Theoretical Physics - physics730

Module No.	**physics730**
Category	Elective
Credit Points (CP)	
Semester	8.

Module: Theoretical Physics

Module Elements:

Nr	Course	Course No.	CP	Type	Teaching hours	Semester
1	Ultracold Atomic Gases (E/T)	physics742	6	Lect. + ex.	3+1	WT
2	Group Theory (T)	physics751	7	Lect. + ex.	3+2	WT
3	Superstring Theory (T)	physics752	7	Lect. + ex.	3+2	WT
4	Theoretical Particle Astrophysics (T)	physics753	7	Lect. + ex.	3+2	ST
5	General Relativity and Cosmology (T)	physics754	7	Lect. + ex.	3+2	ST
6	Quantum Field Theory (T)	physics755	7	Lect. + ex.	3+2	ST
7	Critical Phenomena (T)	physics756	7	Lect. + ex.	3+2	ST
8	Effective Field Theory (T)	physics757	7	Lect. + ex.	3+2	WT/ST
9	Quantum Chromodynamics (T)	physics758	7	Lect. + ex.	3+2	WT/ST
10	Quantum Field Theory for Condensed Matter Physics (T)	physics759	5	Lect. + ex.	2+1	WT/ST
11	Computational Physics (T)	physics760	7	Lect. + ex. + proj.	2+2+1	WT/ST
12	Supersymmetry (T)	physics761	6	Lect. + ex.	3+1	WT/ST
13	Transport in mesoscopic systems (T)	physics762	5	Lect. + ex.	2+1	WT/ST
14	Advanced Topics in String Theory (T)	physics763	7	Lect. + ex.	3+2	ST
15	Advanced Topics in Field and String Theory (T)	physics764	7	Lect. + ex.	3+2	ST
16	Advanced Topics in Quantum Field Theory (T)	physics765	7	Lect. + ex.	3+2	ST
17	Physics of Higgs Bosons (T)	physics766	7	Lect. + ex.	3+2	WT
18	Computational Methods in Condensed Matter Theory (T)	physics767	7	Lect. + ex.	3+2	WT/ST
19	General Relativity for Experimentalists (T)	physics768	7	Lect. + ex.	3+2	WT/ST
20	Lattice QCD (T)	physics769	7	Lect. + ex.	3+2	ST/WT
21	Random Walks and Diffusion (T)	physics7502	3	Lect. + ex.	1+1	ST
22	Selected Topics in Modern Condensed Matter Theory (T)	physics7503	7	Lect. + ex.	3+2	WT
23	Theory of Superconductivity and Superfluidity (T)	physics7504	5	Lect. + ex.	2+1	WT/ST

Nr	Course	Course No.	CP	Type	Teaching hours	Semester
24	Relativity and Cosmology I (T)	GR I	8	Lect. + ex.	4+2	WT
25	Relativity and Cosmology II (T)	GR II	8	Lect. + ex.	4+2	ST
26	Quantum Field Theory I (T)	QFT I	8	Lect. + ex.	4+2	ST
27	Quantum Field Theory II (T)	QFT II	8	Lect. + ex.	4+2	ST
28	Geometry in Physics (T)	GiP	8	Lect. + ex.	4+2	ST
29	Topology for Physicists (T)	Topology	6	Lect. + ex.	3+1	ST
30	Fundamentals of Molecular Symmetry (E/A/T)	FundMolSym	4	Lecture	2	ST
31	Physical biology (T/A)	PhysBio	8	Lect. + ex.	4+2	ST
32	Statistical physics of soft matter and biomolecules (T/A)	SoftMatter	8	Lect. + ex.	4+2	ST
33	Statistical physics far from equilibrium (T)	StatPhysNE	8	Lect. + ex.	4+2	ST
34	Disordered systems (T)	Disorder	8	Lect. + ex.	4+2	ST
35	Nonequilibrium physics with interdisciplinary applications (T)	Nonequilibrium	4	Lect. + ex.	2+1	ST
36	Probability theory and stochastic processes for physicists (T)	Probability	4	Lecture	3	WT

Requirements:

Preparation:

Content: Advanced lectures in theoretical physics from the catalogue of selected courses.

Aims/Skills: Preparation for Master's Thesis work; broadening of scientific knowledge

Form of Testing and Examination: Requirements for the submodule examination (written examination): successful work with the exercises

Length of Module: 1 semester

Maximum Number of Participants: ca. 100

Registration Procedure: s. https://basis.uni-bonn.de u. http://bamawww.physik.uni-bonn.de

Note: Note: The students must obtain 18 CP in all out of the modules physics700, -710, -720, -730.

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Ultracold Atomic Gases (E/T) - physics742

Course	**Ultracold Atomic Gases (E/T)**
Course No.	physics742

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

Requirements:

Preparation: Quantum Mechanics

Form of Testing and Examination: Requirements for the examination (written or oral): successful work with the exercises

Length of Course: 1 semester

Aims of the Course: This lecture discusses both the experimental and theoretical concepts of ultra-cold atomic gases.

Contents of the Course:

Almost hundred years ago, in 1924, A. Einstein and S.N. Bose predicted the existence of a new state of matter, the so-called Bose-Einstein condensate. It took 70 years to successfully realize this macroscopic quantum state in the lab using ultracold atomic gases (Nobel prize 2001). The main challenge was to achieve cooling to Nanokelvin temperatures, the coolest temperatures ever reached by mankind. Nowadays, ultracold gases are exciting systems to study a broad range of quantum phenomena. These phenomena range from the direct observation of quantum matter waves and superfluidity over the creation of artificial crystal structures as analogous to solids, to the realization of complex quantum phase transitions of interacting atoms, e.g. the formation of a bosonic Mott-insulator or the BCS superconducting state for Fermions. In this lecture we will discuss both the experimental and theoretical concepts of ultra-cold atomic gases.

Outline: Introduction and revision of basic concepts, Fundamentals of atom-laser interaction

Laser cooling & trapping, Bose-Einstein condensation of atomic gases. Dynamics of Bose-Einstein condensates

Optical lattices: strongly interacting atomic gases and quantum phase transitions

The crossover of Fermi-gases between a BCS superconducting state and a Bose-Einstein condensate of molecules.

Recommended Literature: C. J. Pethick and H. Smith, Bose-Einstein Condensation in Dilute Gases (Cambridge University Press)

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Group Theory (T) - physics751

Course	**Group Theory (T)**
Course No.	physics751

Category	**Type**	**Language**	**Teaching hours**	**CP**	**Semester**
Elective	Lecture with exercises	English	3+2	7	WT

Requirements:

Preparation: physik421 (Quantum Mechanics)

Form of Testing and Examination: Requirements for the examination (written): successful work with the

Length of Course: 1 semester

Aims of the Course: Acquisition of mathematical foundations of group theory with regard to applications in theoretical physics

Contents of the Course:

Mathematical foundations:

Finite groups, Lie groups and Lie algebras, highest weight representations, classification of simple Lie algebras, Dynkin diagrams, tensor products and Young tableaux, spinors, Clifford algebras, Lie super algebras

Recommended Literature:

B. G. Wybourne; Classical Groups for Physicists (J. Wiley & Sons 1974)

H. Georgi; Lie Algebras in Particle Physics (Perseus Books 2. Aufl. 1999)

W. Fulton, J. Harris; Representation Theory (Springer, New York 1991)

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Superstring Theory (T) - physics752

Course	**Superstring Theory (T)**
Course No.	physics752

Category	**Type**	**Language**	**Teaching hours**	**CP**	**Semester**
Elective	Lecture with exercises	English	3+2	7	WT

Requirements:

Preparation:

Quantum Field Theory (physics755)

Group Theory (physics751)

Advanced Theoretical Physics (physics607) / Advanced Quantum Field Theory (physics7501)

Theoretical Particle Physics (physics615)

Form of Testing and Examination: Requirements for the examination (written): successful work with the

Length of Course: 1 semester

Aims of the Course: Survey of modern string theory as a candidate of a unified theory in regard to current research

Contents of the Course:

Bosonic String Theory, Elementary Conformal Field Theory

Kaluza-Klein Theory

Crash Course in Supersymmetry

Superstring Theory

Heterotic String Theory

Compactification, Duality, D-Branes

M-Theory

Recommended Literature:

D. Lüst, S. Theisen; Lectures on String Theory (Springer, New York 1989)

S. Förste; Strings, Branes and Extra Dimensions, Fortsch. Phys. 50 (2002) 221, hep-th/0110055

C. Johnson, D-Brane Primer (Cambridge University Press 2003)

M. Green, J. Schwarz, E. Witten; Superstring Theory I & II (Cambridge University Press 1988)

H.P. Nilles, Supersymmetry and phenomenology (Phys. Reps. 110 C (1984) 1)

J. Polchinski; String Theory I & II (Cambridge University Press 2005)

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Theoretical Particle Astrophysics (T) - physics753

Course	**Theoretical Particle Astrophysics (T)**
Course No.	physics753

Category	Type	Language	Teaching hours	CP	Semester
Elective	Lecture with exercises	English	3+2	7	ST

Requirements:

Preparation:

General Relativity and Cosmology (physics754)

Quantum Field Theory (physics755)

Theoretical Particle Physics (physics615)

Form of Testing and Examination: Requirements for the examination (written): successful work with the exercises

Length of Course: 1 semester

Aims of the Course: Introduction to the current status at the interface of particle physics and cosmology

Contents of the Course:

Topics on the interface of cosmology and particle physics:

Inflation and the cosmic microwave background;

baryogenisis,

Dark Matter,

nucleosynthesis

the cosmology and astrophysics of neutrinos

Recommended Literature:

J. Peacock, Cosmological Physics (Cambridge University Press 1998)

E. Kolb, M. Turner; The Early Universe (Addison Wesley 1990)

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General Relativity and Cosmology (T) - physics754

Course	**General Relativity and Cosmology (T)**
Course No.	physics754

Category	**Type**	**Language**	**Teaching hours**	**CP**	**Semester**
Elective	Lecture with exercises	English	3+2	7	ST

Requirements:

Preparation:

physik221 and physik321 (Theoretical Physics I and II)

Differential geometry

Form of Testing and Examination: Requirements for the examination (written): successful work with the exercises

Length of Course: 1 semester

Aims of the Course: Understanding the general theory of relativity and its cosmological implications

Contents of the Course:

Relativity principle

Gravitation in relativistic mechanics

Curvilineal coordinates

Curvature and energy-momentum tensor

Einstein-Hilbert action and the equations of the gravitational field

Black holes

Gravitational waves

Time evolution of the universe

Friedmann-Robertson-Walker solutions

Recommended Literature:

S.Weinberg; Gravitation and Cosmology (J. Wiley & Sons 1972)

R. Sexl: Gravitation und Kosmologie, Eine Einführung in die Allgemeine Relativitätstheorie (Spektrum Akadem. Verlag 5. Aufl 2002)

L.D. Landau, E.M. Lifschitz; Course of Theoretical Physics Vol.2: Classical field theory (Butterworth-Heinemann 1995), also available in German from publisher Harry Deutsch

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Quantum Field Theory (T) - physics755

Course	**Quantum Field Theory (T)**
Course No.	physics755

Category	**Type**	**Language**	**Teaching hours**	**CP**	**Semester**
Elective	Lecture with exercises	English	3+2	7	ST

Requirements:

Preparation: Advanced quantum theory (physics606)

Form of Testing and Examination: Requirements for the examination (written): successful work with the exercises

Length of Course: 1 semester

Aims of the Course: Understanding quantum field theoretical methods, ability to compute processes in quantum electrodynamics (QED) and many particle systems

Contents of the Course:

Classical field theory

Quantization of free fields

Path integral formalism

Perturbation theory

Methods of regularization: Pauli-Villars, dimensional

Renormalizability

Computation of Feynman diagrams

Transition amplitudes in QED

Applications in many particle systems

Recommended Literature:

N. N. Bogoliubov, D.V. Shirkov; Introduction to the theory of quantized fields (J. Wiley & Sons 1959)

M. Kaku, Quantum Field Theory (Oxford University Press 1993)

M. E. Peskin, D.V. Schroeder; An Introduction to Quantum Field Theory (Harper Collins Publ. 1995)

L. H. Ryder; Quantum Field Theory (Cambridge University Press 1996)

S. Weinberg; The Quantum Theory of Fields (Cambridge University Press 1995)

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Critical Phenomena (T) - physics756

Course	**Critical Phenomena (T)**
Course No.	physics756

Category	Type	Language	Teaching hours	CP	Semester
Elective	Lecture with exercises	English	3+2	7	ST

Requirements:

Preparation:

Advanced quantum theory (physics606)

Theoretical condensed matter physics (physics617)

Form of Testing and Examination: Requirements for the examination (written): successful work with the exercises

Length of Course: 1 semester

Aims of the Course: Acquisition of important methods to treat critical phenomena

Contents of the Course:

Mean Field Approximation and its Improvements

Critical Behaviour at Surfaces

Statistics of Polymers

Concept of a Tomonaga-Luttinger Fluid

Random Systems

Phase Transitions, Critical Exponents

Scale Behaviour, Conformal Field Theory

Special Topics of Nanoscopic Physics

Recommended Literature:

J. Cardy, Scaling and Renormalization in Statistical Physics (Cambridge University Press, 1996)

A. O. Gogolin, A. A. Nersesyan, A.N.Tsvelik; Bosonisation and strongly correlated systems (Cambridge University Press, 1998)

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Effective Field Theory (T) - physics757

Course	**Effective Field Theory (T)**
Course No.	physics757

Category	Type	Language	Teaching hours	CP	Semester
Elective	Lecture with exercises	English	3+2	7	WT/ST

Requirements:

Preparation:

Advanced quantum theory (physics606)

Quantum Field Theory (physics755)

Form of Testing and Examination: Requirements for the examination (written): successful work with the exercises

Length of Course: 1 semester

Aims of the Course: Understanding basic properties and construction of Effective Field Theories, ability to perform calculations in Effective Field Theories

Contents of the Course:

Scales in physical systems, naturalness

Effective Quantum Field Theories

Renormalization Group, Universality

Construction of Effective Field Theories

Applications: effective field theories for physics beyond the Standard Model, heavy quarks, chiral dynamics, low-energy nuclear physics, ultracold atoms

Recommended Literature:

S. Weinberg; The Quantum Theory of Fields (Cambridge University Press 1995)

J.F. Donoghue et al.; Dynamics of the Standard Model (Cambridge University Press 1994)

A.V. Manohar, M.B. Wise; Heavy Quark Physics (Cambridge University Press 2007)

P. Ramond, Journeys Beyond The Standard Model (Westview Press 2003)

D.B. Kaplan, Effective Field Theories (arXiv:nucl-th/9506035)

E. Braaten, H.-W. Hammer; Universality in Few-Body Systems with Large Scattering Length (Phys. Rep. 428 (2006) 259)

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Quantum Chromodynamics (T) - physics758

Course	**Quantum Chromodynamics (T)**
Course No.	physics758

Category	**Type**	**Language**	**Teaching hours**	**CP**	**Semester**
Elective	Lecture with exercises	English	3+2	7	WT/ST

Requirements:

Preparation:

Advanced quantum theory (physics606)

Quantum Field Theory (physics755)

Form of Testing and Examination: Requirements for the examination (written): successful work with the exercises

Length of Course: 1 semester

Aims of the Course:

Understanding basic properties of Quantum Chromodynamics, ability to compute

strong interaction processes

Contents of the Course:

Quantum Chromodynamics as a Quantum Field Theory

Perturbative Quantum Chromodynamics

Topological objects: instantons etc.

Large N expansion

Lattice Quantum Chromodynamics

Effective Field Theories of Quantum Chromodynamics

Flavor physics (light and heavy quarks)

Recommended Literature:

S. Weinberg; The Quantum Theory of Fields (Cambridge University Press 1995)

M.E. Peskin, D.V. Schroeder; An Introduction to Quantum Field Theory (Westview Press 1995)

F.J. Yndurain; The Theory of Quark and Gluon Interactions (Springer 2006)

J.F. Donoghue et al.; Dynamics of the Standard Model (Cambridge University Press 1994)

E. Leader and E. Predazzi; An Introduction to Gauge Theories and Modern Particle Physics (Cambridge University Press 1996)

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Quantum Field Theory for Condensed Matter Physics (T) - physics759

Course	**Quantum Field Theory for Condensed Matter Physics (T)**
Course No.	physics759

Category	**Type**	**Language**	**Teaching hours**	**CP**	**Semester**
Elective	Lecture with exercises	English	2+1	5	WT/ST

Requirements: Quantum mechanics I (physik421)

Preparation:

Quantum mechanics II (physics606), Thermodynamics and statistical physics (physik521)

Can be heard in parallel to physics617: "Theoretical Condensed Matter Physics"

Form of Testing and Examination: Requirements for the examination (written or oral): attendance of and successful work with the exercises

Length of Course: 1 semester

Aims of the Course:

Knowledge of quantum field theory of interacting many-body systems at finite temperature

Knowledge of quantum field theory for non-equilibrium systems

Ability to construct and evaluate perturbation theory using Feynman diagram

Contents of the Course:

Fock space and occupation number representation for bosons and fermions

Green's functions: analytical properties and their relation to observable quantities

Elementary linear response theory

Equations of motion

Perturbation theory in thermodynamic equilibrium: Feynman diagrams, Matsubara technique

Perturbation theory away from equilibrium: Keldysh technique

Infinite resummations of perturbation expansions

Exemplary application to model system

Recommended Literature:

W. Nolting, Grundkurs Theoretische Physik 7: Vielteilchen-Theorie (Springer, Heidelberg 2009)

A. A. Abrikosov, L. P. Gorkov, I. E. Dzyaloshinskii, Methods of Quantum Field Theory in Statistical Physics (Dover, New York 1975 and later editions)

Xiao-Gang Wen, Quantum Field Theory of Many-Body Systems, Oxford Graduate Texts (Oxford University Press, Oxford 2004)

A. Altland and B. Simons, Condensed Matter Field Theory (Cambridge University Press, Cambridge 2006)

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Computational Physics (T) - physics760

Course	**Computational Physics (T)**
Course No.	physics760

Category	Type	Language	Teaching hours	CP	Semester
Elective	Lecture with exercises and project work	English	2+2+1	7	WT/ST

Requirements: Knowledge of a modern programming language (like C, C++)

Preparation: Theoretical courses at the Bachelor degree level

Form of Testing and Examination:

successful participation in exercises,

presentation of an independently completed project

Length of Course: 1 semester

Aims of the Course: ability to apply modern computational methods for solving physics problems

Contents of the Course:

Statistical Models, Likelihood, Bayesian and Bootstrap Methods

Random Variable Generation

Stochastic Processes

Monte-Carlo methods

Markov-Chain Monte-Carlo

Recommended Literature:

W.H. Press et al.: Numerical Recipes in C (Cambridge University Press)

http://library.lanl.gov/numerical/index.html

C.P. Robert and G. Casella: Monte Carlo Statistical Methods (Springer 2004)

Tao Pang: An Introduction to Computational Physics (Cambridge University Press)

Vesely, Franz J.: Computational Physics: An Introduction (Springer)

Binder, Kurt and Heermann, Dieter W.: Monte Carlo Simulation in Statistical Physics (Springer)

Fehske, H.; Schneider, R.; Weisse, A.: Computational Many-Particle Physics (Springer)

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Supersymmetry (T) - physics761

Course	**Supersymmetry (T)**
Course No.	physics761

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

Requirements: Quantum Field Theory I

Preparation:

Form of Testing and Examination: Individual Oral Examinations

Length of Course: 1 semester

Aims of the Course: Teach the students the basics of supersymmetric field theory and how it can be tested at the LHC.

Contents of the Course: Superfields; Supersymmetric Lagrangians; MSSM; Testing the MSSM at the LHC

Recommended Literature:

Theory and phenomenology of sparticles: An account of four-dimensional N=1 supersymmetry in high energy physics.

M. Drees, (Bonn U.) , R. Godbole, (Bangalore, Indian Inst. Sci.) , P. Roy, (Tata Inst.) . 2004. 555pp.

Hackensack, USA: World Scientific (2004) 555 p.

Weak scale supersymmetry: From superfields to scattering events.

H. Baer, (Florida State U.) , X. Tata, (Hawaii U.) . 2006. 537pp.

Cambridge, UK: Univ. Pr. (2006) 537 p.

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Transport in mesoscopic systems (T) - physics762

Course	**Transport in mesoscopic systems (T)**
Course No.	physics762

Category	Type	Language	Teaching hours	CP	Semester
Elective	Lecture with exercises	English	2+1	5	WT/ST

Requirements:

Preparation:

Classical mechanics

Elementary thermodynamics and statistical physics (physik521)

Advanced quantum theory (physics606)

Introductory theoretical condensed matter physics (physics617)

Form of Testing and Examination: Requirements for the examination (written or oral); successful work with the exercises

Length of Course: 1 semester

Aims of the Course:

Understanding essential transport phenomena in solids and mesoscopic systems

Acquisition of important methods for treating transport problems

Contents of the Course:

Linear response theory

Disordered and ballistic systems

Semiclassical approximation

Introduction to quantum chaos theory, chaos and integrability in classical and quantum mechanics

Elements of random matrix theory

Specific problems of mesoscopic transport (weak localization, universal conductance fluctuations,

shot noise, spin-dependent transport, etc.)

Quantum field theory away from thermodynamic equilibrium

Recommended Literature:

K. Richter, Semiclassical Theory of Mesoscopic Quantum Systems, Springer, 2000 (http://www.physik.uni-regensburg.de/forschung/richter/richter/pages/research/springer-tracts-161.pdf)

M. Brack, R. K. Bhaduri, Semiclassical Physics, Westview Press, 2003

S. Datta, Electronic Transport in Mesoscopic Systems, Cambrige University Press, 1995

M. C. Gutzwiller, Chaos in Classical and Quantum Mechanics, Springer, New York, 1990

F. Haake, Quantum signatures of chaos, Springer, 2001

M. L. Mehta, Random matrices, Elsevier, 2004

J. Imry, Introduction to mesoscopic physics, Oxford University Press

Th. Giamarchi, The physics of one-dimensional systems, Oxford University Press

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Advanced Topics in String Theory (T) - physics763

Course	**Advanced Topics in String Theory (T)**
Course No.	physics763

Category	Type	Language	Teaching hours	CP	Semester
Elective	Lecture with exercises	English	3+2	7	ST

Requirements:

Preparation:

Quantum Field Theory (physics755)

Group Theory (physics751)

Advanced Theoretical Physics (physics607) / Advanced Quantum Field Theory (physics7501)

Theoretical Particle Physics (physics615)

Superstring Theory (physics752)

Form of Testing and Examination: active participation in exercises, written examination

Length of Course: 1 semester

Aims of the Course: Detailed discussion of modern string theory as a candidate of a unified theory in regard to current research

Contents of the Course:

Realistic compactifications

Interactions

Effective actions

Heterotic strings in four dimensions

Intersecting D-branes

Recommended Literature:

D. Lüst, S. Theisen: Lectures on String Theory (Springer, New York 1989)

S. Förste: Strings, Branes and Extra Dimensions, Fortsch. Phys. 50 (2002) 221, hep-th/0110055

C. Johnson: D-Brane Primer (Cambridge University Press 2003)

M. Green, J. Schwarz, E. Witten: Superstring Theory I & II (Cambridge University Press 1988)

H.P. Nilles: Supersymmetry and Phenomenology (Phys. Reps. 110C (1984)1)

J. Polchinski: String Theory I & II (Cambridge University Press 2005)

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Advanced Topics in Field and String Theory (T) - physics764

Course	**Advanced Topics in Field and String Theory (T)**
Course No.	physics764

Category	**Type**	**Language**	**Teaching hours**	**CP**	**Semester**
Elective	Lecture with exercises	English	3+2	7	ST

Requirements: Prerequisite knowledge of Quantum Field Theory, Superstring Theory, and General Relativity is helpful.

Preparation:

Quantum Field Theory (physics755)

Advanced Theoretical Physics (physics607) / Advanced Quantum Field Theory (physics7501)

Superstring Theory (physics752)

Form of Testing and Examination: active participation in exercises, oral or written examination

Length of Course: 1 semester

Aims of the Course: An introduction into modern topics in Mathematical High Energy Physics in regard to current research areas

Contents of the Course:

String and Supergravity Theories in various dimensions

Dualities in Field Theory and String Theory

Topological Field Theories and Topological Strings

Large N dualities and integrability

Recommended Literature:

Selected review articles an arXiv.org [hep-th]

J. Polchinski: String Theory I & II

S. Weinberg: Quantum Theory of Fields

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Advanced Topics in Quantum Field Theory (T) - physics765

Course	**Advanced Topics in Quantum Field Theory (T)**
Course No.	physics765

Category	Type	Language	Teaching hours	CP	Semester
Elective	Lecture with exercises	English	3+2	7	ST

Requirements: Prerequisite knowledge of Quantum Field Theory

Preparation:

Quantum Field Theory (physics755)

Advanced Theoretical Physics (physics607) / Advanced Quantum Field Theory (physics7501)

Form of Testing and Examination: active participation in exercises, oral or written examination

Length of Course: 1 semester

Aims of the Course: Covers advanced topics in Quantum Field Theory that are relevant for current developments in the field.

Contents of the Course: TBA

Recommended Literature:

Selected articles on arXiv.org [hep-th]

TBA

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Physics of Higgs Bosons (T) - physics766

Course	**Physics of Higgs Bosons (T)**
Course No.	physics766

Category	**Type**	**Language**	**Teaching hours**	**CP**	**Semester**
Elective	Lecture with exercises	English	3+2	7	WT

Requirements:

Preparation: Theoretical Particle Physics (physics615)

Form of Testing and Examination:

Requirement for the examination (written or oral): successful participation in the exercises

Length of Course: 1 semester

Aims of the Course:

Understanding the physics of electroweak symmetry breaking, and the interpretations of the recently discovered signals for the existence of a Higgs boson

Contents of the Course:

Spontaneous symmetry breaking

The Higgs mechanism

The Higgs boson of the Standard Model

Experimental situation

Extended Higgs sectors

Precision calculations

Recommended Literature:

J. Gunion, H.E. Haber, G.L. Kane and S. Dawson: The Higgs Hunter's Guide (Frontiers of Physics, 2000)

A. Djouadi: Anatomy of Electroweak Symmetry Breaking I (Phys. Rep. 457 (2008) 1, hep-ph/0503173)

A. Djouadi: Anatomy of Electroweak Symmetry Breaking II (Phys. Rep. 459 (2008) 1, hep-ph/0504090)

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Computational Methods in Condensed Matter Theory (T) - physics767

Course	**Computational Methods in Condensed Matter Theory (T)**
Course No.	physics767

Category	**Type**	**Language**	**Teaching hours**	**CP**	**Semester**
Elective	Lecture with exercises	English	3+2	7	WT/ST

Requirements:

Preparation:

Quantum Field Theory (physics755)

Advanced Theoretical Physics (physics607) / Advanced Quantum Field Theory (physics7501)

Advanced Theoretical Condensed Matter Physics (physics638)

Form of Testing and Examination: Active participation in exercises, written examination

Length of Course: 1 semester

Aims of the Course: Detailed discussion of computational tools in modern condensed matter theory

Contents of the Course:

Exact Diagonalization (ED)

Quantum Monte Carlo (QMC)

(Stochastic) Series expansion (SSE)

Density Matrix Renormalization (DMRG)

Dynamical Mean Field theory (DMFT)

Recommended Literature: will be given in the lecture

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General Relativity for Experimentalists (T) - physics768

Course	**General Relativity for Experimentalists (T)**
Course No.	physics768

Category	**Type**	**Language**	**Teaching hours**	**CP**	**Semester**
Elective	Lecture with exercises	English	3+2	7	WT/ST

Requirements:

Preparation: Theoretische Physik I & II, Analysis I & II

Form of Testing and Examination: Weekly homework sets (50% required), Final exam

Length of Course: 1 semester

Aims of the Course: The students shall learn the basics of general relativity and be able to apply it to applications such as experimental tests of GR, GPS, astrophysical objects and simple issues in cosmology.

Contents of the Course:

Review of special relativity

Curved spacetime of GR

Experimental tests of GR

GPS

Black holes

Gravitational waves

Introductory cosmology

Recommended Literature:

GRAVITY, by James Hartle

A FIRST COURSE IN GENERAL RELATIVITY, by Bernard Schutz

EXPLORING BLACK HOLES, by Taylor and Wheeler

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Lattice QCD (T) - physics769

Course	**Lattice QCD (T)**
Course No.	physics769

Category	Type	Language	Teaching hours	CP	Semester
Elective	Lecture with exercises	English	3+2	7	ST/WT

Requirements:

Preparation: Quantum Mechanics 1+2, Quantum Field Theory 1

Form of Testing and Examination: Written / oral examination

Length of Course: 1 semester

Aims of the Course: To give an introduction to the quantum field theory on the lattice

Contents of the Course:

- Introduction: Quantum mechanics on the lattice
- Numerical algorithms
- Spin systems on the lattice: The Ising model
- Scalar field theory on the lattice: Discretization; Perturbation theory; Continuum limit
- Gauge fields: Link variables; Plaquette action; Wilson loop and confinement
- Fermions on the lattice: Fermion doubling; Different formulations for lattice fermions; Axial anomaly; Chiral fermions
- Use of Effective Field Theory methods: Extrapolation in the quark masses; Resonances in a finite volume

Recommended Literature:

J. Smit, Introduction to quantum fields on a lattice: A robust mate, Cambridge Lect. Notes Phys. (2002)

I. Montvay and G. Münster, Quantum Fields on a Lattice, Cambridge Monographs on Mathematical Physics, Cambridge University Press 1994

C. Gattringer and Ch. Lang, Quantum Chromodynamics on the Lattice: An Introductory Presentation

Series: Lecture Notes in Physics, Vol. 788

H.J. Rothe, Lattice Gauge Theories: An Introduction, World Scientific, (2005)

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Random Walks and Diffusion (T) - physics7502

Course	**Random Walks and Diffusion (T)**
Course No.	physics7502

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

Requirements:

Preparation: Quantum mechanics and Thermodynamics

Form of Testing and Examination: Requirements for the (written or oral) examination: Successful work within the exercises

Length of Course: 1 semester

Aims of the Course: The aim of the course is to introduce the student to random processes and their application to diffusion phenomena

Contents of the Course: Basics of probability theory, Master equation and Langevin equation, Law of large numbers and Central Limit Theorem, First passage problems, Large scale dynamics, Dynamical scaling.

Recommended Literature: Will be announced in the first lecture

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Selected Topics in Modern Condensed Matter Theory (T) - physics7503

Course	**Selected Topics in Modern Condensed Matter Theory (T)**
Course No.	physics7503

Category	Type	Language	Teaching hours	CP	Semester
Elective	Lecture with exercises	English	3+2	7	WT

Requirements:

Preparation:

- Introductory Condensed Matter Theory
- Quantum Mechanics
- Statistical Physics

Form of Testing and Examination: oral or written examination

Length of Course: 1 semester

Aims of the Course:

Knowledge of topics of contemporary condensed matter research

Knowledge of theoretical methods of condensed matter physics

Contents of the Course:

Covers topics and methods of contemporary research, such as

- Feynman diagram technique
- Phase transitions and critical phenomena
- Topological aspects of phenomena in condensed matter physic

Recommended Literature:

R. D. Mattuck, A Guide to Feynman Diagrams in the Many-Body Problem

N. Goldenfeld, Lectures on Phase Transitions and the Renormalization Group

B. A. Bernevig, Topological Insulators and Topological Superconductors

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Theory of Superconductivity and Superfluidity (T) - physics7504

Course	**Theory of Superconductivity and Superfluidity (T)**
Course No.	physics7504

Category	Type	Language	Teaching hours	CP	Semester
Elective	Lecture with exercises	English	2+1	5	WT/ST

Requirements:

Preparation: Quantum Mechanics, Thermodynamics and Statistics, Quantum Field Theory

Form of Testing and Examination: Requirements for the (written or oral) examination: Successful participation in the exercises

Length of Course: 1 semester

Aims of the Course: The goal of the course is to introduce students to the theory of superconductivity and superfluidity.

Contents of the Course: Phenomenological theory of basic superconductivity, type I and type II superconductivity, vortices and their dynamics, Meissner-Ochsenfeld Effekt, microscopic theory of superconductivity: Gor'kov equation, BCS theory, Migdal theorem, strong coupling theory of superconductivity: Eliashberg equation, Andreev scattering, Josephson effect, Anderson theorem: impurity scattering, Collective excitations in superconductors and superfluids, Anderson (Higgs) mechanism for the mass generation. Superfluidity in 3He, superconductivity in heavy fermion compounds, high temperature superconductivity and open questions.

Recommended Literature: Will be announced in the first lecture

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Relativity and Cosmology I (T) - GR I

Course	**Relativity and Cosmology I (T)**
Course No.	GR I

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

Requirements:

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

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Relativity and Cosmology II (T) - GR II

Course	**Relativity and Cosmology II (T)**
Course No.	GR II

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

Requirements:

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

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Quantum Field Theory I (T) - QFT I

Course	**Quantum Field Theory I (T)**
Course No.	QFT I

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

Requirements:

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)

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Quantum Field Theory II (T) - QFT II

Course	**Quantum Field Theory II (T)**
Course No.	QFT II

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

Requirements:

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)

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Geometry in Physics (T) - GiP

Course	**Geometry in Physics (T)**
Course No.	GiP

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

Requirements:

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

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Topology for Physicists (T) - Topology

Course	**Topology for Physicists (T)**
Course No.	Topology

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

Requirements:

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)

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Fundamentals of Molecular Symmetry (E/A/T) - FundMolSym

Course	**Fundamentals of Molecular Symmetry (E/A/T)**
Course No.	FundMolSym

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

Requirements:

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).

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Physical biology (T/A) - PhysBio

Course	**Physical biology (T/A)**
Course No.	PhysBio

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

Requirements:

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 alignement

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)

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

Course	**Statistical physics of soft matter and biomolecules (T/A)**
Course No.	SoftMatter

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

Requirements:

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).

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Statistical physics far from equilibrium (T) - StatPhysNE

Course	**Statistical physics far from equilibrium (T)**
Course No.	StatPhysNE

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

Requirements:

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)

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Disordered systems (T) - Disorder

Course	**Disordered systems (T)**
Course No.	Disorder

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

Requirements:

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

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Nonequilibrium physics with interdisciplinary applications (T) - Nonequilibrium

Course	**Nonequilibrium physics with interdisciplinary applications (T)**
Course No.	Nonequilibrium

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

Requirements:

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 desription (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)

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

Course	**Probability theory and stochastic processes for physicists (T)**
Course No.	Probability

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

Requirements:

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)

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