# Elective Courses Theoretical Physics - ECThPhysics

| *Module No.* | **ECThPhysics** |
|---|---|
| *Category* | Elective |
| *Credit Points (CP)* | 7 |
| *Semester* | 1. |

### Module: Elective Courses Theoretical Physics

*Module Elements:*

| Nr | Course | Course No. | CP | Type | Teaching hours | Semester |
|---|---|---|---|---|---|---|
| 1 | Advanced Quantum Theory | physics606 | 7 | Lect. + ex. | 3+2 | WT |
| 2 | Group Theory (T) | physics751 | 7 | Lect. + ex. | 3+2 | WT |
| 3 | General Relativity and Cosmology (T) | physics754 | 7 | Lect. + ex. | 3+2 | ST |
| 4 | Quantum Field Theory (T) | physics755 | 7 | Lect. + ex. | 3+2 | ST |
| 5 | Computational Physics (T) | physics760 | 7 | Lect. + ex. + proj. | 2+2+1 | WT/ST |
| 6 | Advanced Quantum Field Theory (T) | physics7501 | 7 | Lect. + ex. | 3+2 | WT |

**Requirements for Participation:**

for physics606: none

for all other modules: physics606

**Form of Examination:** written examination

**Content:** see with the course

**Aims/Skills:** see with the course

**Course achievement/Criteria for awarding cp's:** successfull 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:** at least 7 cp out of this area must be achieved

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## Advanced Quantum Theory - physics606

| *Course* | **Advanced Quantum Theory** |
|---|---|
| *Course No.* | physics606 |

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

**Requirements for Participation:**

**Preparation:** Theoretical courses at the Bachelor degree level

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

**Length of Course:** 1 semester

**Aims of the Course:** Ability to solve problems in relativistic quantum mechanics, scattering theory and many-particle theory

**Contents of the Course:**

Born approximation, partial waves, resonances

advanced scattering theory: S-matrix, Lippman-Schwinger equation

relativistic wave equations: Klein-Gordon equation, Dirac equation

representations of the Lorentz group

many body theory

second quantization

basics of quantum field theory

path integral formalism

Greens functions, propagator theory

**Recommended Literature:**

L. D. Landau, E.M. Lifschitz; Course of Theoretical Physics Vol.3 Quantum Mechanics (Butterworth-Heinemann 1997)

J. J. Sakurai, Modern Quantum Mechanics (Addison-Wesley 1995)

F. Schwabl, Advanced Quantum Mechanics. (Springer, Heidelberg 3rd Ed. 2005)

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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 for Participation:**

**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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## 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 for Participation:**

**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 for Participation:**

**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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## 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 for Participation:** 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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## Advanced Quantum Field Theory (T) - physics7501

| *Course* | **Advanced Quantum Field Theory (T)** |
|---|---|
| *Course No.* | physics7501 |

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

**Requirements for Participation:**

**Preparation:** 3-year theoretical physics course with extended interest in theoretical physics and mathematics

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

**Length of Course:** 1 semester

**Aims of the Course:** Introduction to modern methods and developments in Theoretical Physics in regard to current research

**Contents of the Course:**

Selected Topics in Modern Theoretical Physics for example:

Anomalies

Solitons and Instantons

Quantum Fluids

Bosonization

Renormalization Group

Bethe Ansatz

Elementary Supersymmetry

Gauge Theories and Differential Forms

Applications of Group Theory

**Recommended Literature:**

M. Nakahara; Geometry, Topology and Physics (Institute of Physics Publishing, London 2nd Ed. 2003)

R. Rajaraman; Solitons and Instantons, An Introduction to Solitons and Instantons in Quantum Field Theory (North Holland Personal Library, Amsterdam 3rd reprint 2003)

A. M. Tsvelik; Quantum Field Theory in Condensed Matter Physics (Cambridge University Press 2nd Ed. 2003)

A. Zee; Quantum Field Theory in a Nutshell (Princeton University Press 2003)

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