

Module title		Abbreviation
Atoms and Quanta		11-E-A-152-m01
Module coordinator		Module offered by
Managing Director of the Institute of Applied Physics		Faculty of Physics and Astronomy
ECTS	Method of grading	Only after succ. compl. of module(s)
8	numerical grade	--
Duration	Module level	Other prerequisites
1 semester	undergraduate	--
Contents		
<p>1. Structure of atoms: Experimental evidence for the existence of atoms, size of the atom, charges and masses in the atom, isotopes, internal structure, Rutherford experiment, instability of the "classical" Rutherford atom.</p> <p>2. Quantum mechanical foundations of Atomic Physics (short recap of part A.): Light as particle beam, particles as waves, wave functions and probability of presence, uncertainty relation and stability of atoms, energy quantisation in atoms, Franck-Hertz experiment, atomic spectra, Bohr's model and its limitations, non-relativistic Schrödinger equation.</p> <p>3. The non-relativistic hydrogen atom: Hydrogen and hydrogen-like atoms, central potential and angular momentum in QM, Schrödinger equation of the H-atom, atomic orbitals: Radial and angular wave functions, quantum numbers, energy eigenvalues.</p> <p>4. Atoms in external fields: orbital magnetic dipole moment, gyromagnetic ratio, magnetic fields: normal Zeeman effect, electrical fields: Stark effect.</p> <p>5. Fine and hyperfine structure: Electron spin and magnetic spin moment, Stern-Gerlach experiment, Einstein-de Haas effect, glimpse of the Dirac equation (spin as a relativistic phenomenon and existence of antimatter), electron spin resonance (ESR), spin-orbit interaction, relativistic fine structure, Lamb shift (quantum electrodynamics), nuclear spin and hyperfine structure.</p> <p>6. Multi-electron atoms: Helium atom as simplest example, indistinguishability of identical particles, (anti)symmetry with respect to particle exchange, fermions and bosons, relation to spin, Pauli principle, orbital and spin wave function of two-particle systems (spin singlets and triplets), LS- and jj-coupling, Periodic Table of the Elements, Aufbau principles and Hund's rules.</p> <p>7. Light-matter interaction: Time-dependent perturbation theory (Fermi's Golden Rule) and optical transitions, matrix elements and dipole approximation, selection rules and symmetry, line broadening (lifetime, Doppler effect, collision broadening), atomic spectroscopy.</p> <p>8. Laser: Elementary optical processes (absorption, spontaneous and stimulated emission), stimulated emission as light amplification, Einstein's rate equations, thermal equilibrium, non-equilibrium character of a laser: Rate equations, population inversion and laser condition, basic structure of a laser, optical pumping, 2-, 3- and 4-level lasers, examples (ruby laser, He-Ne laser, semiconductor laser).</p> <p>9. Inner-shell excitations and X-ray physics: Generation of x-radiation, bremsstrahlung and characteristic spectrum, X-ray emission for elemental analysis (EDX), X-ray absorption and contrast formation in X-ray images, X-ray photoemission, non-radiative Auger processes, synchrotron radiation, application examples.</p> <p>10. Molecules and chemical bonding: Molecular hydrogen ion (H_2^+) as simplest example: Rigid molecule approximation and LCAO approach, bonding and anti-bonding molecular orbitals, hydrogen molecule (H_2): Molecular orbital vs. Heitler-London approximation, diatomic heteronuclear molecules: covalent vs. ionic bonding, van der Waals bonds and Lennard-Jones potential, (time allowing: conjugated molecules).</p> <p>11. Molecule rotations and vibrations: Born-Oppenheimer approximation, energy levels of the rigid rotator (symmetric and asymmetrical molecules), centrifugal expansion, molecule as (an)harmonic oscillator, Morse potential, normal modes, vibrational-rotational interaction.</p> <p>12. Molecular spectroscopy: Transition matrix elements, vibrational spectroscopy: Infrared spectroscopy and Raman effect, vibrational-rotational transitions: Fortrat diagram, electronic transitions: Franck-Condon principle.</p>		
Intended learning outcomes		
<p>The students understand the basic principles and contexts of quantum phenomena as well as Atomic and Molecular Physics. They understand the ideas and concepts of quantum theory and Astrophysics and the relevant experiments to observe and measure quantum phenomena. They are able to apply mathematical methods to the</p>		

formulation of physical contexts and autonomously apply their knowledge to the solution of mathematical-physical tasks.

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

V (4) + Ü (2)

Module taught in: Ü: German or English

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

written examination (approx. 120 minutes)

Language of assessment: German and/or English

Allocation of places

--

Additional information

--

Workload

240 h

Teaching cycle

--

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

--

Module appears in

Bachelor's degree (1 major) Mathematics (2015)
 Bachelor's degree (1 major) Mathematical Physics (2015)
 Bachelor's degree (1 major) Computational Mathematics (2015)
 Bachelor's degree (1 major, 1 minor) Physics (Minor, 2015)
 Bachelor's degree (1 major) Mathematical Physics (2016)
 Bachelor's degree (1 major) Mathematical Physics (2020)
 Bachelor's degree (1 major, 1 minor) Physics (Minor, 2020)
 Bachelor's degree (1 major) Mathematics (2023)
 exchange program Physics (2023)
 Bachelor's degree (1 major) Mathematical Physics (2024)