www.hfml.ru.nl/

Research:
- Connection with high magnetic fields
- Interdisciplinary research

Description of research:
Connection with high magnetic fields
In condensed matter physics the application of high magnetic fields is widespread. A (high) magnetic field changes the thermodynamic state of any system and a study of this change provides new and unique information. In some cases new states of matter (suppression superconductivity, quantum Hall effects, etc.) are discoverd.
In the area of the fundamental properties of matter the main emphasis is on nanostructures ranging from, those made from lithographically etched semiconductor to self-assembled supramolecular structures. Pioneering scientific discoveries are often done in the highest magnetic fields, which are available at HFML.

Interdisciplinary research
Magnetic fields also find applications in chemistry or biology related research. These applications comprise instrumental developments like high field Electron or Nuclear Magnetic Resonance (ESR and NMR) but also ordering of mesa molecular systems in high magnetic fields.
Finally there are also research activities in magnet technology.

Opportunities for students:
Many experiments can be done in the laboratory. Ranging from low temperature (mK) experiments, laser spectroscopy, far infrared spectroscopy, magnetostriction, magnetisation, susceptibility and transport experiments. Much research is performed in collaboration with other groups both within the university and other (European) research departments. This open and international character provides a broad orientation for the students. Research done at HFML provides an excellent training as experimental physicist, which is highly appreciated on the labor market (both in academia as in industry).

5.3.5 Electronic Structure of Materials (IMM)

Head:	Prof.Dr. R.A. de Groot
Scientific staff:	Dr.Ir. G.A. de Wijs
Secretariat:	Ms J.P.M. Föllings-Reuvers (a.follings@science.ru.nl); room: HG 03.049; tel. (36)52981
Website	www.ru.nl/esm

Research is related with:

- Anionogenic ferromagnets. Ultra relativistic Divac compounds
- Half-metallic materials and spin-electronics
- Materials for hydrogen storage
- Electronic, optic and mechanical properties of organics and refractory superalloys
- Photovoltaics

Description:
The main goal is to understand and design the physical properties of various new materials, including artificial nanostructures, from ab initio calculations.

Modern quantum-mechanical computations within Density Functional Theory (DFT) and extensions like GW and Bethe-Salpeter schemes allow to investigate the electronic, magnetic, optical and mechanical properties of interesting materials.

Although the work is theoretical in nature, and mainly involves large scale computer work, we aim for a close collaboration with experimental groups.

Opportunities for students:
Several oppertunities exist for students to participate in the ongoing research of the group. A master student works on an identifiable subject. Subjects range from "theoretical" to quite applied. Usually his/her work results into a publication in an international journal. For qualified students industrial apprenticeships are possible.

5.3.6 Molecular and Laser Physics (IMM)

Head:	Prof. Dr D.H. Parker
Scientific staff:	Dr F.J.M. Harren
Secretary:	Ms M. Speijers (m.speijers@science.ru.nl) room: HG 01.719; tel: (36)52025
Website:	http://www.ru.nl/mollaserphys/

Research:

- Molecular dynamics of atmospherically relevant processes
- Development of new lasers and molecular beam techniques
- Trace Gas Research

Description:
Molecular dynamics of atmospherically relevant processes
Many processes are possible during a collision between a molecule and another molecule, electron or photon. Most simply, elastic scattering can take place, where the molecular internal energy remains the same but the velocity changes. Inelastic scattering is more interesting - here the rotational and vibrational energy changes, which can lead to non-equilibrium population distributions and even laser or maser action. Chemical reaction, the most complicated and important collision process, can also occur, often via a short-lived transition state complex. The same sort of transition state complex is directly prepared and probed in photodissociation studies of so-called 'half-collision' reactions.

In recent years quantum mechanical theory has been able to quantitatively describe a few of the simplest reactive and inelastic scattering processes. For the more complicated 'real-world' scattering systems laboratory work is essential. Experimental research on molecular scattering dynamics has blossomed worldwide in the last years due to new powerful laser- and molecular beam-based techniques, especially the velocity map imaging technique developed here in our group in Nijmegen.

A general theme of our research centers on the dynamics of molecular processes relevant to atmospheric processes. The central molecule in this theme is molecular oxygen. We continue to deepen our understanding of the surprisingly complex molecule and, most recently, of Van der Waals clusters containing molecular oxygen. Another related species of interest is the hydroxyl radical. We have an active and synergetic collaboration with the Theoretical Chemistry Institute in Nijmegen in all of these studies.

In our current research on molecular scattering we use velocity map imaging and also the laser induced fluorescence technique in studies of photodissociation, inelastic scattering and most recently, reactive scattering. We are studying, for example, inelastic collisions between the OH and CO molecules, which is a key process in atmospheric chemistry and in combustion. Molecular beams of the reactants are formed and cross each other in a small region that is probed using laser induced fluorescence. With laser spectroscopy the precise quantum state distributions of both species can be obtained before and after collision. The results obtained are used to improve the theoretical potential energy surfaces describing the collision complex. In another related project the photodissociation dynamics of OH are studied using velocity map imaging. In this technique a laser is used to selectively photoionize the O and H atom dissociation products without changing the energy obtained from the initial photodissociation step. Carefully designed ion optics guides the ions onto a two-dimensional detector in a way that uniquely 'maps' the nascent product velocity. The full three-dimensional product velocity distribution can then be calculated from the experimental two-dimensional ion image. Up to now no such measurements have been possible for OH, despite it being the most important free radical in atmospheric chemistry. In collaboration with Prof. Ubachs of the Free University of Amsterdam we plan to chart out OH dissociation pathways for the ultraviolet to extreme ultraviolet (300-100 nm) spectrum.

Development of new lasers and molecular beam techniques
Progress in both fundamental and applied experimental research relies on increasingly better diagnostic techniques. Technique development is thus an important research line on its own in the group. As an example, two-dimensional velocity map imaging of ions and electrons has been improved over the last years and applied to the study of bimolecular collisions and photodissociation, surface scattering and chemical reactions.

An important drawback of present lasers systems in the infrared wavelength region is their lack of laser power and ability to generate every laser frequency in the infrared. The use of novel non-linear materials and the technique of parametric oscillation offer the possibility to avoid this and to generate continuous-wave, continuous tunable, narrowband radioation with high output powers at wavelengths between 2.5 and 10 micrometers.
Another state-of-the-art method under development includes proton transfer mass spectrometry with ion cyclotron trapping for signal enhanchement.

Trace Gas Research
The reliable sensing of minute quantities of trace gases in complicated gas mixtures is an innovative, highly important and most exciting task in practically all technical and life sciences. The Trace Gas Research Group is focused on the development and application of trace gas detection methods with lasers and mass spectrometers. For this we use laser spectroscopical methods such as photoacoustic spectroscopy, frequency modulation spectroscopy and cavity ring down spectroscopy, while within mass spectrometry proton transfer reactions are used to gain high sensitivity for volatile organic compounds. The focus is, thereby, on state-of-the-art detection of substances at sub-part per billion (volume) concentrations, on-line, non-invasive, with high selectivity and detection speed. See also www.ru.nl/tracegasfacility

Next to the research group we operate a Life Science Trace Gas Facility, in which scientists from Biological, Chemical and Medical fields are supported to perform trace gas research for which 'conventional' equipment lacks adequate sensitivity. The facility operates unique state-of-the-art trace gas detectors that allow real time measurements at unprecedented detection levels. Research areas are covered ranging from plant-pathogen interaction to the effect of smoking on the lungs and the study of the effect of tuberculosis.

Opportunities for students:
There are opportunities for students in fundamental molecular reaction dynamics, the development of new instrumental techniques with lasers and molecular beams or the trace gas research with applications in medical sciences. Much of the research is in cooperation with our research groups in Europe and the USA, at University level or with industry.

5.3.7 Molecule and Biophysics (IMM)

Professor:	Prof. Dr W.J. van der Zande
Scientific staff:	Prof. Dr W.L. Meerts, Prof. Dr Marc J.J. Vrakking (FOM-Institute AMOLF)
Secretariat:	Ms E. Gouwens (e.gouwens-vanoss@science.ru.nl) room HG 01.712; tel. (36)53010
Website:	www.ru.nl/molphys

Research:
- Biomolecular structure and function.
- Molecular detection and recognition.
- Electrons and molecules.
- Instrumental developments

Description:
Biomolecular structure and function
Structure and functionality of biological molecules are strongly related. Biophysical processes take place at a well defined temperature. These molecules often change in structure during their reactions; hence stiffness and flexibility have to be accurately tuned. Laser spectroscopy and in particular high resolution laser spectroscopy is the most accurate tool to determine the structure of the molecules. Also the flexibility of these molecules is encoded in their spectra as a consequence of the rules of nature imposed by quantum mechanics. We use high resolution laser techniques to find very precise answers on the structure and flexibility of

small size biomolecules with the long term aim to explore the limits of these techniques in the direction of 'real' biomolecules. Experiments are performed in close collaboration and in an exchange program with the Heinrich Heine University in Düsseldorf and in collaboration with the theoretical chemistry program at this university.

Molecular detection and recognition
Small molecules such as atmospheric species are easily recognized by their spectral structures. However, also these molecules have spectral features that are extremely weak, while at the same time these properties are highly relevant to atmospheric problems as a consequence of the enormous amounts of these molecules in our atmosphere. Using cavity ring down spectroscopy, absorption characteristics of small molecules are quantified in order to understand the effects of collisions and improve the use of these data. In the mid-infrared and far-infrared, large molecules reveal not only structure but also their internal flexibility. The study and generation of these spectra is a growing field in the group.

Electrons and molecules
In our upper atmosphere, molecules are often present as ions. The reaction of these ions with electrons is experimentally studied in a large scale storage ring experiment in Stockholm in collaboration with the University of Stockholm while we develop instrumentation and determine the properties of these reactions that are directly related to airglow and auroral phenomena in our upper atmosphere.

Instrumental developments
The group MBf is respossible for the design ansd constructor of a FIR or THz radiator source based on a free electrolaser. A large and ambitious project.

Opportunities for students:
The world around us contains molecules in all shapes, forms and size. Molecular processes dominate daily life. The understanding of molecular behavior, the detection and recognition of molecular behavior and in particular the interaction between the molecular world and electromagnetic radiation is central in the research themes of this group.
Therefore all students are welcome to perform or to join the scientific program in the department in all phases of their university program.

5.3.8 Scanning Probe Microscopy (IMM)

Head:	Ms Prof. Dr S. Speller
Scientific staff:	Dr. J.A.A.W. Elemans
Secretariat:	Ms M.L. Beenen(mailto:ml.beenen@science.ru.nl) room HG 01.074; tel. (36)52121
Website:	wiki.science.ru.nl/spm/Main_Page

Research:
- Nanophysics
- Nanoscopic electron physics
- Supramolecular structures
- Biomolecules
- Applied Physics
- Imaging of catalytic reactions in a liquid STM

In our research group Scanning Probe Microscopy (SPM) we are interested in phenomena on very small length scales. The long-term aim is to unravel mechanisms and processes that couple physical and biologic structures. For this purpose advanced scanning probe microscopy methods are developed and applied. The research programme combines materials, organic layers and bio(-medical) systems in order to address solid-state / biologic hybrid nanosystems. We are an interdisciplinary team of physicists, chemists, natural scientists, engineers and biologists.
We collaborate with the Computational and Theory groups, the Supramolecular Chemistry and the Biochemistry groups within the Institute of Molecules and Materials (IMM) of the Faculty of Science. In addition, collaborations exist with a large number of international top laboratories and industries.

Description:
Nanophysics
This research includes magnetic surfaces and interfaces and electronic and magnetic properties of low dimensional objects such as nano-wires, ultra thin films and multilayers. One of the central themes is '**nanomagnetism**', an area that combines fundamental challenges with a high potential of practical applications (sensors, data storage). We develop and apply new Scanning Probe Methods, partly pioneered in Nijmegen. New future developments are the combination of these approaches to allow the study of matter with the highest spatial and spectroscopic resolution.
A new theme is '**magnetite**' and its role in navigation of vertebrates. Magnetite particles exist in many vertebrates and it is assumed that they are the key to the magnetic sense. In a multidisciplinary approach we study the structure and physical properties of biogenic magnetite nanoparticles and try to elucidate the mechanism in magnetotransduction. We use scanning probe microscopy, such as AFM/MFM and STM, electron microscopy, and collaborate with biologists and theorists. Our studies also include magnetite layers and ferrofluids, and also the histological environment of the magnetite.
Further subjects in nanophysics are electron transport through nano objects studied by scanning tunneling spectroscopy, and atomic-scale signatures of magnetic transitions. An especially interesting subject is the development of scanning probe instruments for practical conditions, ie. in liquids and electrolytes. We apply these new methods to the study of liquid-solid interfaces and of reactions in organic molecules and proteins.

Nanoscopic electron physics
In this theme the properties of conduction electrons in extremely small geometries are studied. Examples are the conductivity of a single atom, single electron tunneling and the effect of adsorbed molecules on the tunneling probability of electrons. Under these conditions (semi-) classical descriptions completely fail and only quantum mechanics will lead to a correct description.

Supramolecular structures
In collaboration with the Organic Chemistry groups that are responsible for the synthesis of increasingly complex systems with tailor made properties, the physical properties of individual molecules and molecular aggregates are being studied with scanning probe methods. Processes such as self assembly and catalysis can be observed and triggered on nano scale.

Biomolecules
Functional molecules are being prepared on surfaces where they are studied with Scanning Probe techniques. The goal is to measure specific interactions with protein in order to gain more insight in the relation structure-properties of bio materials.

Applied Physics
Many of the topics described above are at the interface between fundamental and applied research (a distinction that is often rather arbitrary). This is illustrated by the industrial collaboration often within European projects and within NanoLab Nijmegen.

Imaging of catalytic reactions in a liquid STM
The use of Scanning Tunneling Microscopy (STM) has opened the possibility to study chemical reactions at the single molecule level with (sub)molecular resolution. A few examples of visualization of such a reaction, which in many cases occurs under ultrahigh vacuum conditions, have already been described. Most reactions in industry or in biology, however, take place in a liquid. To be able to look at chemical reactions at a surface in this more realistic environment, we make use of a home-built liquid Scanning Tunneling Microscope. The catalysts, which are immobilized at a solid-liquid interface, are metal-porphyrin molecules that are synthesised in the organic chemistry laboratory. This research is ideal for students who are interested to work on a cutting edge interdisciplinary research topic with great potential for understanding the way catalysts work at the single molecule level.
Suitable profile: physical-chemical, physical

The research is mostly performed by PhD students and postdocs in collaboration with undergraduate students. The senior scientists supervise the various PhD and undergraduate projects and are also involved in short time pilot projects, that if succesfully, will later be integrated into the research programme.

Opportunities for students:
For students, there is ample opportunity to participate in the research of basically all the projects mentioned above. Our philosophy however is that the students should have their own, individual projects, that can but not necessarily have to be part of a larger project. Though not a necessary condition, many of these student projects lead to one or more publications in international journals. Supervision is usally done by one of the more senior group members (PhD's, postdocs or faculty). There are also possibilities of joint projects (with other graduate or Phd students) and often the undergraduate projects may lead to a PhD project. Because of the large spectrum of projects there is ample choice for the students and if the facilities allow it, also projects of their own design belong to the possibilities.

5.3.9 Spectroscopy of Solids and Interfaces (IMM)

Head:	Prof. Dr Th. Rasing
Scientific staff:	Dr A. Kirilyuk, Dr A. Kimel
Secretariat:	Ms M.L.G. van Breemen-de Wit (m.vanbreemen@science.ru.nl) room HG 01.074; tel. (36)53141
Website:	www.ru.nl/imm/ssi

Research topics:
- Nanomagnetism
- (Sub)nanosized magnetic clusters
- Ultra fast carrier and spin dynamics, coherent control
- Nanophotonics
- Supramolecular structures
- Liquid crystals and polymers
- Applications

Mission: to understand the relation between properties and structure of condensed matter, in particular of nanoscopic, magnetic and molecular materials with a focus on phenomena occurring on ultra short time scales (femto seconds).In this regime quantum mechanical principles and surfaces and interfaces play a dominant role and may lead to surprising new results. For this research novel, advanced optical and scanning probe techniques are being developed and applied.

Description:
Nanomagnetism
This field of research includes magnetic surfaces and interfaces and electronic and magnetic properties of low dimensional objects such as nano-wires, ultra thin films and multilayers. This exciting area combines fundamental challenges with a high potential of practical applications (sensors, datastorage). We use new Scanning Probe and Nonlinear Optical techniques that were partly pioneered in Nijmegen like Magnetization induced Second Harmonic Generation. New future developments are the combination of these approaches to allow the study of matter with the highest spatial (in-plane as well as out of plane) and temporal resolution.

(Sub)nanosized magnetic clusters
The goal is a comprehensive study of nanosized clusters of various oxides, both free and deposited on surfaces, that form the building blocks of new materials. Special attention is on the correlation between crystallographic structure, electronic states and magnetic properties. The combination of structural (infrared vibrational spectroscopy, SEM), electronic (UV ionization spectroscopy for free clusters, STM spectroscopy for clusters on a surface) and magnetic (Stern-Gerlach experiments for free clusters, magneto-optics and spin-polarized STM for the deposited ones) information will provide an unprecedented insight into the properties of these interesting strongly-correlated materials.

Ultra fast carrier and spin dynamics, coherent control
The dynamics of electrons and holes in semiconductors and metals (in the presence of electric and magnetic fields) can be studied using ultrashort femto-second (fs) laser pulses. In this way electron-electron, electron-phonon and electron-magnon interactions can be probed directly, in contrast to standard transport experiments that only probe time - averaged quantities. For example, an intriguing question is: how fast can the magnetization of a magnetic system be changed (reversed)? This is an exciting area of fundamental research with far reaching practical consequences for opto-electronics, spintronics and magnetic recording. We have pioneered novel methods to create very fast controllable magnetic field pulses (Th. Gerrits, Nature **418** (2002) and A. Kimel et al, Nature **435** 2005) and have also

demonstrated the possibility to observe and exploit the ultrafast spin dynamics in anti-ferromagnetically ordered materials (A. Kimel et al, Nature **429** (2004)).
We are further exploring complete coherent optical control of spins in magnetic media that eventually could lead to purely optical switching.

Nanophotonics
The goal is to achieve the control of electronic and magnetic properties at femtosecond time scales with nanometer spatial resolution, where usual optical tools fail. Scattering-type near-field scanning-probe microscopy is being developed to achieve a resolution down to 10 nm. This, combined with femtosecond laser pulses, will allow the real-time observation of ultrafast nanometer-scale dynamics. On the other hand, plasmonic structures will be developed and used to concentrate electromagnetic optical waves in a sub-wavelength volume and achieve modification and amplification of opto-magnetic effects.

Supramolecular structures
In collaboration with the Organic Chemistry groups (Nolte, Rowan, van Hest) that are responsible for the synthesis of increasingly complex systems with tailor made properties, the physical properties of individual molecules and molecular aggregates are being studied with scanning probe and nonlinear optical techniques. This highly interdisciplinar field is a strongly growing research area with connections to biology.

Liquid crystals and polymers
These fascinating materials combine a large variety of interesting fundamental phenomena with a huge potential for application (LCD's: Liquid Crystal Displays and Biosensors). Topics of current research are light induced ordering, nano patterned surfaces, phase transitions and dynamics in very thin films. A new development is the exploration of the hierarchy of ordering in LC-cells (from the molecular nanoscale to the macroscopic scale of the LCD) for the application of LC cells as biosensors. This work is done in collaboration with Organic Chemistry (Nolte, Rowan).

Applications
Many of the topics described above are at the interface between fundamental and applied research (a distinction that is often rather arbitrary). This is illustrated by the industrial collaboration with for example Philips, Siemens, Thales, Hitachi Maxell, Seagate and others, often within European projects. Some of these applied research projects are monitored by an external advisory/user committee where researchers from industrial laboratories play an important role. This allows students to have contacts with industry and their approach to research at a quite early stage, which gives extra opportunities for students who desire a career in industry. There are also possibilities to do (part of) a research project in an industrial laboratory, both in the Netherlands and abroad.

Opportunities for students:
The research is mostly done by PhD students and postdocs in collaboration with undergraduate students. The senior scientists supervise the various PhD and undergraduate projects and are also involved in short time pilot projects, that if succesfully, will later be integrated in the research programme.
For students, there is ample opportunity to participate in the research of basically all the

projects mentioned above. Our philosophy however is that the students should have their own, individual projects, that can but not necessarily have to be part of a larger project. Though not a necessary condition, the past experience shows that most of these student projects lead to one or more publications in international journals. There are also possibilities of joint projects (with other graduate or Phd students) and often the undergraduate projects may lead to a PhD project. Part of the research internship can be done abroad as part of the Socrates Programme (for example Leuven, Oxford, Marseille) or within one of the many European collaborations.

5.3.10 Theory of Condensed Matter (IMM)

Head:	Prof.Dr. M.I. Katsnelson
Scientific staff:	Ms Prof.Dr. A. Fasolino
Secretariat:	Ms J.P.M. Föllings-Reuvers (a.follings@science.ru.nl); room: HG 03.049; tel. (36)52981
Website:	www.ru.nl/tcm

Research
- physical properties of solids
- physical properties of liquids
- essentially many-body properties

Description of research
The aim of condensed matter theory is an explanation of physical properties of solids and liquids on the base of fundamental physical principles. A broad class of phenomena, from strength, plasticity, friction, to magnetism, superconductivity, and superfluidity, can be explained in terms of laws of quantum mechanics. However, in practice it is an extremelly difficult problem, first of all, due to its essentially many-body character. The Theory of Condensed Matter group deals with this problem on different levels, such as model considerations of basic many-body effects for quantum and classical systems, realistic simulations of physical properties of specific materials, and phenomenological description of complicated phenomena such as equilibrium and nonequilibrium phase transitions.

Opportunities for students
The department of Theory of Condensed Matter offers several theoretical and/or computational research projects at the Bachelor and Master level. Students are advised to contact the head and members of the department to choose a project of mutual interest at the right level. Master projects are in general related to one topic of current interest of the group and aim at reaching some original scientific result.

5.4 Donders Centre for Neuroscience (DCN)

5.4.1 Donders Centre for Neuroscience (DCN)

All research groups from the Faculty of Science and the University Medical Center St. Radboud, working in the field of Neuroscience, collaborate within the Donders Centre for Neuroscience (DCN). The research groups, most relevant for physics, are the Dept.of Biophysics (van Opstal, Kappen, Gielen) and the new research group on NeuroInformatics

(Professor currently recruited) within FNWI and the dept. of Clinical Neurophysiology (Stegeman) within the UMCN. The DCN collaborates with the Center for Cognitive NeuroImaging on advanced NeuroImaging techniques (EEG, MEG, fMRI) and data-analysis. The research activities closely related to physics concentrate on experimental and theoretical approaches to

- Understanding localization and identification using auditory, visual and vestibular information
- Motor control and robotics
- Computational Neuroscience
- Natural and Artificial intelligence.

Contact information:

Secratary: Mw. J.I.M. (Judith) Fontaine
T: (+31) (0)24 3614244
E: neuroscience@donders.ru.nl
or
Prof. Dr C. Gielen (Director DCN), tel 024 3614242
Dr A. Vink (Managing Director DCN), tel. 024 3668578
www.ru.nl/dcn/current/vm/donders_centre_for/

5.4.2 Biophysics

The Biophysics group is funded both by the Faculty of Science and the University Medical Centre and collaborates with the Dept. of Biophysics of the University Medical Centre.

Head:	Prof. Dr C.C.A.M. Gielen
Scientific staff:	Prof. Dr H.J. Kappen, Prof. Dr A.J. van Opstal, Dr J.A.M. van Gisbergen, Dr H.H.L.M. Goossens (UMC), Dr T.F. Oostendorp (UMC)
Secretariat:	Ms J. Fontaine and Mw I. Helsen (mbfys@science.ru.nl), room GG 21.16.0.20; tel.: (36)14244
Website:	www.ru.nl/mbphysics

Research:

- Brain and behaviour
- Machine learning and artificial intelligence

Description of research:

Brain and behaviour

The research focuses on the neuronal information processing by the central nervous system, in particular on the sensory coding of visual, auditory and vestibular information and on sensori-motor transformations which map the sensory information into motor commands (eye, head, and arm movements) for appropriate action. The studies include an experimental and a theoretical approach. With regard to experiments the group collaborates with researchers in the Donders Institute (http://www.ru.nl/donders/), which houses advanced equipment for measuring and imaging of neuronal activity, and with research groups in the University Medical Center St. Radboud.

The topic of neuronal information processing is addressed from different perspectives:

- Experimental research based on a system-theoretical approach. By presenting various complex stimuli and by measuring responses to those stimuli, we aim to elucidate and to characterize the functional properties and hierarchical structure of processes involved in perception and action.
- Electrophysiological studies recording neuronal activity in primates and humans.
- Characterization of source location of brain structures that contribute to neuronal activity using the bioelectricity of brain (electro-encephalography, EEG and magneto-encephalography MEG) in collaboration with the department of Neurology and the Donders Center for Cognitive Neuroimaging.
- Theoretical research modelling biological neurons and the information storage and retrieval by networks of neurons.

The theoretical research focuses on insight in information processing in neurobiological systems as well as on applications of knowledge using artificial neural networks. In the former, we develop models for complex biological neurons and investigate learning and communication between neurons, as well as the dynamics of self-organization and information storage by networks of neurons.

Machine learning and artificial intelligence
One day, we will have computers that can think and learn like humans. But this will be far in the future. Nevertheless, artificial intelligence research is producing useful methods that provide solutions in many branches of industry. At the department of Biophysics, there is an group of physicists that develop novel machine learning methods and that apply these methods to AI applications. In particular, methods that have a close resemblance to methods from statistical physics, such as mean field and Bethe approximations and Monte Carlo sampling, are developed by the group and are among the best methods world-wide. Applications are in the areas of medical expert systems, genetics, multi-agent control problems, and time-series forecasting. Soms of these applications are commercialized through spin-off companies or with industrial partners. Students that are interested to write their Master's thesis in this research direction are adviced to follow courses in statistical physics and the courses Introduction to Pattern Recognition, Machine Learning, and Computational Physics.

Opportunities for students:
The department of Biophysics offers several experimental and theoretical research projects for a Bachelor or Master project. Students are advised to contact the head of the Biophysics department or one of the members of the scientific staff for more details.

6 Examinational Regulations

The examination regulations have been laid down in two documents. The Education and Examination Regulations (OER) govern the general organization and scope of education and examinations. More specific regulations can be found in the Rules and Guidelines of the Examination Committee.
This chapter first discusses a number of points from these regulations plus a number of practical aspects. The full text of the OER can be found on the internet, the Rules and Guidelines of the Examination Committee can be found below.
The study programme of Physics and Astronomy includes a propaedeutic examination, a Bachelor's examination, a Master's examination and a Doctoraal examination. Each examination comprises a number of interim examinations.
All interim examinations are administered at least twice a year: the first time shortly after the last lecture given; re-sits are scheduled later in the year. In some subjects, students are given a third opportunity to take an interim examination. A student can sit an interim examination up to a maximum of 3 times, provided he or she is registered as a regular student, external student (student who is entitled to sit examinations, but may not attend lectures and receives no grant) or institutional student (student who is not entitled to a grant and pays the institution fee instead of the legal tuition fee). If an interim examination has been taken more than once, the highest score will count. If, after three sittings, a student has not been able to pass the examination, he or she may request the examination committee in writing for permission to take the examination once more. The regulation stating the maximum of three examination sittings came into force as of 1 September 1999 and applies to interim examinations for which students have registered for the first time since that date, and all following interim examinations.
Some interim examinations may only be taken when certain components have been completed successfully. See OER: www.ru.nl/ons/onderwijszaken/onderwijs-_en/

6.1 Interim examinations

Students need to register for all interim examinations in the Master's phase. They can do so via KISS, which can be accessed on the computer terminals located at various places in the building. Each student will receive a personal password. Through KISS, you can register for interim examinations, look up your examination results, change your address, etc. Make sure you register before the closing date (5 working days before the date of examination).
Practical exams are also examination components for which students should register.
A few weeks after the examination, the results can be looked up via KISS. For privacy reasons, results are not disclosed over the telephone!

6.2 Master's Thesis

The procedure for assessing the master's thesis results is more stringent than the procedure for assessing other study components. The report is read by the graduation supervisor and a second staff member. The procedure is as follows:

- The graduation supervisor (supervising professor) is responsible for the dissertation and mark

- The graduation supervisor nominates a scientific staff member from outside his/her branch of learning as a second assessor, by letter or e-mail to the secretariat of the institute, at least 5 weeks before the date on which the mark is to be submitted
- The secretariat of the institute communicates the nomination to the chairman of the examination committee or, in case the chairman is not present, to the secretary or other deputy designated by the chairman
- When approved, the nomination will be communicated by letter or e-mail to the graduation supervisor
- The dissertation will be submitted to the second assessor at least 3 weeks before the date on which the mark should be known
- The second assessor will have 10 working days to assess the work placement results
- Within those 2 weeks, the graduation supervisor will inform the second assessor of the mark awarded for the work placement
- Within those 10 days, the second assessor will state whether or not he/she agrees with the mark given
- If the second assessor does not agree with the mark given, this will be reported to the graduation supervisor and the secretariat of the institute
- The secretariat will keep anonymous records of the dissertations the second assessor has assessed otherwise
- The graduation supervisor and second assessor will jointly determine the final mark. In the event that they cannot come to an agreement, the graduation supervisor will determine the mark and will report the matter to the examination committee

6.3 The Master's examination

Students should register for the Master's (Doctoraal) examination in Physics and Astronomy no later than the closing date (see appendix B for dates).
To register for the Master's (Doctoraal) examination, students **must** submit the following documents:

- valid student card
- valid passport or identity card
- last obtained certificate (if obtained outside the RU)

Only for students who were registered as external students during part of their study:

- a confirmation of external student status. This is a statement from the institute confirming that the student in question did not receive any education during the period that he/she was registered as an external student.

The Student Administration/Examination Office will **only** register students for the Master's examination if all the results of the interim examinations are in the possession of and have been processed by the Student Administration/Examination Office.

The regulations governing the examinations in August are somewhat different. For these, students can register up to the end of May, and may do so even if several marks have not yet been obtained. These marks have to be delivered before August 31, 2010; 12:00 a.m.

There are approximately 10 examinations scheduled each year (see appendix). The diplomas are presented once every three months. If students need proof of graduation before the date of presentation (e.g. when applying for a job), they can obtain written proof of graduation from the chairman of the examination committee. Students may also enquire at the Student Administration/Examination Office whether the examination committee has already signed the Master's certificate. If this is the case, the Student Administration/Examination Office will supply a certified copy of it.

6.4 Regels en Richtlijnen van de Examencommissie

Artikel 1: Toepassingsgebied

Deze regels en richtlijnen zijn van toepassing op de tentamens in de opleiding Natuur- en Sterrenkunde, hierna te noemen: de opleiding.

Artikel 2: Begripsomschrijving

In deze regels en richtlijnen wordt verstaan onder:
1. examenregeling: de onderwijs- en examenregeling voor de in artikel 1 genoemde opleiding;
2. examinandus: degene die zich onderwerpt aan een tentamen of examen;
3. tentamen: het onderzoek naar en de beoordeling van kennis, vaardigheden en inzicht, ongeacht de vorm waarin dit onderzoek plaatsvindt;
4. student: degene die als zodanig is ingeschreven voor de opleiding;
5. examinator: examinator als bedoeld in artikel 7.12 lid 3 WHW.

Artikel 3: Dagelijkse gang van zaken examencommissie

De examencommissie wijst uit haar midden een lid aan dat belast is met de behartiging van de dagelijkse gang van zaken van de examencommissie.

Artikel 4: Vaststelling uitslag examen

1. De kandidaat is geslaagd voor het propedeutisch examen als de beoordelingen die hij/zij ontvangen heeft voor de onderdelen van het propedeutisch examen voldoen aan de volgende voorwaarden:
   1. Alle beoordelingen op hoogstens één na zijn voldoende, dat wil zeggen tenminste 6.0, respectievelijk voldaan, gevolgd of vrijstelling. Er zijn geen beoordelingen lager dan 5.
   2. Het gemiddelde van alle beoordelingen is ten minste 6.
2. De kandidaat is geslaagd voor het bachelorexamen als hij/zij de propedeuse heeft behaald en de beoordelingen die hij/zij ontvangen heeft voor de onderdelen van de postpropedeuse, voldoen aan de volgende voorwaarde: alle beoordelingen zijn voldoende, dat wil zeggen tenminste 6.0, respectievelijk voldaan, gevolgd of vrijstelling
3. De kandidaat is geslaagd voor het masterexamen als de beoordelingen die hij/zij ontvangen heeft voor de onderdelen van het masterexamen voldoen aan de volgende voorwaarde: alle beoordelingen zijn voldoende, dat wil zeggen tenminste 6.0, respectievelijk voldaan, gevolgd of vrijstelling.
4. In bijzondere gevallen kan de examencommissie van het hierboven bepaalde afwijken.

Artikel 5: Judicia

Er worden 4 categoriën onderscheiden:

- Geen judicium: Het gewogen gemiddelde van alle vakken is kleiner dan 7.5
- Bene meritum: Het gewogen gemiddelde van alle vakken ligt tussen 7.5 en 8.0
- Cum Laude: Het gewogen gemiddelde van alle vakken ligt tussen 8.0 en 9.0
- Summa cum laude: Het gewogen gemiddelde van alle vakken is groter dan 9.0

Het gewogen gemiddelde wordt bepaald door de studielast (aantal ec) per vak.

Artikel 6: Cijfers

De cijfers die voor de beoordeling van de tentamens uitsluitend gebruikt mogen worden zijn: 10,0; 9,5; 9,0; 8,5; 8,0; 7,5; 7,0; 6,5; 6,0; 5,0; 4,5; 4,0; 3,5; 3,0; 2,5; 2,0; 1,5; 1,0; voldaan.

Artikel 7: Aanmelding tentamens

1. Deelneming aan een schriftelijk tentamen als bedoeld in artikel 8 lid 1, kan pas plaatsvinden na deugdelijke en tijdige aanmelding bij de facultaire studentenadministratie.
2. Als tijdige aanmelding geldt een opgave tenminste 5 werkdagen voor het tijdstip waarop het desbetreffende tentamen zal worden afgenomen. De examencommissie kan in bijzondere gevallen toestaan dat een latere aanmelding niettemin als tijdig wordt aangemerkt.

Artikel 8: De orde tijdens een tentamen

1. De desbetreffende examinator zorgt dat t.b.v. de schriftelijke examinering, surveillanten worden aangewezen die erop toezien dat het tentamen in goede orde verloopt.
2. De desbetreffende examinator informeert de examinandi bij schriftelijke examinering vooraf over de voorgenomen normering van de tentamenonderdelen.
3. De examinandus is verplicht zich op verzoek van de surveillant te legitimeren.
4. De examinandus is verplicht de aanwijzingen van de examencommissie c.q. de examinator, die voor de aanvang van het tentamen zijn gepubliceerd, alsmede aanwijzingen die tijdens het tentamen en onmiddellijk na afloop daarvan worden gegeven, op te volgen.
5. Volgt de examinandus een of meer aanwijzingen als bedoeld in het vierde lid niet op, dan kan hij door de examencommissie c.q. de examinator worden uitgesloten van de verdere deelname aan het desbetreffende tentamen. De uitsluiting heeft tot gevolg dat geen uitslag wordt vastgesteld van dat tentamen. Voordat de examencommissie c.q. de examinator een besluit tot uitsluiting neemt, stelt zij de examinandus in de gelegenheid te worden gehoord.

Artikel 9: Fraude

1. Er is sprake van fraude wanneer als gevolg van handelen of verzuim van handelen van een examinandus het vormen van een juist oordeel omtrent zijn kennis, inzicht en vaardigheden geheel of gedeeltelijk onmogelijk wordt.

2. In geval van fraude tijdens het afleggen van een tentamen kan de examinator de examinandus uitsluiten van verdere deelname aan het tentamen.
3. De beslissing inzake uitsluiting wordt genomen naar aanleiding van door de examinator of surveillant geconstateerde of vermoede fraude.
4. In spoedeisende gevallen kan de examinator een voorlopige beslissing tot uitsluiting nemen op grond van zijn constatering c.q. vermoeden of, indien van toepassing, een mondeling verslag van de surveillant. Desgevraagd draagt de examinator er zorg voor dat, binnen een redelijke termijn, het verslag van de geconstateerde of vermoede fraude op schrift wordt gesteld en in afschrift aan de examinandus wordt verstrekt.
5. De examinandus kan aan de examencommissie verzoeken de uitsluiting ongedaan te maken.
6. Voordat de examencommissie een beslissing neemt op een verzoek, als bedoeld in het vijfde lid, stelt zij de examinandus en de examinator in de gelegenheid te worden gehoord.
7. Een uitsluiting heeft tot gevolg dat geen uitslag wordt vastgesteld voor het in het tweede lid bedoelde tentamen.

Artikel 10: Dubbele Bachelor Wiskunde en Natuur- & Sterrenkunde

1. Studenten die de dubbele bachelor Wiskunde en Natuur- & Sterrenkunde volgen, hebben een verzwaard studieprogramma in de propedeusefase (75 ec) en de postpropedeusefase (150 ec).
2. In de propedeusefase komen de wiskundevakken Wiskunde en Computers (3 ec) en Euclidische Meetkunde (3) te vervallen als verplichte vakken.
3. In de postpropedeusefase zijn de wiskundevakken Inleiding Statistiek (3 ec), Krommen en Oppervlakken (3 ec) en Inleiding Partiële Differentiaalvergelijkingen (6 ec) verplichte vakken.
4. In de postpropedeusefase
    1. wordt een keuze gemaakt tussen de wiskundevakken Discrete wiskunde 1 (3 ec) en Discrete Wiskunde 2 (3 ec);
    2. wordt het verplichte natuurkundevak Practicum Natuurkunde 2b (6 ec) vervangen door Practicum Natuurkunde 2c (3 ec)
    3. wordt 3 ec keuzeruimte benut voor het ontbrekende wiskundevak Discrete Wiskunde 1 (3 ec) of Discrete Wiskunde 2 (3 ec), dan wel het complemeteren van het natuurkundevak Practicum Natuurkunde 2c tot Practicum Natuurkunde 2b (6 ec in plaats van 3 ec).
5. In de postpropedeusefase komt het wiskundevak Logica 1 (3 ec) te vervallen als verplicht vak.
6. In de postpropedeusefase wordt één Bachelorstage (12 ec) verricht bij een Wiskunde- of Natuurkunde-afdeling naar keuze.
7. Bovenstaande regels (artikel 10.1-10.6) worden getoetst in een gezamenlijke zitting van de examencommissies van de opleidingen Wiskunde en Natuur- en Sterrenkunde.

Artikel 11: Minoren

1. Het samenhangende vakkenpakket omvattende Getallen (6 ec), Analyse 1 (6 ec), Analyse 2 (6 ec), Symmetrie (6 ec), Inleiding Fouriertheorie (3 ec) en Krommen en Oppervlakken

(3 ec) is goedgekeurd als minor Wiskunde. Het natuurkundevak Inleiding Groepentheorie komt dan te vervallen als verplicht vak.

2. Het samenhangende vakkenpakket omvattende Voortgezette Kansrekening (3 ec), Inleiding Biofysica (3 ec), Neurofysica (3 ec), Gewone Differentiaalvergelijkingen (3 ec), Inleiding Magnetische Resonantie (2 ec), Numerieke Wiskunde (3), Neural Networks and Information Theory (3 ec), Markovketens (3ec) , Magnetic Resonance of Living Systems (4 ec), en een verplicht keuzevak (3 ec) is goedgekeurd als minor Neurosciences. Voor het verplichte keuzevak dient te worden gekozen uit Stochastische Processen (6 ec; in plaats van Markov ketens), Inleiding Fouriertheorie (3 ec), Moleculaire Biofysica (3 ec), Biologische Stromingsleer (3 ec) of Inleiding Partiële Differentiaalvergelijkingen (6 ec).
3. Het samenhangende vakkenpakket Celbiochemie (6 ec), Moleculaire Biologie (6 ec), Celbiologie der Dieren (6 ec), Biochemie & Moleculaire Biologie 2 (6 ec) en Toegepaste Bioinformatica (6 ec) is goedgekeurd als minor Biologie.
4. Het samenhangende vakkenpakket Atoom- en Molecuulbouw (6 ec), Reacties en Kinestiek (3 ec), Chemische Thermodynamica (3 ec), Synthese Biomoleculen (3 ec), Coördinatie-Chemie (3 ec), Chemische binding 1 (3 ec), Chemische Binding 2 (3 ec), Kristalstructuur (3 ec) en Microscopische Technieken (3 ec) is goedgekeurd als minor Chemie.

Artikel 12: Wijziging regels en richtlijnen

Geen wijzigingen vinden plaats die van toepassing zijn op het lopende studiejaar, tenzij de belangen van de studenten daardoor redelijkerwijs niet worden geschaad.

Artikel 13: Inwerkingtreding

Deze regels en richtlijnen treden onder voorbehoud in werking op 1 september 2009. De definitieve versie is te raadplegen op het web: http://science.ru.nl/winst

Aldus vastgesteld door de examencommissie voor de opleiding Natuur- en Sterrenkunde.

7 The Administrative Structure

The master programme Physics and Astronomy is one out of eleven master programs of the Faculty of Science. In this chapter an outline is given of the administrative structure of the Faculty.

The Executive Board of the Faculty is formed by the Dean, two Vice-Deans (for research and education) and a Managing Director (HRM, administration and PR). One Student Assessor, who has an advisory vote, completes the board. There is a Joint Faculty Council (FGV) of the Faculty Employees' Council (OC) and the Faculty Students' Council (FSR). The FGV has the right of consent in regard to policy plans, faculty regulations, education and examination regulations, and quality control of education and research.

The Faculty of Science is one out of the nine faculties and together they make up the Radboud University, which is run by the University Board (CVB). The Joint University Council (UGV) of the Employees' Council (OR) and Students' Council (USR) advises the University Board.

7.1 The Educational Institute for Mathematics, Physics and Astronomy (WiNSt)

The Faculty of Science encompasses 6 research institutes and 4 educational institutes. The educational institute for Mathematics, Physics and Astronomy (WiNSt) is one of the educational institutes and it is chaired by a Director of Education. The institute homes the School of Mathematics and the School of Physics and Astronomy. A programme coordinator is responsible for each of the educational programmes. The programme coordinator is supported by authorative committees: an Education Committee, an Examination Committee and a Committee for Study Advice at the end of the first year. The Education Committee advises on matters relating to education, by own initiative or on request. This Committee consists of 8 members: 4 scientific staff and 4 students.

8 Student Facilities

This chapter provides an overview of the facilities accessible to students. Names and addresses can be found in Appendix A. For more information see: http://www.ru.nl/students

Student Advisor

For advice on matters relating to their studies, students can contact the Student Advisor (see Appendix A). The Student Advisor monitors the students' progress. Students whose progress is not quite up to par are invited for an interview. This service is much appreciated, particularly in connection with the 'tempo' or performance-related grant. The Student Advisor assists students to answer questions about the choice of suitable fields of study, internal or external traineeships. If preferable, he may refer them to staff faculty of the institute and advisors at the central university level or beyond. He may also provide information on study skills training and study planning. You can call on him at any time you like. He will either help you immediately or make an appointment.

Student Affairs Office

At the university Student Affairs Office (see Appendix A) you can obtain information on student counsellors, student psychologists and the Study and Career Advice Group. At the desk you can make an appointment with a student counsellor or psychologist, or register for study skills training. Here you can also ask any questions concerning registration, obtain information on the Graduation Fund and Emergency Fund, report study delays due to special circumstances, obtain basic information on student financing, register for examinations through the Examination Office of the Arts Faculties, and obtain various flyers, forms and brochures. The Student Affairs Office also houses the KISS Help Desk.

Infotheque

At the 'infotheque' of the Student Affairs Office you can find all the information and documentation you need on study programmes offered at the Radboud University Nijmegen and other institutions, the labour market, and studying and doing work experience abroad. The infotheque also has excellent computer facilities, which enable you to search for information on the Internet (if necessary, with the help of special search engines).

Student Counselling Service

You can contact the Student Counselling Service (see Appendix A) if you have any study-related or personal questions. The Student Counselling Service also organizes various courses which will help you to develop study and professional skills (e.g. 'Writing Papers' and 'Speaking in Public'). The following professionals and bodies are part of the Student Counselling Service:

- study and careers consultant
- student counsellors
- student psychologists

- skills instructors
- Grievance Person and Undesired Behaviour Complaints Committee
- SLAG: Study and Career Advice Group
- Service Point Labour Market for the Highly Educated.

Central Student Administration

The Central Student Administration (see Appendix A) takes care of the registration of all students at the Radboud University Nijmegen. Its other activities include:

- managing student data
- issuing certificates of registration
- processing applications for tuition fee refunds

Students are registered as soon as the payment of tuition fee has been settled and the registration form has been processed. Registered students receive a student card. Information on study results is provided by the secretariat of the faculty or department responsible for the study programme in question.

KISS (RU Internet Service for Students)

All students at the Radboud University Nijmegen (RU) have access to KISS. KISS enables you to look up the results of the interim examinations you have taken, register for seminars and interim examinations, change your address, send and receive e-mail, create your own Web page and surf the Internet. KISS is also used to send the monthly newsletter to all RU students. This newsletter contains all kinds of news on the Radboud University Nijmegen. At the beginning of the first year, you will receive information on your KISS account and your personal login code. The first time you use KISS, you should convert this code into a personal password. If you cannot remember your password, you can apply for a new password at the Student Affairs Office (for which you need to submit your student card). You can find the KISS program on the Internet via www.student.run.nl/. If you want to use the university's computer facilities to go on the Internet, you need the Surfkit CD-ROM to install the software for dial-up access to the server. This CD-ROM can be obtained from the Student Affairs Office. If you have any questions about or problems with your KISS account, contact the Student Affairs Office or send an e-mail to: *helpdesk@student.ru.nl*.

Computing

Students may use the computers located in the various computer rooms. Each student has a login code that enables them to gain access to the network, send and receive e-mails and go online.

University Library

The central University Library (UB) is on the Erasmuslaan and is open to everyone. To borrow books from the library you need to show your student card. Most of the book collection is stored in a central repository that is not open to the public. This entails that all the applications for books and journals from the collection need to be made via the Online Public Catalogue (OPC), with the exception of the collections of reference works in the Catalogue Room and Reading Room, which are directly accessible to the public. The Catalogue Room contains library catalogues, bibliographies, and directories, the Reading Room dictionaries, encyclopaedias, biographical materials, special bibliographies, and catalogues of manuscripts and early printed books.

Faculty Library

The Faculty Library (see Appendix A) is also accessible to students. Here you can consult and borrow books and journals, and study in peace.

Syllabus Office (Dictaten Centrale)

Syllabuses can be bought at the Syllabus Office (see Appendix A). Chapter 4 mentions the subjects for which you need to purchase syllabuses. The costs of books and syllabuses will not amount to more than a few hundred Euro's per semester.

Faculty Student Administration

To register for examinations and examination subjects and obtain information on student registration, contact the Student Administration of the Science Faculties (see Appendix A).

General Notice Board

The general notice board for students of Physics and Astronomy is located near the Physics Lab on the first floor, wing 8, in the Huygens building. On this board, you can find the latest information on lectures, interim examinations, etc.

Possibilities of appeal

With regard to examination-related matters, students can appeal to the Examination Appeals Board of the Radboud University Nijmegen. In addition to the Examination Appeals Board, there is a Higher Education Appeals Tribunal in The Hague. For procedures see: http://www.ru.nl/students

Functionally disabled, chronically ill and dyslexic students

Functional disabilities and chronic diseases are disorders of a permanent nature that tend to slow down the progress of the students suffering from them. These include: visual, auditory and motor dysfunctions, linguistic dysfunctions (dyslexia), speech impediments, reduced endurance, impaired memory and powers of concentration, organic dysfunctions, mental disorders, epilepsy, rheumatism, ME, severe migraine, whiplash injuries and RSI. Education is organized in such a way that functionally disabled students are just as likely to succeed as any other student. For this purpose, they have recourse to all kinds of legal and academic regulations for funding, housing, study materials, education and examination. For these students to make the best possible use of the Radboud University Nijmegen's facilities it is essential that they contact the study advisor and student counsellor at their earliest convenience (e.g. before they begin their studies). This also leaves time to discuss the required facilities and financial consequences. Further information can be found on the website: www.ru.nl/studentenzaken/

There is also a 'sounding-board group' for students with a handicap at the Radboud University Nijmegen. This group promotes the interests of handicapped students, and provides information on the existing facilities and policies, and where necessary, tries to improve these in collaboration with the student counsellors. The group consists of students, lecturers, a student counsellor and a policy official. Students and lecturers are requested to report to this group any regulations that are lacking or are not implemented properly (for example, with regard to accessibility of buildings).

Address: Comeniuslaan 4, P.O. Box 9102, 6500 HC Nijmegen, tel. (024) 3512345, e-mail: *klankbord-handicap@dsz.ru.nl*

University chaplaincy

The University Chaplaincy at the Catholic University of Nijmegen extends a warm welcome to all students and staff from abroad. In the Chaplaincy we work from an ecumenical Christian perspective. There are two Catholic pastors and one Protestant.

Students and staff from all backgrounds are welcome, whatever your faith or persuasion. We intend to be a place where people share experiences, talk about issues that matter to them, and make friends.

More information: www.ru.nl/chaplaincy/home/vm/university/

9 Student Activities

9.1 Marie Curie

Marie Curie is the Student Association for Physics and Astronomy, meant for all students. Its basic goal is providing these students with the opportunity to get to know each other in an informal way. Here are a few ways (out of many) to achieve this.

- We share a canteen with two other student associations on the Faculty of Science where coffee, tea, candybars and sodas are sold during lunch hours, all at very affordable prices. On top of that it is the perfect place to hang out with your fellow students before, between or after classes, to study with nice music on the background, take a break on one of the many couches or maybe to challenge your companions for a game.
- Besides that, plenty of activities are organised. Sporting competitions (pool, karting), laserquest-matches, movie nights and barbecues are just a couple of examples. There are also loads of get-togethers for students, where one can for example play casino games, compete in interesting quizzes or just have a relaxing drink with other students.
- A great deal of time is spent in organising course-related activities. Several times a year we visit a company which houses physicists (f.e. ESA/ESTEC, FOM and Thales). Also, we organise a symposium in which physics is set in different perspectives once a year.
- Four times a year Marie Curie provides you with the opportunity to order books you need for classes. Prieces lie way below those which are common in bookstores. Serway and Vector Calculus can only be obtained from Institute WiNSt.
- Marie Curie has its own magazine too, named Impuls. It updates its readers on everything that is happening in Marie Curie and around our study, but you can also find interviews, interesting stories, views and a lot more.
- Last but definitely not least two study tours are organised every year. It enables 18 of our members to experience culture and physics in great destinations in- and outside Europe. In past years we travelled through Japan, South-Africa, India, Canada and Scandinavia whilst in 2009 we head for Russia. In May there will be a short break.

In case all this information has not convinced you: membership is only 8 Euro. Although not obligatory, over 90% of the students in Physics and Astronomy become a member. If you would like more information or want to become a member right away: check our website at www.marie-curie.nl/ or contact us at: bestuur@marie-curie.nl

10 Appendices

In this appendices many practical details are given, important for students as well as staff. The telephone numbers look like (36)54321. That means: calling from inside the university you only need the last 5 figures. Calling from outside the university, but within Nijmegen you need all 7 figures. Calling from elsewhere you also need the area code prefix, 024 within the Netherlands, but 24 outside the Netherlands.

10.1 Appendix A: Important departments and persons

1. Educational Institute for Mathematics, Physics and Astronomy (WiNSt)

Director and educational coordinator (Astro)Physics	Prof. Dr N. de Groot
Educational coordinator Mathematics:	Prof. Dr H.T. Koelink
Coordinator (Astro)Physics:	Dr G.W.M. Swart
Coordinator Mathematics:	Ms M. Dekkers MSc
Student-assessor (Astro)Physics:	Sander Uijlen
Student-assessor Mathematics:	Anna Kirilyouk
Secretary (Astro)physics:	Ms J.Th.M. Vos - van der Lugt
Secretary Mathematics:	(secrons@science.ru.nl)
	Ms M. van Megen (m.vanmegen@science.ru.nl)
	Room: HG 01.831; tel.: 024-(36)52739

The office is open: Monday through Thursday, 08:30 - 16:30 p.m.; Friday, 08:30 - 12:30 p.m.

2. Board of Examination of Physics and Astronomy

President:	Prof. Dr T.H.M. Rasing
Members:	Ms Prof. Dr A. Fasolino
	Prof. Dr S.J. de Jong
	Prof. Dr J.J. ter Meulen
	Prof. dr R.H.P. Kleiss
	Dr G.W.M. Swart

3. Education Committee of Physics and Astronomy

President:	Ms Prof. Dr. A. Fasolino
Members:	Dr W. Beenakker
	Dr A. Kimel
	Dr J. Hörandel
	Dr G.W.M. Swart
	Fiona van der Burgt (student)
	Madelon Bours (student)
	Erik van Loon (student)
	Koen Reijnders (student)

4. PR committee of WiNSt

President:	Prof. Dr W.J. van der Zande
Members:	Prof. Dr Erik Koelink
	Dr Theo Smits
	Ms Mirte Dekkers MSc
	Drs Lennart van Haaften
	Antonie v.d. Heuvel (student)
	Mike Hoffmeister (student)
	Gillian Lustermans (student)

5. Student Advisor

Dr G.W.M. Swart (g.swart@science.ru.nl)
Room: HG 01.832; tel. (36)52559

6. Coordinator of Physics and Astronomy

Dr G.W.M. Swart (g.swart@science.ru.nl)
Room: HG01.832; tel. (36)52559

7. Coordinator International Affairs for Physics

Prof. Dr D. Parker (parker@science.ru.nl)
Room: HG 01.718; tel. (36)53423

8. Library of the Faculty of Physics and Astronomy

Heijendaalseweg 135, Huygensgebouw, ground floor, wing 2
Open: Monday through Thursday, 08:30 - 20:00 p.m. *(Except Summer Holidays)* and Friday 08:30 - 17:30 p.m.

Internetadres:www.ru.nl/fnwi/bibliotheek

9. Office of administration and exams for Students FNWI

Room: HG 00.134; tel. (36)53392 of (36)52247
The office is open:

- Monday through Thursday, 13:00 - 16:00 p.m.
- Friday, 09:00 - 12:00 a.m.

10. Lecture notes in stock

Address: Erasmusplein 1, 2e floor, room 2.031A, tel. (36) 16250
Open: Monday through Thursday, 09:00 - 16:30 p.m.; Friday 09:00 - 13:00 p.m.
Except periods without education

Address at Internet: www.ru.nl/dictaten

11. Student counsellors' Office

Postaddress: POBox 9102, 6500 HC Nijmegen
Visit address: Comeniuslaan 4

Tel.: (36)12345
Internet address: www.ru.nl/students/facilities/student_counsellors/

Open: Monday through Friday, 10:00 - 17:00 p.m. (Except the first Friday afternoon of every month).

12. University Chaplaincy

Pastores: John Hacking, Theo Koster o.p. and Ms Ds Froukien Smit
Address: Erasmuslaan 9, 6525 GE Nijmegen, tel.: 3619188.
info@studentenkerk.ru.nl.
Internet address: www.ru.nl/studentenkerk

13. Board of the Faculty of Science, Mathematics, and Information Theory

Dean:	Prof. Dr J.M.E. Kuijpers
Vice-dean education:	Prof. Dr J.J. ter Meulen
Vice-dean research:	Prof. Dr Ir. J.C.M. van Hest
Dir. Management:	Dr. A. Geurtsen RC
Student-assessor:	M. van Teeseling
Secretary:	Drs D.A.L.E. de Vries

14. Board of Marie Curie

Chairman:	Luc Hendriks
Vice-chairman:	Nick Leijten
Secretary:	Erik van Loon
Treasurer:	Eline de Jong
Members:	Edo van Veen
	Gillian Lustermans

15. Board of Faculty Student Councel

Members:	Anneke Mak, MLW
	Joep Bos, Scheikunde
	Martijn Wehrens, Scheikunde/Biologie
	Lisette de Hoop, Milieu Natuurwetenschappen
	Lars Hanssen, Biologie
	Marc Schoolderman, Informatica/Wiskunde

Internet address: www.ru.nl/fnwi/fsr

Email: fsr@science.ru.nl

10.2 Appendix B: Dates of Examinations 2009/2010

Masters exams

date of exams	final date of registration	presentation
Sept. 24 - 2009	Sept. 10 - 2009	Dec. 15 - 2009
Oct. 29 - 2009	Oct. 15 - 2009	Dec. 15 - 2009
Nov. 26 - 2009	Nov. 12 - 2009	March 26 - 2010
Dec. 17 - 2009	Dec. 03 - 2009	March 26 - 2010
Jan. 28 - 2010	Jan. 14 - 2010	March 26 - 2010
Febr. 25 - 2010	Feb. 11 - 2010	June 23 - 2010
March 25 - 2010	March 11 - 2010	June 23 - 2010
April 29 - 2010	April 15 - 2010	June 23 - 2010
May 27 - 2010	May 12 - 2010	Oct. 13 - 2010
June 24 - 2010	June 10 - 2010	Oct. 13 - 2010
August 31 - 2010	May 31 - 2010	Oct. 13 - 2010

Please note that the admittance to the exam of August 31, 2010, is subject to a special arrangement. The deadline for application is already scheduled at May 31, 2010, but it is allowed to have a few marks still missing. The last mark has to be filled in at last at August 31, 2010.

For more information look at the notice-board.

10.3 Appendix C: Teaching 2009/2010

1. **Semesters**:
   - 1st half-year: Monday August 31, 2009 through Friday January 29, 2010
   - 2nd half-year: Monday February 01, 2010 through Friday July 16, 2010
2. **Quarters**:
   - 1st quarter: Monday August 31, 2009 through Friday November 06, 2009
   - 2nd quarter: Monday November 9, 2009 through Friday January 29, 2010
   - 3rd quarter: Monday February 01, 2010 through Friday April 16, 2010
   - 4th quarter: Monday April 19, 2010 through Friday July 2, 2010
3. **Vacation periods**:
   - Winter break:
     Monday December 21, 2009 through Friday January 01, 2010
   - Spring break: Monday February 15, 2010 trough Friday Februari 19, 2010
   - May break: Friday 30, 2010 through Friday May 07, 2010
   - Summer Holidays: Monday July 19, 2010 through Friday August 27, 2010
4. **Holidays**:
   - Easter break: Good Friday April 2, 2010 through Monday April 5, 2010
   - Ascension day: Thursday May 13, 2010 through Friday May 14, 2010
   - Whit Monday: May 24, 2010

11 List of lecturers

Name	Email	Tel.	Room
Beenakker, Dr. W.J.P.	w.beenakker@science.ru.nl	52803	HG03.828
Drenthen, Dr. M.A.M.	m.drenthen@science.ru.nl	52730	HG02.826
Falcke, Prof. dr. H.D.E.	h.falcke@astro.ru.nl	52020	HG03.721
Fasolino, Prof. dr. A.	a.fasolino@science.ru.nl	52222	HG03.073
Filthaut, Dr. F.	f.filthaut@hef.ru.nl	52308	HG03.808
Gielen, Prof. dr. C.C.A.M.	s.gielen@donders.ru.nl	14242	0.16 M244
Groot, Prof. dr. N. de	n.degroot@hef.ru.nl	53343	HG03.828
Groot, Prof. dr. P.J.	p.groot@astro.ru.nl	52801	HG03.731
Groot, Prof. dr. R.A. de	r.degroot@science.ru.nl	52211	HG03.065
Hörandel, Dr. J.R.	j.horandel@astro.ru.nl	52802	HG03.734
Hageman, Dr. P.R.	p.hageman@science.ru.nl	53158	HG03.531
Haren, Ir. R.A.H.M. van	r.vanharen@science.ru.nl	52007	HG01.827
Harren, Dr. F.J.M.	f.harren@science.ru.nl	52128	HG01.732
Heckman, Prof. dr. G.J.	g.heckman@math.ru.nl	53233	HG03.737
Hundsdorfer, Dr. W.	Willem.Hundsdorfer@cwi.nl	020 5924211	
Jong, Prof. dr. S.J. de	s.dejong@hef.ru.nl	52168	HG03.827
Jonkergouw, Drs. P.A.J.	p.jonkergouw@amd.ru.nl	13681	1.27
König, Dr. A.C.	a.konig@hef.ru.nl	52090	HG03.824
Kappen, Prof. dr. H.J.	b.kappen@donders.ru.nl	14241	0.12 M244
Katsnelson, Prof. dr. M.I.	m.katsnelson@science.ru.nl	52995	HG03.062
Kimel, Dr. A.V.	a.kimel@science.ru.nl	53080	HG00.729
Kiriliouk, Dr. A.I.	a.kirilyuk@science.ru.nl	53183	HG01.077
Kleiss, Prof. dr. R.H.P.	r.kleiss@science.ru.nl	53283	HG03.826
Klok, Drs. P.F.	p.klok@hef.ru.nl	52214	HG03.077
Koelink, Prof. dr. H.T.	e.koelink@math.ru.nl	52597	HG03.742
Maan, Prof. dr. ir. J.C.	jc.maan@science.ru.nl	53422	HFML 02.14
Nelemans, Dr. G.A.	nelemans@astro.ru.nl	52983	HG03.735
Nielsen, M.T.B.		52808	
Norris, Prof. dr. D.G.	d.norris@donders.ru.nl	10649	38
Rasing, Prof. dr. T.H.M.	th.rasing@science.ru.nl	53102	HG01.072
Schellekens, Prof. dr. A.N.J.J.	b.schellekens@science.ru.nl	52982	HG03.076
Segers, S.A.J.	s.segers@science.ru.nl	53201	HG02.832
Speller, Prof. dr. S.E.	s.speller@science.ru.nl	52369	HG01.075
Vrakking, Prof. dr. M.J.J.	m.vrakking@amolf.nl	52025	
Wiegerinck, Dr. W.A.J.J.	w.wiegerinck@donders.ru.nl	15040	UMC126.0.24
Wiegers, Dr. S.A.J.	s.wiegers@science.ru.nl	52947	ML01.08
Wijs, Dr. ir. G.A. de	g.dewijs@science.ru.nl	52984	HG03.075
Zande, Prof. dr. W.J. van der	w.vanderzande@science.ru.nl	52101	HG01.715

12 Index of Courses