

Module No.:  
Credit Points (CP):  
Category:  
Semester:

physics70d  
3-8  
Elective  
1.-2.



## Module: Elective Advanced Lectures: BCGS Courses

### Module Elements:

Nr.	Course Title	Number	CP	Type	Workload	Sem.
1.	Selected courses from catalogue	see catalogue	3-8	see catalogue	90-240 hrs	WT/ST

#### **Requirements for Participation:**

none

#### **Form of Examination:**

see with the course

#### **Content:**

Advanced lectures within the Bonn Cologne Graduate School of Physics and Astronomy (BCGS).

#### **Aims/Skills:**

Preparation for Master's Thesis work; broadening of scientific knowledge

#### **Course achievement/Criteria for awarding cp's:**

see with the course

**Length of Module:** 1 or 2 semester

**Maximum Number of Participants:** ca. 100

#### **Registration Procedure:**

s. <https://basis.uni-bonn.de> u. <http://bamawww.physik.uni-bonn.de>

Note: The student must achieve at least 18 CP out of all 4 Elective Advanced Modules

# Module: Elective Advanced Lectures: BCGS Courses

Module No.: physics70d

Course:



## Relativity and Cosmology I (T)

Course No.:

Category	Type	Language	Teaching hours	CP	Semester
Elective	Lecture with exercises	English	4+2	8	WT

### Requirements for Participation:

#### Preparation:

Training in theoretical physics at the B.Sc. level

#### Form of Testing and Examination:

Written or oral examination

#### Length of Course:

1 semester

### Aims of the Course:

Introduction into Einstein's theory of general relativity and its major applications

### Contents of the Course:

Gravity as a manifestation of geometry  
Introduction to differential geometry  
Einstein field equations  
The Schwarzschild solution  
Experimental tests  
Gravitational waves

### Recommended Literature:

T. Padmanabhan, Gravitation: Foundation and Frontiers  
J. B. Hartle, Gravity: An introduction to Einstein's general relativity

# Module: Elective Advanced Lectures: BCGS Courses

Module No.: physics70d

Course:



## Relativity and Cosmology II (T)

Course No.:

Category	Type	Language	Teaching hours	CP	Semester
Elective	Lecture with exercises	English	4+2	8	ST

### Requirements for Participation:

#### Preparation:

Training in theoretical physics at the B.Sc. level

#### Form of Testing and Examination:

Written or oral examination

#### Length of Course:

1 semester

### Aims of the Course:

Application of Einstein's theory of general relativity to black holes and cosmology

### Contents of the Course:

Black holes

Introduction to cosmology

The early Universe

### Recommended Literature:

V. Mukhanov, Physical Foundations of Cosmology

T. Padmanabhan, Gravitation: Foundation and Frontiers

J. B. Hartle, Gravity: An introduction to Einstein's general relativity

# Module: Elective Advanced Lectures: BCGS Courses

Module No.: physics70d

Course:



## Quantum Field Theory I (T)

Course No.:

Category	Type	Language	Teaching hours	CP	Semester
Elective	Lecture with exercises	English	4+2	8	ST

### Requirements for Participation:

#### Preparation:

Training in theoretical physics at the B.Sc. level

#### Form of Testing and Examination:

Written or oral examination

#### Length of Course:

1 semester

### Aims of the Course:

Methods of quantum field theory are in use in almost all areas of modern physics. Strongly oriented towards applications, this course offers an introduction based on examples and phenomena taken from the area of solid state physics.

### Contents of the Course:

Second quantization and applications  
Functional integrals  
Perturbation theory  
Mean-field methods

### Recommended Literature:

A. Altland and B.D. Simons, Condensed Matter Field Theory (Cambridge University Press, Cambridge, second edition: 2010)

# Module: Elective Advanced Lectures: BCGS Courses

Module No.: physics70d

Course:



## Quantum Field Theory II (T)

Course No.:

Category	Type	Language	Teaching hours	CP	Semester
Elective	Lecture with exercises	English	4+2	8	ST

### Requirements for Participation:

#### Preparation:

Quantum Field Theory I

#### Form of Testing and Examination:

Written or oral examination

#### Length of Course:

1 semester

### Aims of the Course:

Quantum field theory is one of the main tools of modern physics with many applications ranging from high-energy physics to solid state physics. A central topic of this course is the concept of spontaneous symmetry breaking and its relevance for phenomena like superconductivity, magnetism or mass generation in particle physics.

### Contents of the Course:

Correlation functions: formalism, and their role as a bridge between theory and experiment  
Renormalization  
Topological concepts

### Recommended Literature:

A. Altland and B.D. Simons, Condensed Matter Field Theory (Cambridge University Press, Cambridge, second edition: 2010)

# Module: Elective Advanced Lectures: BCGS Courses

Module No.: physics70d

Course:



## Geometry in Physics (T)

Course No.:

Category	Type	Language	Teaching hours	CP	Semester
Elective	Lecture with exercises	English	4+2	8	ST

### Requirements for Participation:

#### Preparation:

Training in theoretical physics at the B.Sc. level

#### Form of Testing and Examination:

Written or oral examination

#### Length of Course:

1 semester

### Aims of the Course:

The course introduces the background in differential geometry necessary to understand the geometrically oriented languages of modern theoretical physics. Applications include the coordinate invariant formulation of electrodynamics, phase space and symplectic mechanics, and a brief introduction to the foundations of general relativity.

### Contents of the Course:

exterior calculus  
manifolds  
Lie groups  
fibre bundles

### Recommended Literature:

M. Gökeler & T. Schücker, Differential geometry, gauge theory, and gravity, Cambridge University Press, 1987.

# Module: Elective Advanced Lectures: BCGS Courses

Module No.: physics70d

Course:



## Topology for Physicists (T)

Course No.:

Category	Type	Language	Teaching hours	CP	Semester
Elective	Lecture with exercises	English	3+1	6	ST

### Requirements for Participation:

#### Preparation:

Bachelor of physics or mathematics; the basics of exterior calculus are assumed

#### Form of Testing and Examination:

Written or oral examination

#### Length of Course:

1 semester

### Aims of the Course:

This course gives an introduction to various topological concepts and results that play an important role in modern theoretical physics.

### Contents of the Course:

Elements of homotopy theory: homeomorphic spaces, homotopic maps, fundamental group, covering spaces, homotopy groups, long exact homotopy sequence of a fibration  
 Homology and cohomology: Poincare lemma, Mayer-Vietoris sequence, Cech-deRham complex, Hurewicz isomorphism theorem, spectral sequences  
 Vector bundles and characteristic classes: Euler form, Thom isomorphism, Chern classes  
 Applications: Berry phase; Dirac monopole problem; visualization of closed differential forms by Poincare duality; cohomology of electrical conductance; supersymmetry and Morse theory; index theorems; homotopy classification of topological insulators

### Recommended Literature:

R. Bott and L.W. Tu: Differential forms in algebraic topology (Springer, 1982)  
 A.S. Schwarz, Topology for physicists (Springer, 1994)

# Module: Elective Advanced Lectures: BCGS Courses

Module No.: physics70d

Course:



## Nuclear physics II (E)

Course No.:

Category	Type	Language	Teaching hours	CP	Semester
Elective	Lecture	English	3	5	WT

### Requirements for Participation:

#### Preparation:

Nuclear Physics I, Quantum Mechanics

#### Form of Testing and Examination:

Part of the obligatory courses for area of specialisation Nuclear and Particle Physics, separate oral examination is possible exceptionally.

#### Length of Course:

1 semester

### Aims of the Course:

Study of nuclear reactions, fission and fusion.

### Contents of the Course:

- Kinematics in nuclear reactions
- Cross section
- Rutherford scattering
- Scattering in quantum mechanics
- The Born approximation
- Partial wave analysis
- Inelastic scattering, resonances
- Optical model
- Direct, compound, spallation and fragmentation reactions
- Neutron sources and detectors
- Neutron cross sections
- Fission
- Nuclear reactors
- Fusion
- Solar fusion
- Man-made thermonuclear fusion
- Controlled thermonuclear fusion

### Recommended Literature:

A script for parts of the course will be distributed during the course.  
K.S. Krane, Introductory nuclear physics, chapters 11-14

# Module: Elective Advanced Lectures: BCGS Courses

Module No.: physics70d

Course:



## Physics of Detectors (E/A)

Course No.:

Category	Type	Language	Teaching hours	CP	Semester
Elective	Lecture	English	3	4	ST

### Requirements for Participation:

#### Preparation:

Nuclear Physics I, Quantum Mechanics

#### Form of Testing and Examination:

Part of the obligatory courses for area of specialisation Nuclear and Particle Physics, separate oral examination is possible exceptionally.

#### Length of Course:

1 semester

### Aims of the Course:

Study detection methods of experimental techniques in nuclear and particle physics.

### Contents of the Course:

- Interaction of electrons and charged heavy particles in matter
- Coherent effects: Cherenkov and transition radiation
- Interaction of gamma-radiation in matter
- Detection of neutral particles: neutrons and neutrinos
- Measurement of 4-momentum in particle physics
- Ionisation detectors: Bragg chamber, avalanche detectors
- Position sensitive detectors: drift chambers, time-projection chamber
- Anorganic and organic scintillators
- Energy detection, calorimeter and shower detectors
- Semiconductor detectors
- Position sensitive Si detectors (strip-, pixel-detectors)
- Ge detectors
- Low background measurements
- Lifetime measurements
- Mössbauer Spectroscopy
- Basic principles of analogue and digital signal processing

### Recommended Literature:

A script or slides of the course will be distributed during the course.

R. Leo, Techniques for Nuclear and Particle Physics Experiments

K Kleinknecht, Detektoren für Teilchenstrahlung

G.F. Knoll, Radiation Detection and Measurement

# Module: Elective Advanced Lectures: BCGS Courses

Module No.: physics70d

Course:



Particle physics (E)

Course No.:

Category	Type	Language	Teaching hours	CP	Semester
Elective	Lecture	English	3	4	ST

## Requirements for Participation:

### Preparation:

Quantum Mechanics

### Form of Testing and Examination:

Part of the obligatory courses for area of specialisation Nuclear and Particle Physics, separate oral examination is possible exceptionally.

### Length of Course:

1 semester

## Aims of the Course:

Introduction into particle physics, accelerators and detectors

## Contents of the Course:

- Relativistic kinematics
- Interaction of radiation with matter
- Particle accelerators
- Targets and detectors
- Symmetries in particle physics
- QED
- Weak interaction, neutrinos
- Quark model
- QCD
- Standard model
- Cosmology

## Recommended Literature:

A script for course will be available on-line

D.H. Perkins: Introduction to High Energy Physics, Cambridge University Press, ISBN 0521621968

H. Frauenfelder, E.M. Henley: Subatomic Physics, Prentice Hall, ISBN 0138594309

F. Halzen: A.D. Martin: Quarks and Leptons, John Wiley and Sons, ISBN 0471887412

D. Griffiths: Introduction to Elementary Particles, John Wiley and Sons ISBN: 0471603864

B. Povh, K. Rith, C. Scholz, F. Zetsche: Teilchen und Kerne, Springer-Verlag, ISBN 3540659285

C. Berger: Elementarteilchenphysik, Springer-Verlag, ISBN 3-540-41515-7

# Module: Elective Advanced Lectures: BCGS Courses

Module No.: physics70d

Course:



## Groundbreaking experiments in nuclear physics (E)

Course No.:

Category	Type	Language	Teaching hours	CP	Semester
Elective	Lecture	English	2	3	ST

### Requirements for Participation:

#### Preparation:

Basic knowledge in Nuclear Physics

#### Form of Testing and Examination:

Part of courses for area of specialisation Nuclear and Particle Physics, separate oral examination is possible exceptionally.

#### Length of Course:

1 semester

### Aims of the Course:

Study of original publications of fundamental experiments in nuclear physics. The students should participate actively in the course.

### Contents of the Course:

- Discovery of radioactivity
- Rutherford and his many discoveries using alpha sources
- The discovery of the neutron and deuteron
- Determination of magnetic moments
- Hofstadters electron scattering experiments
- The use of cosmic rays to discover mesons
- Fermi work in neutron physics
- Properties of neutrinos
- Mößbauereffekt

### Recommended Literature:

Will be distributed during the course.

# Module: Elective Advanced Lectures: BCGS Courses

Module No.: physics70d

Course:



## Condensed Matter Physics II (E)

Course No.:

Category	Type	Language	Teaching hours	CP	Semester
Elective	Lecture	English	3	4	ST

### Requirements for Participation:

#### Preparation:

Basic knowledge in condensed matter physics and quantum mechanics

#### Form of Testing and Examination:

Oral examination

#### Length of Course:

2 semesters

### Aims of the Course:

Advanced topics in condensed matter physics with examples of current research.

### Contents of the Course:

The entire course (Condensed Matter I & II, given in 2 semesters) covers the following topics:

Crystal structure and binding

Reciprocal space

Lattice dynamics and thermal properties

Electronic structure (free-electron gas, Fermi surface, band structure)

Semiconductors and metals

Transport properties

Dielectric function and screening

Superconductivity

Magnetism

### Recommended Literature:

Skriptum (available during the course)

Ashcroft/Mermin: Solid State Physics

Kittel: Introduction to Solid State Physics

Ibach/Lüth: Festkörperphysik

# Module: Elective Advanced Lectures: BCGS Courses

Module No.: physics70d

Course:



## Semiconductor Physics and Nanoscience (E/A)

Course No.:

Category	Type	Language	Teaching hours	CP	Semester
Elective	Lecture	English	2	3	ST

### Requirements for Participation:

#### Preparation:

Basic knowledge in condensed matter physics

#### Form of Testing and Examination:

No examination

#### Length of Course:

1 semester

### Aims of the Course:

Understanding of theoretical and experimental concepts of semiconductor physics, nanotechnology as well as aspects of future information technology.

Knowledge of basic fields and important applications of information technology.

### Contents of the Course:

Semiconducting material and nanostructures represent the backbone of modern electronics and information technology. At the same time they are fundamental to the research of problems of modern solid state physics, information technology and biophysics. This lecture will provide an introduction to semiconductor physics and its applications.

Topics covered are

introduction to semiconductor physics, crystalline structure, band structure, electronic and optical properties,

heterostructures, junction and interfaces,

basic semiconductor device concepts,

up to date techniques and strategies of information technology ranging from nowadays preparation technologies and nanoscience to concepts of molecular electronic and bioelectronics.

### Recommended Literature:

Skriptum (available during the course)

Bergmann/Schäfer, Experimentalphysik (Band 6: Festkörper)

Ibach/Lüth, Festkörperphysik

# Module: Elective Advanced Lectures: BCGS Courses

Module No.: physics70d

Course:



## Superconductivity (E/A)

Course No.:

Category	Type	Language	Teaching hours	CP	Semester
Elective	Lecture	English	2	3	ST

### Requirements for Participation:

#### Preparation:

Basic knowledge in condensed matter physics

#### Form of Testing and Examination:

Oral examination

#### Length of Course:

1 semester

### Aims of the Course:

Understanding of the fundamental aspects of superconductivity.

### Contents of the Course:

The lecture provides an overview of the fundamental aspects of superconductivity, theoretical description and technological applications, including the following topics:

Basic experimental facts and critical parameters  
 Phenomenological description: London equations  
 Ginzburg-Landau theory  
 Magnetic flux quantization  
 Type I and type II superconductors, characteristic length scales, vortices  
 Microscopic description: BSC theory  
 Electron-phonon interaction, Cooper pairs  
 Josephson effects  
 Applications of superconductivity in science, transport, and medicine  
 Brief introduction to unconventional superconductivity with recent examples

### Recommended Literature:

J. F. Annett: Superconductivity, Superfluids and Condensates (2004)  
 M. Tinkham: Introduction to Superconductivity (1996)  
 V. V. Schmidt: The Physics of Superconductors (1997)  
 J. R. Waldram: Superconductivity of Metals and Cuprates (1996)  
 D. R. Tilley and J. Tilley: Superfluidity and Superconductivity (1990)

# Module: Elective Advanced Lectures: BCGS Courses

Module No.: physics70d

Course:



## Magnetism (E/A)

Course No.:

Category	Type	Language	Teaching hours	CP	Semester
Elective	Lecture	English	2	3	WT

### Requirements for Participation:

#### Preparation:

Basic knowledge in condensed matter physics

#### Form of Testing and Examination:

Oral examination

#### Length of Course:

1 semester

### Aims of the Course:

Understanding of magnetism in condensed matter systems

### Contents of the Course:

The lecture introduces to the magnetism in condensed matter systems. Starting from basic concepts of the magnetic properties of free atoms it is aimed to illustrate the extremely rich field of collective magnetism that arises from the mutual interaction of an extremely large number of interacting particles.

Topics covered are

Magnetism of free atoms

Magnetism of ions in the crystal electric field

Magnetic interactions and ordering phenomena

Magnetic ground states and excitations

Itinerant magnetism

Magnetic frustration and low dimensionality

Magnetic order vs. competing ordering phenomena

### Recommended Literature:

Skriptum (available during the course)

S. Blundell, Magnetism in Condensed Matter

Ashcroft/Mermin, Solid State Physics

Kittel, Festkörperphysik

# Module: Elective Advanced Lectures: BCGS Courses

Module No.: physics70d

Course:



## Experimental methods in condensed matter physics (E/A)

Course No.:

Category	Type	Language	Teaching hours	CP	Semester
Elective	Lecture	English	2	3	WT

### Requirements for Participation:

#### Preparation:

Basic knowledge in condensed matter physics

#### Form of Testing and Examination:

Oral examination

#### Length of Course:

1 semester

### Aims of the Course:

Understanding of experimental concepts in condensed matter science

Knowledge of basic fields and important applications

### Contents of the Course:

The lecture introduces to modern experimental approaches in solid state physics. Basic concepts are illustrated with examples of physical problems investigated employing different methods.

Topics covered are

Introduction on sample preparation

X-ray powder diffraction

Specific heat, Thermal expansion

Magnetization and magnetic susceptibility

DC-Transport

Dielectric spectroscopy

Photo-emission spectroscopy

Inelastic scattering (neutrons, light)

THz spectroscopy / Optical spectroscopy

Scanning probe microscopy/spectroscopy (AFM, STM)

### Recommended Literature:

Skriptum (available during the course)

Bergmann/Schäfer, Experimentalphysik (Band 6: Festkörper)

Ibach/Lüth, Festkörperphysik

Ashcroft/Mermin, solid state physics

# Module: Elective Advanced Lectures: BCGS Courses

Module No.: physics70d

Course:



## Physics of Surfaces and Nanostructures (E/A)

Course No.:

Category	Type	Language	Teaching hours	CP	Semester
Elective	Lecture	English	2	3	WT

### Requirements for Participation:

#### Preparation:

Basic knowledge of solid state physics

#### Form of Testing and Examination:

Oral examination

#### Length of Course:

1 semester

### Aims of the Course:

Understanding of fundamental concepts in surface and nanostructure science

Knowledge of basic fields and important applications

### Contents of the Course:

The lecture introduces to modern topics of surface and nanostructure physics. Basic concepts are illustrated with examples and the link to technical applications is emphasised. Topics covered are

- surface structure and defects,
- adsorption and heterogeneous catalysis,
- surface thermodynamics and energetics
- surface electronic structure and quantum dots,
- magnetism at surfaces
- epitaxy and thin film processes,
- oxide films
- ion beam processes at surfaces,
- clusters,
- graphene

### Recommended Literature:

Michely: Skriptum (available during the course)

H. Ibach: Physics of Surfaces and Interfaces (Springer, Berlin 2006)

K. Oura et al: Surface Science - an introduction (Springer, Berlin 2003)

M. Prutton: Introduction to Surface Physics (Oxford University Press, 1994)

H. Lüth: Solid Surfaces, Interfaces and Thin Films, (Springer, Berlin 2001)

M. Henzler/ W. Göpel: Oberflächenphysik des Festkörpers (Teubner, Stuttgart 1994)

# Module: Elective Advanced Lectures: BCGS Courses

Module No.: physics70d

Course:



## Introduction to neutron scattering (E/A)

Course No.:

Category	Type	Language	Teaching hours	CP	Semester
Elective	Lecture	English	2	3	ST

### Requirements for Participation:

#### Preparation:

Basic knowledge in condensed matter physics

#### Form of Testing and Examination:

Oral examination

#### Length of Course:

1 semester

### Aims of the Course:

Understanding of the basic concepts and techniques of elastic and inelastic neutron scattering experiments.

### Contents of the Course:

The lecture introduces to the techniques of elastic and inelastic neutron scattering that can be used to determine the crystal or magnetic structure as well as the dispersion of nuclear or magnetic excitations.

Topics covered are

Crystal structures and reciprocal space

Neutron powder diffraction

Single-crystal diffraction

Structure refinements

Inelastic neutron scattering

Phonon dispersion

Magnetic excitations

Examples of current research (high-temperature superconductors, manganates with colossal magnetoresistivity, multiferroics)

Polarized neutron scattering

### Recommended Literature:

Skriptum (available during the course)

S. W. Lovesey, Theory of Neutron Scattering from Condensed Matter, Oxford (1981)

G. E. Bacon, Neutron Diffraction, Oxford (1979)

Shirane, Shapiro and, Tranquada, Neutr. Scattering with a triple-axis spectrometer, Cambridge (2002)

Izyumov, Ozerov, Magnetic Neutron Diffraction Plenum (1970)

Marshall and Lovesey, Theory of thermal neutron scattering, Oxford (1971)

Squires, Introduction to the theory of Thermal Neutron scattering, Cambridge (1978)

# Module: Elective Advanced Lectures: BCGS Courses

Module No.: physics70d

Course:



## Optical Spectroscopy (E/A)

Course No.:

Category	Type	Language	Teaching hours	CP	Semester
Elective	Lecture	English	2	3	WT/ST

### Requirements for Participation:

#### Preparation:

Basic knowledge in condensed matter physics

#### Form of Testing and Examination:

Oral examination

#### Length of Course:

1 semester

### Aims of the Course:

Understanding of the basic concepts and techniques of optical spectroscopy on solid-state samples.

### Contents of the Course:

Topics covered are:

Electromagnetic waves in matter, dielectric function

Electromagnetic response of metals and insulators, Drude-Lorentz model

Kramers-Kronig relations

THz spectroscopy (time domain and cw)

Fourier-transform spectroscopy

Ellipsometry

Examples of current research (phonons, magnons, orbital excitations, superconductors, ...)

### Recommended Literature:

Skriptum (available during the course)

Dressel/Grüner: Electrodynamics of Solids: Optical Properties of Electrons in Matter (Cambridge, 2002)

Klingshirn: Semiconductor Optics (Springer, 1997)

Kuzmany: Solid-State Spectroscopy: An Introduction (Springer, 2009)

# Module: Elective Advanced Lectures: BCGS Courses

Module No.: physics70d

Course:



Astrochemistry (E/A)

Course No.:

Category	Type	Language	Teaching hours	CP	Semester
Elective	Lecture	English	2	4	ST

**Requirements for Participation:****Preparation:**

Atomic Physics, Molecular Physics and Quantum Mechanics at the level of the bachelor courses in physics, Molecular Physics I

**Form of Testing and Examination:**

Oral Examination

**Length of Course:**

1 semester

**Aims of the Course:**

The lecture introduces to astrochemistry of various astrophysical environments. Fundamental processes, such as molecular collisions, fragmentations, and chemical reactions, are explained, and implications for astrophysical observations by means of high resolution spectroscopy are treated.

**Contents of the Course:**

- Detection of Molecules in Space
- Elementary Chemical Processes
- Chemical Networks
- Grain Formation (Condensation)
- Properties of Grains and Ice
- Grain Chemistry
- Diffuse Clouds, Shocks, Dark Clouds, Star Forming Regions

**Recommended Literature:**

- A. Tielens "The Physics and Chemistry of the Interstellar Medium" Cambridge University Press, 2005  
 S. Kwok "Physics and Chemistry of the Interstellar Medium" University Science Books, 2006  
 D. Rehder "Chemistry in Space, From Interstellar Matter to the Origin of Life" Wiley-VCH, Weinheim, 2010  
 J. Lequeux "The interstellar Medium" Springer, 2004  
 A. Shaw "Astrochemistry" Wiley, 2006  
 D. Whittet "Dust in the Galactic Environment", Taylor and Francis, 2nd edition, 2002

# Module: Elective Advanced Lectures: BCGS Courses

Module No.: physics70d

Course:



## Fundamentals of Molecular Symmetry (E/A/T)

Course No.:

Category	Type	Language	Teaching hours	CP	Semester
Elective	Lecture	English	2	4	ST

### Requirements for Participation:

#### Preparation:

Basic knowledge of quantum mechanics

#### Form of Testing and Examination:

Oral Examination

#### Length of Course:

1 semester

### Aims of the Course:

Understanding the fundamental concepts of representation theory and its application to describe the symmetry of molecules

### Contents of the Course:

The lecture introduces to group theory with special emphasis on representations and their use to describe the symmetry of molecules in high-resolution spectroscopy and in molecular physics generally. The theory is accompanied by a series of "prototypical" examples Topics covered are

- symmetry in general and symmetry of a molecule.
- groups and point groups.
- irreducible representations, characters.
- vanishing integral rule
- the Complete Nuclear Permutation-Inversion (CNPI) group.
- the Molecular Symmetry (MS) group).
- the molecular point group.
- classification of molecular states: electronic, vibrational, rotational, and nuclear spin states
- nuclear spin statistical weights
- hyperfine structure
- non-rigid molecules (inversion, internal rotation)

### Recommended Literature:

Jensen: Script (text of powerpoint presentation files; available during the course)

P. Jensen and P. R. Bunker: The Symmetry of Molecules, in: "Encyclopedia of Chemical Physics and Physical Chemistry" (J. H. Moore and N. D. Spencer, Eds.), IOP Publishing, Bristol, 2001.

P. R. Bunker and Per Jensen: "Molecular Symmetry and Spectroscopy, 2nd Edition," NRC Research Press, Ottawa, 1998 (ISBN 0-660-17519-3).

P. R. Bunker and P. Jensen: "Fundamentals of Molecular Symmetry", IOP Publishing, Bristol, 2004 (ISBN 0-7503-0941-5).

# Module: Elective Advanced Lectures: BCGS Courses

Module No.: physics70d

Course:



Physical biology (T/A)

Course No.:

Category	Type	Language	Teaching hours	CP	Semester
Elective	Lecture with exercises	English	4+2	8	ST

## Requirements for Participation:

### Preparation:

Advanced statistical mechanics

### Form of Testing and Examination:

Oral examination

### Length of Course:

1 semester

## Aims of the Course:

Acquaintance with basic concepts of molecular and evolutionary biology; understanding of statistical issues arising in the analysis of sequence data and the application of methods from statistical physics addressing them.

## Contents of the Course:

Statistics of the genome  
Sequence analysis and sequence alignment  
Evolutionary theory and population genetics  
Theory of bio-molecular networks

## Recommended Literature:

J.H. Gillespie, Population Genetics: A concise guide (Johns Hopkins University Press, 2004)  
R. Durbin, S.R. Eddy, A. Krogh, G. Mitchison, Biological Sequence Analysis: Probabilistic Models of Proteins and Nucleic Acids (Cambridge University Press, 1998)  
F. Kepes, Biological Networks (World Scientific, Singapore 2007)  
D.J. Wilkinson, Stochastic Modelling for Systems Biology (Chapman&Hall, 2006)

# Module: Elective Advanced Lectures: BCGS Courses

Module No.: physics70d

Course:



## Statistical physics of soft matter and biomolecules (T/A)

Course No.:

Category	Type	Language	Teaching hours	CP	Semester
Elective	Lecture with exercises	English	4+2	8	ST

### Requirements for Participation:

#### Preparation:

Advanced statistical mechanics

#### Form of Testing and Examination:

Oral examination

#### Length of Course:

1 semester

### Aims of the Course:

Understanding the molecular structure and mesoscopic properties of various types of soft matter systems, in particular with regard to their role in living cells.

### Contents of the Course:

Colloids, polymers and amphiphiles  
Biopolymers and proteins  
Membranes  
Physics of the cell

### Recommended Literature:

J. K. G. Dhont, An Introduction to Dynamics of Colloids (Elsevier, Amsterdam, 1996).  
M. Doi and S. F. Edwards, The Theory of Polymer Dynamics (Clarendon Press, Oxford, 1986).  
S. A. Safran, Statistical Thermodynamics of Surfaces, Interfaces, and Membranes (Addison-Wesley, Reading, MA, 1994).  
G. Gompper, U. B. Kaupp, J. K. G. Dhont, D. Richter, and R. G. Winkler, eds., Physics meets Biology — From Soft Matter to Cell Biology, vol. 19 of Matter and Materials (FZ Jülich, Jülich, 2004).  
D. H. Boal, Mechanics of the Cell (Cambridge University Press, Cambridge, 2002).

# Module: Elective Advanced Lectures: BCGS Courses

Module No.: physics70d

Course:



## Statistical physics far from equilibrium (T)

Course No.:

Category	Type	Language	Teaching hours	CP	Semester
Elective	Lecture with exercises	English	4+2	8	ST

### Requirements for Participation:

#### Preparation:

Advanced statistical mechanics

#### Form of Testing and Examination:

Oral examination

#### Length of Course:

1 semester

### Aims of the Course:

Understanding the generic behavior of fluctuation-dominated systems far from equilibrium, and acquaintance with the basic mathematical tools used for their description.

### Contents of the Course:

Stochastic methods  
Transport processes  
Scale-invariant growth  
Pattern formation far from equilibrium

### Recommended Literature:

P.L. Krapivsky, S. Redner and E. Ben-Naim: A kinetic view of statistical physics (Cambridge University Press, 2010)  
M. Kardar, Statistical Physics of Fields (Cambridge University Press, 2007)

# Module: Elective Advanced Lectures: BCGS Courses

Module No.: physics70d

Course:



## Disordered systems (T)

Course No.:

Category	Type	Language	Teaching hours	CP	Semester
Elective	Lecture with exercises	English	4+2	8	ST

### Requirements for Participation:

#### Preparation:

Advanced statistical mechanics

#### Form of Testing and Examination:

Oral examination

#### Length of Course:

1 semester

### Aims of the Course:

Understanding the novel types of behaviour that arise in systems with quenched disorder, as well as the specific mathematical challenges associated with their theoretical description.

### Contents of the Course:

Disorder average  
Replica methods  
Percolation  
Phase transitions in disordered systems  
Localization  
Glassy dynamics

### Recommended Literature:

D. Stauffer and A. Aharony, Introduction to Percolation Theory (Taylor & Francis, London 1994)  
K.H. Fischer and J.A. Hertz, Spin Glasses (Cambridge University Press, Cambridge 1991)  
K. Binder and W. Kob, Glassy Materials and Disordered Solids (World Scientific, Singapore 2005)  
T. Nattermann, lecture notes

# Module: Elective Advanced Lectures: BCGS Courses

Module No.: physics70d

Course:



## Nonequilibrium physics with interdisciplinary applications (T)

Course No.:

Category	Type	Language	Teaching hours	CP	Semester
Elective	Lecture with exercises	English	2+1	4	ST

### Requirements for Participation:

#### Preparation:

Statistical mechanics

#### Form of Testing and Examination:

Oral examination or term paper

#### Length of Course:

1 semester

### Aims of the Course:

Acquaintance with basic concepts of nonequilibrium physics; ability to apply the basic methods for the investigation of nonequilibrium problems; application of physics-based models to interdisciplinary problems.

### Contents of the Course:

Principles of nonequilibrium physics

Stochastic systems and their description (master equation, Fokker-Planck equation,...)

Analytical and numerical methods

Nonequilibrium phase transitions

Applications to traffic, pedestrian dynamics, economic systems, biology, pattern formation,...

### Recommended Literature:

A. Schadschneider, D. Chowdhury, K. Nishinari: Stochastic Transport in Complex Systems (Elsevier, 2010)

P.L. Krapivsky, S. Redner, E. Ben-Naim: A Kinetic View of Statistical Physics (Cambridge University Press, 2010)

V. Privman (Ed.): Nonequilibrium Statistical Mechanics in One Dimension (Cambridge University Press, 1997)

N.G. Van Kampen: Stochastic Processes in Physics and Chemistry (Elsevier, 1992)

# Module: Elective Advanced Lectures: BCGS Courses

Module No.: physics70d

Course:



## Probability theory and stochastic processes for physicists (T)

Course No.:

Category	Type	Language	Teaching hours	CP	Semester
Elective	Lecture	English	3	4	WT

### Requirements for Participation:

#### Preparation:

Statistical mechanics on the bachelor level

#### Form of Testing and Examination:

Oral examination or term paper

#### Length of Course:

1 semester

### Aims of the Course:

Acquaintance with probabilistic concepts and stochastic methods commonly used in the theory of disordered systems and nonequilibrium phenomena, as well as in interdisciplinary applications of statistical physics.

### Contents of the Course:

Limit laws and extremal statistics  
Point processes  
Markov chains and birth-death processes  
Stochastic differential equations and path integrals  
Large deviations and rare events

### Recommended Literature:

D. Sornette: Critical Phenomena in Natural Sciences (Springer, 2004)  
N.G. Van Kampen: Stochastic Processes in Physics and Chemistry (Elsevier, 1992)