Module title	Abbreviation
Quantum Mechanics and Statistical Physics	11-T-QS-152-m01

Module coordinator	Module offered by
Managing Director of the Institute of Theoretical Physics and Astrophysics	Faculty of Physics and Astronomy

ECTS	Method of grading	Only after succ. compl. of module(s)	
6	numerical grade	--	

Duration	Module level	Other prerequisites	
2 semester	undergraduate	--	

Contents

A. Quantum mechanics:
1. History and principles; limits of classical physics; fundamental historical experiments; from classical physics to quantum mechanics (QM);
2. Wave function and Schrödinger equation (SG): SG for free particles; superposition; probability distribution for pulse measurement; correspondence principles: postulates of QM; Ehrenfest theorem; continuity equation; stationary solutions of SG
3. Formalisation of QM: Eigenvalue equations; Physical significance of the eigenvalues of an operator; state space and Dirac notation; representations in state space; tensor products of state spaces;
4. Postulates of QM (and their interpretation): state; measurement; chronological development; energy-time uncertainty;
5. One-Dimensional problems: The harmonic oscillator; potential level; potential barrier; potential well; symmetry properties;
6. Spin-1/2 systems I: Theoretical description in Dirac notation; Spin 1/2 in the homogeneous magnetic field; two-level systems (qubits);
7. Angular momentum: Commutation and rotations; eigenvalues of the angular momentum operators (abstract); solution of the eigenvalue equation in polar coordinates (concrete);
8. Central potential - hydrogen atom: Bonding states in 3D; Coulomb potential;
9. Motion in an electromagnetic field; Hamiltonian operator; Normal Zeeman effect; canonical and kinetic momentum; Gauge transformation; Aharonov-Bohm effect; Schrödinger, Heisenberg and interaction representation; motion of a free electron in a magnetic field;
10. Spin-1/2 systems II: Formulation using angular momentum algebra;
11. Addition of angular momenta;
12. Approximation methods: Stationary perturbation theory (with examples); variational method; WKB method; time-dependent perturbation theory;
13. Atoms with several electrons: Identical particles; helium atom; Hartree and Hartree-Fock approximation; atomic structure and Hund's rules;

B. Statistical Physics and thermodynamics:
0. Principles of statistics: Elements of statistics (central limit theorem and statistics of extremes); micro- and macro-states; probability space (conditional probability, statistical independence);
1. Statistical Physics: Entropy and probability theory; entropy in classical physics; thermodynamic equilibrium in closed and open systems (with energy and / or particle exchange);
2. Ideal systems: Spin systems; linear oscillators; ideal gas;
3. Statistical Physics and thermodynamics: The 1st law; quasi-static processes; entropy and temperature; generalised forces; the second and third law; reversibility; transition from Statistical Physics to thermodynamics;
4. Thermodynamics: Thermodynamic fundamentals relationship; thermodynamic potentials; changes of state; thermodynamic machines (Carnot engine and efficiency); chemical potential;
5. Ideal Systems II, quantum statistics: Systems of identical particles; ideal Fermi gas; ideal Bose gas and Bose-Einstein condensation; grids and normal modes: Phonons;
6. Systems of interacting particles: Approximation methods (mean-field theory, Sommerfeld expansion); computer simulation (Monte Carlo method); interacting phonons (Debye approximation); Ising models (particularities in 1 and 2 dimensions); Yang-Lee-theorems; Van der Waals equation for real interacting gases;

7. Critical phenomena: Scaling laws, critical slowing down, fast variable as Bad (electron-phonon interaction and BCS superconductivity); magnetism (quantum criticality at low temperatures, quantum phase transitions at T = 0); problems of the thermodynamic limit

Intended learning outcomes

The students have knowledge of the methods of Theoretical Physics. They know the principles of mechanics, Statistical Physics and thermodynamics. They are able to discuss the acquired theoretical concepts and to attribute them to bigger physical contexts.

Courses (type, number of weekly contact hours, language — if other than German)

V (4) + V (4)

Method of assessment (type, scope, language — if other than German, examination offered — if not every semester, information on whether module is creditable for bonus)

oral examination of one candidate each (approx. 30 minutes)
Language of assessment: German and/or English

Allocation of places

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Additional information

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Referred to in LPO I (examination regulations for teaching-degree programmes)

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Module appears in

Bachelor' degree (1 major) Nanostructure Technology (2015)
Bachelor' degree (1 major) Nanostructure Technology (2020)