Faculty of Natural Sciences

IMPORTANT NOTES

If for one subject you can find several different types (lecture, practice, laboratory) of courses then please choose one and only one course from each type in order to be able to perform the subject's requirements successfully.Civil Engineering courses are on the website seperately. Courses chosen from the offer of Faculty of Civil Engineering will be checked and arranged individually by the departmental coordinator.

Subject code	Subject name	Requirement	ECTS credit
BMETE11AF39	Measurement Control Project Work in LabVIEW Environment	Mid-semester mark	3

Course type	Course code	Course language	Timetable information
Laboratory	T1	English	MON:08:15-12:00(F3213)

Subject code	Subject name	Requirement	ECTS credit
BMETE11AF40	Group Theory for Physicists	Exam	5

Course type	Course code	Course language	Timetable information
Lecture	T0	English	WED:12:15-14:00
Practice	T1	English	FRI:10:15-12:00

The aim of the course is to introduce the principles of group theory to physics students: we learn how the symmetries of a system can be used to describe it, and how the symmetries of nature manifest themselves in laws of physics. We apply the concepts of group and representation theory to practical problems. Theory: Symmetries in nature and physics. Definition and basic properties of groups. Some special groups. Homomorphism, isomorphism. Subgroups, cosets, Lagrange's theorem. Normal subgroup, quotient group, first isomorphism theorem. Conjugate, conjugacy classes, centralizer. Group action, orbit, stabilizer. Representations and their properties, equivalent representations, irreducible representations. Schur's lemma. Character of representations, propertires of characters, character tables. Direct sum of representations and their reduction. Product representations. Lie groups, infinitesimal generators, Lie algebras. Topological properties, universal covering group. Rotation group and its representations. Lorentz group and other matrix groups. Calculation: Description of normal modes, crystals, and quantum mechanical wave functions using group theory. Selection rules. – H.F. Jones: Groups, Representations and Physics (IOP Publishing, 1998)– R.L. Liboff: Primer for Point and Space Groups (Springer, 2003).– M.S. Dresselhaus, G. Dresselhaus, A. Jorio: Group Theory - Application to the Physics of Condensed Matter (Springer, 2008).

Subject code	Subject name	Requirement	ECTS credit
BMETE11AF41	Computer Solution of Technical and Physical Problems	Mid-semester mark	3

Course type	Course code	Course language	Timetable information
Laboratory	T1	English	WED:08:15-10:00(F3213)

Subject code	Subject name	Requirement	ECTS credit
BMETE11AX13	Physics for Civil Engineers	Mid-semester mark	2

Course type	Course code	Course language	Timetable information
Lecture	En0	English	TUE:16:15-18:00(KF88); TUE:16:15-18:00(KF88)

Electric charge, Coulomb's law, electric field, electric flux. Work and energy in electricfields. Electric potential. Capacitors, dielectrics. The piezoelectric effect and itsapplications. The contact potential, its application for temperature measurements.Electric current, Kirchhoff's laws, electric circuits. Magnetic field. The Biot-Savart law,Ampere's law. Forces in magnetic fields, practical applications. Magnetic flux, Faraday'slaw. Practical applications of Faraday's law in sensors. Self induction, mutual induction.Varying electromagnetic fields. Magnetic properties of matter, magnetic circuits. ACcircuits,impedance. Sensors in measurements. Measurement of basic electricquantities. Resistance, capacitance and magnetic induction based sensors. Magnetic,thermoelectric and piezoelectric sensors. Measurement of displacement, force,acceleration. Measurement of flow of gases and liquids. Measurement of liquid level.Measurement of humidity and temperature. Thermovision, thermograms.

Subject code	Subject name	Requirement	ECTS credit
BMETE11AX21	Physics 1	Exam	4

Course type	Course code	Course language	Timetable information
Lecture	VE0	English	MON:14:15-16:00(IB026); TUE:14:15-15:00(IB026)
Practice	VE1	English	TUE:15:15-16:00

Mechanics: Measurements, units, models in physics. Space, time, different frames of references. Motion of a particle in 3D. Newton's laws. Work, kinetic energy, potential energy. Work-energy theorem. Conservation laws in mechanics. Motion in accelerated frames, inertial forces. Newton's law of gravitation. Basics of the theory of special relativity. System of particles, conservation laws. Kinematics and dynamics of a rigid body. Oscillatory motion, resonance. Wave propagation, wave equation, dispersion, the Doppler effect. Thermodynamics: Heat and temperature. Heat propagation. Kinetic theory of gases. Laws of thermodynamics. Reversible and irreversible processes, phase transitions. Entropy, microscopic interpretation of entropy. Elements of statistical physics. Static electric and magnetic fields: Electric charge. Electric field, electric flux, electric potential. Basic equations of electrostatics. Applications of Gauss's law. Capacitors, energy of the static electric field. Dielectrics, boundary conditions. Electric current. Magnetic field. Current carrying wire in magnetic field. Magnetic field produced by an electric current, the Biot-Savart law.

Subject code	Subject name	Requirement	ECTS credit
BMETE11AX23	Physics 1i	Exam	4

Course type	Course code	Course language	Timetable information
Lecture	IE0	English	MON:14:15-16:00(IB026)
Lecture	IT0	English	MON:14:15-16:00(IB026)
Practice	IT1	English	TUE:15:15-16:00(IB026)
Practice	IE1	English	TUE:15:15-16:00(IB026)

KINEMATICS: Motion in one dimension. Motion in two dimensions. Position vector. Average velocity, instantaneous velocity. Average acceleration, instantaneous acceleration. Position, velocity and acceleration in Cartesian and polar coordinates. Projectile motion. Circular motion. Curvilinear motion, tangential and radial accelerations. THE LAWS OF MOTION: Inertial frames. Newton's laws. Force, mass. Normal force, tension, spring force, gravitational force, static and kinetic friction. Free body diagrams. The 1st cosmic speed. WORK AND ENERGY: Work of a varying force. Kinetic energy and the work-energy theorem. Power. POTENTIAL ENERGY: Work done by a spring. Work done by gravity. Work done by kinetic friction. Conservative and nonconservative forces. Potential energy. Conservation of mechanical energy. Changes in mechanical energy in the presence of nonconservative forces. Energy diagrams and the equilibrium of a system. The 2nd cosmic speed. LINEAR MOMENTUM AND COLLISIONS: Linear momentum. Conservation of momentum. Elastic and inelastic collisions in 1D, 2D and 3D. Center of mass. Rocket propulsion. ROTATION OF A RIGID OBJECT ABOUT A FIXED AXIS: Angular velocity vector, angular acceleration vector. Rotational kinetic energy. Moment of inertia. The parallel axis theorem. Torque. Work, power, energy. ANGULAR MOMENTUM: Angular momentum of a particle and a system of particles. Conservation of angular momentum. Gyroscopes. Analogy between translational and rotation motion. KEPLER'S LAWS OF PLANETARY MOTION. STATIC EQUILIBRIUM: Conditions of equilibrium for a rigid object. ACCELERATING FRAMES: Inertia forces: the translational inertia force, the centrifugal force, the Coriolis force, the Euler force. Discussion of motion in the rotating frame of the Earth. OSCILLATORY MOTION: Simple harmonic motion, amplitude, phase constant, angular frequency. Mass attached to a spring. Energy of a simple harmonic oscillator. The simple pendulum. The physical pendulum. The torsional pendulum. Damped oscillations. Forced oscillations. Resonance. WAVES: Transverse and longitudinal waves. Travelling waves in 1D. Reflection and transmission of waves. Sinusoidal waves, wavelength, period, wave number, angular frequency. The linear wave equation in 1D and in 3D. Spherical waves, plane waves. The Doppler effect, discussion using a spacetime diagram. Shock waves. Superposition and interference of sinusoidal waves. Standing waves: strings, air columns, membranes. Beats. SPECIAL RELATIVITY, KINEMATICS: The concept of events and observers. The Galilean transformation. The isotropy of the speed of light in any inertial frame. Einstein's postulates. The synchronization of clocks. Spacetime intervals: timelike, lightlike and spacelike intervals. Minkowski diagrams and worldlines of particles and light. The relativity of simultaneity. Length contraction and proper length. Time dilation and proper time. Causality. The twins paradox, the rod-barn paradox, the two spaceships paradox. The paradox of the identically accelerated twins. The acoustic Doppler effect vs. the electromagnetic Doppler effect. Velocity transformation. SPECIAL RELATIVITY, DYNAMICS: Linear momentum. Newton's 2nd law in its correct form. Kinetic energy. Connection between mass and energy. Relativistic formulas for elastic and inelastic collisions. Relation between the energy and the momentum of a particle. Acceleration due to a constant force. TEMPERATURE: Thermal equilibrium, thermal contact. The 0th law of thermodynamics. Temperature scales. Thermal expansion of solids and liquids. The ideal gas. Extensive and intensive state variables: volume, mass, pressure, temperature. HEAT AND THE 1ST LAW OF THERMODYNAMICS: Internal energy. Heat. Heat capacity, specific heat, molar specific heat. Latent heat. Work done on an ideal gas. The 1st law of thermodynamics. Adiabatic, isobaric, isovolumetric, isothermal processes. THE KINETIC THEORY OF GASES: Relationship between microscopic and macroscopic quantities. Average molecular kinetic energy, pressure, temperature. Degrees of freedom. The equipartition of energy. Specific heat at constant volume and at constant pressure. The adiabatic process on a P-V diagram. Specific heat of solids: the Dulong-Petit law. The distribution of atmospheric density at constant temperature: the Boltzmann distribution. Distribution of molecular speeds in an ideal gas: the Maxwell-Boltzmann distribution. Collision frequency and mean free path. HEAT ENGINES, ENTROPY AND THE 2ND LAW OF THERMODYNAMICS: Heat engines. Thermal efficiency. The 2nd law (Kelvin-Planck formulation). Refrigerators and heat pumps. The coefficient of performance. The 2nd law (Clausius). Reversible and irreversible processes. The Carnot engine. Reduced heat. Entropy. The 2nd law (in terms of entropy change). Change in entropy for an ideal gas and reversible processes. Adiabatic free expansion. Irreversible heat transfer. Macrostates, microstates, thermodynamic probability. Connection between entropy and probability.

Subject code	Subject name	Requirement	ECTS credit
BMETE11BG05	Physics for Engineers	Mid-semester mark	3

Course type	Course code	Course language	Timetable information
Lecture	GE0	English	TUE:13:15-16:00(KF84)
Lecture	GN0	German	

1. Laws of mechanics (basic concepts of kinematics, Newton's laws of motion, force laws).2. Physical conservation laws (momentum, angular momentum). Work, power, kinetic energy. Conservation of mechanical energy.3. Harmonic vibrations and és wave phenomena.4. Electrostatics (Coulomb force, electric field strength and potential, capacity, capacitors).5. Electric current, electric resistance; laws of electric circuits.6. Lorentz force acting on a moving charged particle and electric current in magnetic field; torque for a current carrying loop in magnetic field; magnetic dipole monetum.7. Magnetic field produced by moving charged particles and current carrying wires; magnetic field of solenoids, toroids.8. Faraday's law of induction, inductance., Lenz's law.9. Alternate current, RL, RC, RLC circuits.10. Basic concepts of electromagnetic waves.11. Fundamental phenomena of geometric and wave optics.12. Applications and demonstration experiment for the above chapters of the study.

Subject code	Subject name	Requirement	ECTS credit
BMETE11MF02	Physics Laboratory RP	Mid-semester mark	6

Course type	Course code	Course language	Timetable information
Laboratory	T1	English	MON:08:15-14:00

Laboratory topics for students selecting the Research for Physics majors: Superconductivity (Critical Magnetic Field, Persistent Current, Josephson Effect); Infrared and Raman spectroscopy (Drude spectrum of metals, Fan resonance, C60 molecular excitation); Nanophysics (quantum-Hall phenomenon, conductivity quantization, measurement of atomic transmissions); Charge density waves (nonlinear phenomena, dielectric relaxation); Magneto-optic Kerr effect (magnetics of semiconductors).

Subject code	Subject name	Requirement	ECTS credit
BMETE11MF03	Seminar RP1	Mid-semester mark	2

Course type	Course code	Course language	Timetable information
Practice	T1	English	FRI:12:15-14:00

In this seminar course, each student will process, and give a presentation about, a selected topic in modern physics. Knowledge of classical physics (mechanics, electromagnetism, thermodynamics, statistical physics) as well as basics of modern physics (quantum mechanics, quantum solid-state physics, special relativity) is essential.

Subject code	Subject name	Requirement	ECTS credit
BMETE11MF05	Seminar RP3	Mid-semester mark	2

Course type	Course code	Course language	Timetable information
Practice	T1	English	FRI:12:15-14:00

In this seminar course, each student will process, and give a presentation about, a selected topic in modern physics. Knowledge of classical physics (mechanics, electromagnetism, thermodynamics, statistical physics) as well as basics of modern physics (quantum mechanics, quantum solid-state physics, special relativity) is essential.

Subject code	Subject name	Requirement	ECTS credit
BMETE11MF09	Professional Practice RP	Signature	0

Course type	Course code	Course language	Timetable information
Laboratory	E1	English	

The prerequisit to registering this course is successful completion of the course Independent laboratory RP1. The student performs research tasks related to the diploma work topic for 3 weeks, anytime during the summer holiday, under the guidance of the thesis advisor. The signature indicating completion of this course will be entered to Neptun by the responsible teacher, based on the suggestion of the thesis advisor.

Subject code	Subject name	Requirement	ECTS credit
BMETE11MF26	Physics of Semiconductors	Exam	3

Course type	Course code	Course language	Timetable information
Lecture	T0	English	TUE:12:15-14:00

Introduction: importance of semiconductor physics, modern applications, the limitations of electronics. Charge carriers in semiconductors: band structure, envelope function, lattice distortions, impurities, localized states, shallow and deep levels. Band structure of semiconductors: spin-orbit interaction, kp model. Transport phenomena: quasiclassical dynamics, Boltzmann equation, conductivity, Hall-effect, magnetoresistance, thermoelectric and thermomagnetic phenomena. Diffusive phenomena in semiconductors: inhomogeneous semiconductors, diffusion, diffúzió, Einstein-relation, conduction, Gunn-diode, p-n junction, Zener-diode, tunnel diode, bipolar transistors, JFET. Characterization and engineering of semiconductors: traditional and epitaxial growth, characterization techniques, lattice matching, band-engineering, heterostructures, superlattices, highe electron mobility 2DEG and its high frequency applications, fabrication of semiconductor nanostructures. Field effect and its applications: surface density of states, remote doping, Schottky barrier, Schottky diode, ohmic contacts, MOS-structures, High-k dielectrics, flash memories, solar cells, CCD devices, the fundamentals of CMOS technológy. Optical properties of semiconductors: interaction with light, photoconduction, absorpion of free charge carriers, recombination mechanisms, the principles and applications of light emitting diodes and semiconductor lasers.

Subject code	Subject name	Requirement	ECTS credit
BMETE11MF28	Seminar on Nanophysics 2	Mid-semester mark	2

Course type	Course code	Course language	Timetable information
Practice	T1	English	THU:10:15-12:00

Subject code	Subject name	Requirement	ECTS credit
BMETE11MF38	Chemistry in Nanotechnology	Exam	3

Course type	Course code	Course language	Timetable information
Lecture	T0	English	MON:14:15-16:00

The course presents recent developments in nanotechnology and nanoscience using chemical methods. We will overview measurement techniques for nanosclae building blocks, namely transmission electron microscopy (TEM), scanning electron microscopy (SEM), dynamic light scattering (DLS). Synthesis of nanoparticles: chemical, physical and biological methods and chemical stabilization of nanoparticles. Purification and size and shape-selective purification of nanoparticles. The stability of nanoparticles and interactions existing at nanoscale and using them for the self-assembly of nanoscopic components: nanostuctured materials. Usage of nanoparticles in chemistry, medicine and chemical robotics. Targeted drug delivery applications.

Subject code	Subject name	Requirement	ECTS credit
BMETE11MF45	Superconductivity	Exam	3

Course type	Course code	Course language	Timetable information
Lecture	T0	English	WED:14:15-16:00

Phenomenology of superconductors. Meissner effect, London equations, electrodynamics of superconductors. Bardeen-Cooper-Schrieffer theory: ground state, thermodynamic and transport properties. Ginzburg-Landau theory: free energy, GL equations and their solution, Abrikosov vortices, magnetic properties of Type II superconductors. Josephson effect and its applications. High-temperature superconductors. Prerequisites: Modern Solid State Physics.

Subject code	Subject name	Requirement	ECTS credit
BMETE11MF46	Physics Laboratory NA	Mid-semester mark	6

Course type	Course code	Course language	Timetable information
Laboratory	T1	English	MON:08:15-14:00

In the laboratory, students carry out complex measurement tasks close to the state-of-the-art research results; Measurements are performed using modern measuring instruments used in research laboratories, they learn the computer programming of these measuring instruments and make their own measurement control programs. The measurement protocols follow the style of scientific publications. Planned measurement tasks: Basic skills in computer aided measurement control. Lock-in amplifier programming, quartz sensor testing. Programming of digital oscilloscope, investigation of atomic size nano-wires. Temperature controller and digital multimeter programming, phase transition measurement of high temperature superconductor. Electrochemical layer separation. Surface analytical measurements by SIMS and XPS methods. Assembling and testing a scanning tunnel-microscope. ESR / NMR spectroscopy, investigation of modern magnetic materials by measuring the magneto-optic Kerr effect.

Subject code	Subject name	Requirement	ECTS credit
BMETE11MF47	Seminar NA1	Mid-semester mark	2

Course type	Course code	Course language	Timetable information
Practice	T1	English	FRI:12:15-14:00

Subject code	Subject name	Requirement	ECTS credit
BMETE11MF49	Seminar NA3	Mid-semester mark	2

Course type	Course code	Course language	Timetable information
Practice	T1	English	FRI:12:15-14:00

Subject code	Subject name	Requirement	ECTS credit
BMETE11MF55	Modern Solid State Physics	Exam	7

Course type	Course code	Course language	Timetable information
Lecture	T0	English	THU:08:15-11:00(F3M01)
Practice	T1	English	WED:16:15-18:00

This course describes the behavior of interacting many body systems (mainly electron systems) building on solid state physics and statistical physics knowledge gained while earning a BSC degree in Physics. The following topics are discussed: identical particles, second quantization, interacting electron systems in Bloch and Wannier representation, itinerant ferromagnetism, linear response theory, susceptibility of metals, spin density waves, Bose liquid.

Subject code	Subject name	Requirement	ECTS credit
BMETE11MF58	Nanotechnology and Materials Science	Exam	5

Course type	Course code	Course language	Timetable information
Lecture	T0	English	WED:09:15-12:00(F3M01)

This course gives an introduction to the main trends in nanotechnology and material science. We cover advanced fabrication and measurement techniques by giving examples from state-of-the-art research and development results. The course addresses the following topics: Novel concepts and modern material systems in nanotechnology. Advanced imaging methods from electron microscopy to atomic resolution scanning probe techniques. Top-down nanofabrication techniques: photo and electron beam litography, deposition and special patterning techniques. Bottom-up approaches and self-organizing nanostructures. Semiconductor technology and novel concepts in information technologies. Investigation of electronic and vibrational properties by optical spectroscopy. Advanced surface analysis techniques.

Subject code	Subject name	Requirement	ECTS credit
BMETE15AF36	Quantum Mechanics 2	Exam	2

Course type	Course code	Course language	Timetable information
Lecture	T0	English	MON:12:15-14:00

This course conveys advanced knowledge on Quantum Mechanics according to the following topics: The WKB approach, quasi-classical quantization. Scattering theory, scattering amplitude and cross section, Green functions, Lippmann-Schwinger equation, Born series, method of partial waves. Motion in electromagnetic field, Aharonov-Bohm effect, Landau levels. Time evolution and pictures in Quantum Mechanics (Schrödinger, Heisenberg and Dirac pictures). Adiabatic motion and Berry phase. Relativistic Quantum Mechanics, Klein-Gordon equation, Dirac equation, continuity equation, Lorentz invariance, spin and total angular momentum. Free electron and positron. Non -relativistic limit, spin-orbit interactio.– Franz Schwabl: Quantummechanics, Springer 1990– Albert Messiah: Quantummechanics, Vol. 1-2, North Holland, 1986

Subject code	Subject name	Requirement	ECTS credit
BMETE15AF43	Practical Course in Quantum Mechanics 2	Mid-semester mark	3

Course type	Course code	Course language	Timetable information
Practice	T1	English	FRI:08:15-10:00

Subject code	Subject name	Requirement	ECTS credit
BMETE15AF45	Classical and Quantum Chaos	Exam	3

Course type	Course code	Course language	Timetable information
Lecture	T0	English	

Subject code	Subject name	Requirement	ECTS credit
BMETE15AX03	Physics A3	Exam	2

Course type	Course code	Course language	Timetable information
Lecture	GA	English	TUE:12:15-14:00

This course provides an introduction to the fascinating world of quantum mechanics and atomic physics. The following topics will be discussed: Experimental background, blackbody radiation, photoelectric effect, Compton scattering, spectral lines of atoms, Franck-Hertz experiment. Bohr's model of hydrogen. Schrouml;dinger equation. Harmonic oscillator. Quantum theory of angular momentum, spin. Hydrogen atom. Periodic table. Many-electron systems: Helium atom, Hartree method, Hartree-Fock method. Introduction to solid state physics. Electronic properties of solid states.

Subject code	Subject name	Requirement	ECTS credit
BMETE15MF05	The Physics of One-Dimensional Systems	Exam	3

Course type	Course code	Course language	Timetable information
Lecture	T0	English	WED:16:15-18:00

Subject code	Subject name	Requirement	ECTS credit
BMETE15MF60	Quantum Computing Architectures	Exam	3

Course type	Course code	Course language	Timetable information
Lecture	T0	English	WED:12:15-14:00

Subject code	Subject name	Requirement	ECTS credit
BMETE15MF67	Quantum Optics	Exam	5

Course type	Course code	Course language	Timetable information
Lecture	T0	English	
Practice	T1	English	

The course is an introduction to quantum optics. The topics covered are:1. Coherence in classical optics2. Radiative transitions in quantum matter, atoms and semiconductors3. Photodetection, photon statistics, super- and sub-Poissonian light4. Hanbury-Brown and Twiss interferometry, photon antibunching5. Coherent and squeezed states, Wigner functions6. Resonant light-atom interaction, density states, Rabi oscillation7. Atoms in cavities, Purcell effect, strong coupling8. Cold atoms, Bose condensation, optical lattices9. Quantum cryptography and quantum information10. Entanglement, quantum teleportation, Bell inequalitiesQuantum Optics: an Introduction, Mark Fox, OXFORD MASTER SERIES IN PHYSICS, Oxford University Press 2006, ISBN-13: 978ndash;0ndash;19ndash;856673ndash;1 OP

Subject code	Subject name	Requirement	ECTS credit
BMETE15MF69	Many-Body Theory 2	Exam	4

Course type	Course code	Course language	Timetable information
Lecture	T0	English	
Practice	T1	English	

The course extends the T=0 calculations and diagrammatic technique to finite temperatures. The lectures include- Imaginary time formalism, Matsubara frequencies- Finite temperature Green's functions- Diagrammatic rules, self-energy, Dyson equation- Expressing physical quantities in terms of Green's functions- Lehmann representation, linear response theory- Discussion of the finite temperature interacting electron gas, screening, ring diagrams, interaction correction to the equation of state of an electron gas- Superconductivity at finite temperatures within mean-field theory, normal and anomalous Green's functions- Gap equation and its solution at T=0 and around the transition temperature, density of states, spectral functionA.A. Abrikosov, L.P. Gorkov and I. Dzialoshinskii: Methods of Quantum Field Theory in Statistical Mechanics (1963)G.D. Mahan: Many-Particle Physics (Plenum Press, New York and London, 1981)

Subject code	Subject name	Requirement	ECTS credit
BMETE15MF72	Particle Physics	Exam	5

Course type	Course code	Course language	Timetable information
Lecture	T0	English	TUE:08:15-10:00
Practice	T1	English	TUE:16:15-18:00
Practice	T2	English	TUE:16:15-18:00

Aim of the course: introduction to the fundamental phenomena, models and experiments of particle physics.Topics covered: Overview of scales in Nature. Special relativity. Classification of particles.Klein-Gordon and Dirac equations.Introduction to weak interactions. Beta decay, neutrino. Parity and CP violation. CPT symmetry.Introduction to strong interactions. Isospin, strangeness. SU(3) quark model.Relativistic field theory, canonical formalism, Noether theorem.Basic principles of quantum field theory. Feynman rules.Weak interactions: charged currents, FCNC and GIM mechanism. Flavour mixing. Neutrino oscillations.Non-Abelian gauge theories.Fundamentals of quantum chromodynamics.Spontaneous symmetry breaking, Goldstone theorem. Higgs mechanism.Electroweak unification. The Standard Model. The Higgs boson.Overview of latest developments and open problems in particle physics.David Griffiths: Introduction to Elementary Particles (Wiley-VCH)

Subject code	Subject name	Requirement	ECTS credit
BMETE15MF73	Statistical Physics 2	Exam	5

Course type	Course code	Course language	Timetable information
Lecture	T0	English	FRI:08:15-10:00(F3M01)

Practice	T1	English	TUE:10:15-12:00

Critical phenomena: scaling and critical exponents, fundamentals of renormalization group, correlation functions and Ginzburg criterion. Time-dependent correlations: equilibrium correlations, classical fluctuations, Onsager relation. The density operator, Neumann equation, entropy. Kubo formula, fluctuation dissipation theorem. Non-equilibrium dynamics: Brown motion, diffusion, Langevin equation, Fokker Planck equation. Master equation, H theorem, principle of maximal entropy. Detailed balance and Monte Carlo simulations. Simulated annealing. Interacting quantum systems: Superfluidity, Gross-Pitaevskii equation, quantum gases. Kertész János, Zaránd Gergely, Deák András: Statisztikus Fizika jegyzetDavid Chandler: Introduction to Modern Statistical Physics

Subject code	Subject name	Requirement	ECTS credit
BMETE15MF75	Artificial Intelligence in Data Science	Mid-semester mark	5

Course type	**Course code**	**Course language**	**Timetable information**
Lecture	T0	English	THU:16:15-17:00(F3213)
Practice	T1	English	THU:17:15-19:00(F3213)

Machine learning and neural networks, basics concepts. Linear/logistic regression. Feedforward neural networks, backpropagation. Convolutional neural networks. Practical examples: image recognition, feature detection, natural language processing, temporal data processing, model parameter prediction.

Subject code	Subject name	Requirement	ECTS credit
BMETE91AM35	Basics of Mathematics	Exam	3

Course type	**Course code**	**Course language**	**Timetable information**
Lecture	A0	English	TUE:12:15-14:00

Notations, formal languages, formalism in mathematics. Mathematics and the deductive systems. – Propositional logic. The language of propositional logic. Logical operations, tautologies, logical equivalences. A calculus in propositional logic. Completeness and its importance. – First order logic. Language of first order logic: terms, formulas, quantifiers, equality. Structure, model, algebra. Valuation in a model. The concept of logical consequence. Axioms and theorems. Standard and non-standard models. Calculus, deductive and refutation systems. Completeness. Direct and indirect proofs. On the concepts induction and recursion. – The real numbers as ordered field with suprema. The construction of the real numbers. Non-standard real numbers, infinitesimals. – Set theory. Ordered pairs, relations, functions. Equivalence- and ordering relations. Equivalence of sets. Countable and non-countable cardinalities. Cantor’s diagonalization procedure. Continuum hypothesis. Classes, Russel paradoxon. Well -ordering. The axiom of choice and its importance.– R.G. Exner: An Accompaniment to Higher Mathematics, Springer, 1996

Subject code	Subject name	Requirement	ECTS credit
BMETE91AM36	Introduction to Algebra 1	Exam	9

Course type	**Course code**	**Course language**	**Timetable information**
Lecture	A0	English	TUE:10:15-12:00; WED:09:15-11:00; WED:12:15-14:00
Practice	A1	English	TUE:16:15-17:00(T605); WED:15:15-16:00; THU:14:15-15:00 (H406)

Elementary number theory: integers, divisibility, division with remainders, greatest comon divisor, Euclidean algorithm, irreducible numbers and prime numbers,Fundamental Theorem of Arithmetic. Linear Diophantine equations, modular arithmetic, complete and reduced remainder systems, solution of linear congruences. Complex numbers, algebraic and trigonometric forms, Binomial Theorem. Relation between the complex numbers and the geometry of the plane. Roots of unity, primitive roots of unity. Polynomials with one variable, operations, Horner-scheme, rational root test, Fundamental Theorem of Algebra. Irreducibility of polinomials, Schönemann-Eisenstein criterion. Multivariate polynomials, complete and elementary symmetric polynomials, Viete formulas, roots of cubic polynomials. Systems of linear equations in two and three variables, Gaussian and Gauss-Jordan elimination. R^n and its subspaces. Linear combinations, linear independence, spanned subspace, basis, dimension. Coordinate systems, row space, column space, nullspace of a matrix. Subspace of solutions, solutions in the row space. Matrix operations, inverse matrix, base change matrix. Operations with special matrices, PLU decomposition. Solution of systems of equations with the help of PLU decomposition. Determinant as the volume of the parallelepiped. Basic properties, determinant of a matrix. The notion of permutations, transpositions, cycles, expansion of the determinant. Laplace Expansion Theorem, Mutiplication Theorem of Matrices, formula for the inverse of a matrix, Cramer's Rule. Basic properties of matrix rank. Linear maps and their matrices: the matirx of a projection to a subspace. Similar matrices. Optimal solution of inconsistent systems of linear equations, normal equation, solution in the row space and its minimality. Moore-Penrose generalized inverse.– W. Sierpinski: Elementary theory of numbers, North Holland, 1987.– P. Halmos: Finite dimensional vector spaces, Springer, 1967.– V.V. Prasolov, Problems and Theorems in Linear Algebra, AMS, 1994.– P. Halmos C.D. Meyer: Matrix analysis and applied linear algebra (online textbook)– J. Hefferon: Linear Algebra, free online book– K.H. Rosen: Elementary Number Theory and Its Application, 6th Edition, Pearson, 2010.– C.D. Meyer: Matrix Analysis and Applied Linear Algebra, SIAM, 2000.– K.H. Rosen: Elementary Number Theory, Pearson (2011) (online textbook)

Subject code	Subject name	Requirement	ECTS credit
BMETE91AM38	Algebra 1	Exam	7

Course type	Course code	Course language	Timetable information
Lecture	A0	English	TUE:10:15-12:00; TUE:12:15-13:00
Practice	A1	English	MON:14:15-16:00

Groups, semigroups. Basic properties of groups, group homomorphism, subgroups, cosets. Langrange's Theorem. Examples: diherdral groups, quaternion group, symmetric groups, alternating groups. Decomposition of permutations into disjoint cycles, transpositions. Permutation groups, group actions, transitivity, Cayley's Theorem. Cyclic groups, order of a group element. Cauchy's Theorem. Direct product of groups. Normal subgroups, factor group, Homomorphism Theorem, Noether's Isomorphism Theorems. Important subgroups: derived subgroup, centre, class equation. Subgroup chains, Sylow's Theorems, description of the structure of groups of small size. Nilpotent groups. Fundamental Theorem of Finite Abelian Groups. Free groups. Free algebras over rings, ideals, maximal and prime ideals. Description of the polynomial ring R[x]. Principal ideal domains. Noether rings, unique factorization domains (UFD). Factor rings, field extensions, construction of finite fields. Modules over rings, submodules, module homomorphisms. Semisimple modules and rings. The structure of matrix algebras over division rings. Vector space and module constructions: factor module, direct product, direct sum, tensor product. Linear fuction and the dual space. – P.J. Cameron: Introduction to Algebra, Oxford Science Publications, 1998.– Atiyah-Macdonald: Introduction to commutative algebra, online textbook

Subject code	Subject name	Requirement	ECTS credit
BMETE91AM39	Algebra 2	Exam	4

Course type	Course code	Course language	Timetable information
Lecture	A0	English	MON:10:15-12:00; THU:14:15-16:00

Field extensions, construction and uniqueness of simple algebraic extensions, finite and algebraic extensions. Normal extensions, splitting field, separable extension, finite fields, Wedderburn's theorem, Galois group, irreducibility of the cyclotomic polynomials, Galois groups of radical extensions, Galois correspondence, Fundamental theorem of Galois theory. Applications of Galois theory: Fundamental theorem of algebra, ruler and compass constructions, solvability of equations by radicals, Abel–Ruffini theorem. Existence and uniqueness of algebraic closure, transcendental extensions, transcendence of e, Gelfand-Schneider theorem. - Review of the basic concepts of number theory, Euler ? function. Linear congruences and systems of congruences, binomial congruences of higher degree, discrete logarithm, congruences of prime power moduli. Quadratic congruences, Legendre and Jacobi symbol, quadratic reciprocity. Prime numbers: Euclid's theorem, gaps between primes, Chebyshev's theorem, harmonic series of primes, Dirichlet's theorem for (nk + 1). Arithmetic functions: d(n), ?(n), ?(n). Multiplicativity, convolution, Möbius function, the Möbius inversion formula. Prime number theorem, magnitude of the nth prime, prime tests, Rabin–Miller test, RSA function. Diophantine equations: linear diophantine equations, Pythagorean triples, Fermat's two squares theorem, Gaussian integers. – I. Stewart: Galois Theory, CRC Press, 2003– Niven, Zuckerman, Montgomery: An Introduction to the Theory of Numbers, John Wiley amp; Sons, 1960– M.B. Nathanson: Elementary Methods in Number Theory, Springer, 2000