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
BMETE11AF05	Introduction to Solid State Physics	Exam	2

Course type	**Course code**	**Course language**	**Timetable information**
Lecture	E0	English	

Symmetries of crystals, crystal structures, Bravais lattices. Theory of diffraction, structural factor, atomic scattering factor. X-Ray, electron and neutron scattering experiments. Lattice vibrations in harmonic approximation, dynamical matrix, normal coordinates, dispersion relation, density of states. Quantum description of lattice vibrations, energy and momentum of phonons, experimental measurement of the dispersion relation. Bose-Einstein statistics, heat capacity of solid bodies, Debye approximation. Drude model of electrons, transport and optical properties. Fermi-Driac statistics, Sommerfeld expansion, heat capacity, magnetic susceptibility of an electron gas. Electrons in the periodic potential of a crystal, Bloch electrons. Band structure in the nearly free and tight binding approximation, effective mass.

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	

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	
Practice	T1	English	

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	

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)

Basics of mechanics: the essence of physics, modeling, basic concept of measurement, experiments, standard of units, kinematics, curvilinear motion, circular motion, basic laws of dynamics, Newton’s laws, the problem of weight, special forces, the universality of gravity, planetary motion; friction and air-resistance, work, energy, power, energy conservation and work-energy theorem, linear momentum, impulse, collisions, ballistic pendulum, extended objects, rigid bodies, rotation, angular momentum, moment of inertia. Basics of thermodynamics: pressure, Pascal's law, atmospheric pressure, Archimed's law, buoyancy, flow of gases and liquids, Bernoulli's equation, temperature, thermal equilibrium, absolute scale, thermal expansion, phase-transitions, concept of ideal gases, state-equation of an ideal gas, Joule experiment, work done on/bye the gas, heat exchange, internal energy, equipartition theorem, special processes (isobar, isochor, isotherm, adiabatic), 1st law of thermodynamics.Required knowledge: Basics of undergraduate mathematics (analysis, ordinary differential equations, integration).

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; TUE:14:15-15:00
Lecture	VN0	German	
Practice	VE1	English	TUE:15:15-16:00
Practice	VN1	German	

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	IT0	English	MON:14:15-16:00
Lecture	IE0	English	MON:14:15-16:00
Lecture	IN0	German	
Practice	IE1	English	TUE:15:15-16:00
Practice	IN1	German	
Practice	IT1	English	TUE:15:15-16:00

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	GN0	German	
Lecture	GE0	English	

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	

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	

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	

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
BMETE11MF07	Independent Laboratory RP1	Mid-semester mark	7

Course type	Course code	Course language	Timetable information
Laboratory	E1	English	

The student must have chosen a diploma work topic before registering to this course. The student performs research tasks related to the diploma work topic during the semester, under the guidance of the thesis advisor.

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 prerequisite 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
BMETE11MF14	Theory of Magnetism 2	Exam	3

Course type	Course code	Course language	Timetable information
Lecture	T0	English	

The basic concepts and results from the first part of the course are assumed to be familiar. The following topics are discussed: spontaneous breaking of symmetry in the Heisenberg model, crystal field theory, symmetries and degeneracies, transition metal atoms in cubic crystal field, further symmetry breakings and symmetries, itinerant ferromagnetism, correlated metals, heavy fermions.

Subject code	Subject name	Requirement	ECTS credit
BMETE11MF24	Transport in Complex Nanostructures	Exam	3

Course type	Course code	Course language	Timetable information
Lecture	T0	English	

The course overviews the complex physical phenomena in various hybrid nanostructures with a special emphasis on the following topics of superconductiong nanostructures and spintronics: Introduction to mesoscopic superconductivity. Andreev reflections, BTK theory and mesoscopic proximity effects. Multiple Andreev Reflections. Advanced applications of the Josephson effect. Investigation of Andreev Bound states and the current-phase relation. Andreev Qubits. Superconducting islands, Andreev states in quantum dots. Majorana fermions. Basic concepts of spintronics. Magnetization measurements: magnetic force microscopy, scanning NV center methods, X-ray magnetic circular dichroism, etc. Magnetoresistance phenomena (AMR, GMR, TMR). Spin injection, non-local measurements. Semiconductor spintronics, Rashba effect, spin relaxation, weak anti-localization. Spintronics in quantum dots. Optical spin injection, electron spin resonance. Spin Hall phenomena. Exotic spin structures, multi ferroic materials, skyrmions. Antiferromagnetic spintronics. Spin transfer torque, spin pumping.

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

Course type	Course code	Course language	Timetable information
Lecture	T0	English	

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	

Subject code	Subject name	Requirement	ECTS credit
BMETE11MF30	Interacting Spin Systems in Real Materials	Exam	3

Course type	**Course code**	**Course language**	**Timetable information**
Lecture	T0	English	

The lecture aims at the understanding of the magnetic properties of various Mott insulators, comparing theoretical understanding with experimental measurements. It builds on the "Theory of magnetism II" course (but it can also be followed on its own). Topics: The origin of spin exchanges in materials. Neutron and optical spectra. Excitations in S=1/2 and S=1 spin chains, AKLT state. Spin ladders in a magnetic field. Spin waves in LaCu2O4 and other antiferromagnets, comparing calculated spectra with neutron experiments. Magnetization plateaus in SrCu2(BO3)2 and in frustrated systems, the role of quantum fluctuations and lattice distortions. Ground state degeneration and magnetic monopoles in spin ice. Nematic and multipolar ordering in frustrated systems. Magnetoelectric coupling in multiferroic materials. Realization of the Kitaev model in two and three-dimensional iridium oxides, the role of strong spin-orbit coupling. Magnetic excitations with finite Chern number.

Subject code	Subject name	Requirement	ECTS credit
BMETE11MF32	Independent Laboratory RP2	Mid-semester mark	13

Course type	**Course code**	**Course language**	**Timetable information**
Laboratory	E1	English	

The student must have chosen a diploma work topic before registering to this course. The student performs research tasks related to the diploma work topic during the semester, under the guidance of the thesis advisor.

Subject code	Subject name	Requirement	ECTS credit
BMETE11MF33	Diploma Work RP	Mid-semester mark	30

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 RP2. The student performs research tasks related to the diploma work topic during the semester, under the guidance of the thesis advisor.

Subject code	Subject name	Requirement	ECTS credit
BMETE11MF34	Topological Insulators	Exam	3

Course type	**Course code**	**Course language**	**Timetable information**
Lecture	T0	English	

An important finding of the previous decade is that even the (non-interacting) band theory of electrons in solids can provide fundamental novelties. Topological insulators are crystalline band-insulator materials accomodating conducting – occasionally perfectly conducting – surface states. In this lecture series we use simple models to introduce the topological invariants that are important in band theory, we provide theoretical tools to calculate those, and show how topology protects the surface states from certain perturbations. We provide insight into the general theory of topological insulators, and review a few related experimental arrangements and results.Topics: One-dimensional crystals with chiral symmetry: the Su-Schrieffer-Heeger model. Adiabatic dynamics in quantum mechanics, Berry phase, Chern number. Adiabatic charge pumping in a one-dimensional crystal. Quantum Anomalous Hall effect: the Qi-Wu-Zhang model. Two-dimensional time-reversal-invariant topological insulators: the Bernevig-Hughes-Zhang model. Quantized conductance of two-dimensional topological insulators.Literature: J. Asbóth, L. Oroszlány, A. Pályi: A Short Course on Topological Insulators, (Springer, 2016)Prerequisites: quantum mechanics, band theory of crystalline solids (tight-binding models).

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

Course type	**Course code**	**Course language**	**Timetable information**
Lecture	T0	English	

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	

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	

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	

The students process a leading field of modern physics, and present their part to the others as a scientific talk.

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	

The students process a leading field of modern physics, and present their part to the others as a scientific talk.

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	
Practice	T1	English	

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	

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	

Subject: Based on the undergraduate learning of Quantum Mechanics this course provides advanced knowledge in Quantum Mechanics according to the following topics: Identical particles, He-atom, Hartree- and Hartree-Fock approximation. 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 interaction. Necessary background: basic knowledge in Quantum Mechanics, Electrodynamics and Relativistic Mechanics Literature: – 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	

Subject: Problem solving course related to the lecture in Advanced Quantum Mechanics (Quantum Mechanics 2). The following topics are covered: Identical particles, He-atom, Hartree- and Hartree-Fock approximation. 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 interaction. Necessary background: basic knowledge in Quantum Mechanics, Electrodynamics and Relativistic Mechanics Literature: – Franz Schwabl: Quantummechanics, Springer 1990 – Albert Messiah: Quantummechanics, Vol. 1-2, North Holland, 1986

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

Course type	Course code	Course language	Timetable information
Lecture	GA	English	

Topics:1. Units, definitions. Speed of light.2. Special relativity. Time dilation, length contraction.3. Relativistic mass, energy. Fission and fusion of atoms.4. Boltzmann distribution. Statistical temperature. Entropy.5. Atomic physics. Blackbody radiation. Photoelectric effect. Franck-Hertz experiment.6. 1D Schrödinger equation.7. Solution of 1D problems, (stepwise pot. tunneling, harmonic osc.)8.-9. H atom.10. Stern–Gerlach experiment, Pauli Exclusion Principle.11. Periodic table. Molecules.12. Band structure, conductivity.13. Semiconductor physics.14. Application.Necesssary background: sound knowledge in Mechanics and Electromagnetism, as well as in Mathematics (Analysis and Linear Algebra) at undergraduate level.

Subject code	Subject name	Requirement	ECTS credit
BMETE15MF51	Electronic Structure of Solid Matter	Exam	4

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

Building on the quantum mechanics and solid state physics studies of the Physics BSC education, this course aims to discuss modern theories and methods for the electronic structure of solid matter. The following topics will be outlined: Foundations of the static density functional theory. Variational and pseudopotential methods. Ab initio methods for correlated systems (LDA+U, self-interaction correction, DMFT). Group theory and time reversal in band structure. Surface states, the Rashba-Bycskov effect. Alloy theory, the coherent potential approximation. Metallic (itinerant) magnetism, method of the disordered local moments. Jenő Sólyom: Fundamentals of the Physics of Solids II, Electronic properties (Springer-Verlag Berlin Heidelberg 2009)

Subject code	Subject name	Requirement	ECTS credit
BMETE15MF53	The Physics of Disordered Systems	Exam	4

Course type	Course code	Course language	Timetable information
Lecture	T0	English	

Goal: Disorder is present everywhere around us, and it leads to fascinating phenomena. This course is supposed to cover some of these subjects, including Anderson's localization theory, Coulomb glasses and spin glasses, hysteresis or percolation, Griffith phases, just to name a few. Prerequisites: Quantum mechanics, intermediate level solid state physics, statistical physics. Subjects to be covered: Structural disorder: Polimers, fractals, liquids, glasses, quasicrystals, amorphous metals, granular materials. Percolation. Disordered magnetic systems: Hysteresis, memory effects, and Preisach model. Domain wall motion: mean field theory, Barkhausen noise. Disordered ferromagnets and Griffith phase. Frustrated spin systems and spin glasses: phenomenology, Sherrington -Kirkpatrick model, TAP equations. Replicas, and replica symmetry breaking. Droplet theory. Localization theory: Disordered semiconductors and impurity bands. Localization transition and Anderson's theory. The scaling theory of localization. The Coulomb glass. Critical wave function and multifractal properties. Quantum Hall effect. Quantum glasses: The Bose glass. Fisher scaling and the strong disorder fixed point.

Subject code	Subject name	Requirement	ECTS credit
BMETE15MF71	Advanced Quantum Field Theory	Exam	4

Course type	**Course code**	**Course language**	**Timetable information**
Lecture	T0	English	

This course builds upon Quantum Field Theory (BMETE15MF65, cf. https://physics.bme.hu/BMETE15MF65_kov?language=en) and discusses advanced topics such as(i) renormalization group and scaling;(ii) role of symmetries and their breaking,(iii) advanced functional techniques, non-perturbative methods and their applications,(iv) effective action, effective potential and(v) instantons and quantum tunneling. – M.E. Peskin, D.V. Schroeder: An Introduction to Quantum Field Theory (1995, Addison-Wesley)– C. Itzykson, J-B. Zuber: Quantum Field Theory (2006, Dover Publications)– S. Weinberg: The Quantum Theory of Fields I-III (1995, 1996, 2000, Cambridge University Press)

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

Course type	**Course code**	**Course language**	**Timetable information**
Lecture	T0	English	
Practice	T2	English	
Practice	T1	English	

The course aims to survey the fundamental phenomena, models and experimental methods of particle physics. Topics covered: – Discovery of particles, their properties and classification.– Locality, relativistic fields. Dirac equation. Electromagnetic interaction, gauge invariance.– Strong interaction. Isospin symmetry. Fundamentals of SU (3) quark model of hadrons. Discovery of colour, basics of quantum chromodynamics.– Weak interactions. Neutrinos. Parity and CP violation, CPT invariance. Basics of Fermi theory. FCNC problem, GIM mechanism. The W and Z intermediate bosons and the Higgs particle.– Particle accelerators. Principles of particle detection.– Open problems and perspectives in particle physics. Necessary background: – Advanced mechanics (material of course BMETE15AF32)– Quantum mechanics (material of course BMETE15AF49) Recommended background:– Advanced quantum mechanics (material of course BMETE15AF36)– Group theory (material of course BMETE11AF40) Literature: Lecture notes available online at https://physics.bme.hu/BMETE15MF72_kov?language=en

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

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

Subject:1. Ferromagnetic phase transition: The Ginzburg-Landau theory. Conditional free energy, Ginzburg-Landau functional. 2. Correlation functions and their scaling properties. Universal scaling collapse, and connection between various critical exponents. Classical linear response. 3. Basic ideas of renormalization group. 4. Superfluidity: basic phenomena, the two-fluid model, the Gross-Pitaevskii functional and the time independent Gross-Pitaevskii equations, vortices and healing length. 5. Basic properties of density matrix and density operators, mixed states and pure states. 6. Neumann equation. Spin in an external magnetic field, spin relaxation. 7. The equilibrium structure of the density operator. Neumann entropy and the principle of maximal entropy. 8. Linear response theory. Energy dissipation and generalized susceptibilities, the Kubo formula.9. Kubo formula, classical and quantum noise, and the fluctuation-dissipation theorem. 10. Classical limit of the fluctuation-dissipation theorem, Onsager’s regression hypothesis, and Nyquist-Johnson noise. 11. Markov processes. H-theorem for closed and open systems. 12. Detailed balance, Monte-Carlo simulations, simulated annealing. 13. Langevin equation and Brownian motion. Drift, diffusion, and Eistein relation. 14. Fokker-Planck equations, velocity relaxation of a particle, and diffusion equation. Prerequisite: sound knowledge in Statistical Physics at undergraduate level

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	
Practice	T1	English	

Aim: Introduction to machine learning from a physicist's perspective, with the aim to understand how it works and less emphasis on tricks or parameter optimization.Subjects: Regression. Image segmentation. Decision tree. Deep learning (from scratch in numpy). Higher level implementations (tensorflow, sklearn, keras). Convolutional neural networks. Pre-trained models. Data augmentation. Textual data. Sequential data. Game models.

Subject code	Subject name	Requirement	ECTS credit
BMETE15MF77	Quantum World	Exam	3

Course type	Course code	Course language	Timetable information
Lecture	T0	English	

This course is aimed at students who wish to explore the strange world of the quantum, building upon the usual quantum mechanics course for physics students. Its central question is: what is the world described by the laws of quantum physics like?The main topics are the following: – Paradoxes of quantum theory and their implications;– Quantum probabilities and consistent histories;– Decoherence and the origin of classical behaviour.These issues are approached primarily from a physicist's perspective, nevertheless they are also central to our understanding and interpretation of quantum theory from a philosophical perspective as well.Required knowledge: undergraduate quantum mechanics (material of BMETE15AF49 and BMETE15AF36 courses)Literature:– R. Omnés: The Interpretation of Quantum Mechanics, 1994. Princeton University Press– R.B. Griffiths: Consistent Quantum Theory, 2002. Cambridge University Press.– M. Schlosshauer: Decoherence and the Quantum-To-Classical Transition, 2007. Springer-Verlag Berlin Heidelberg– W.H. Zurek: Decoherence, einselection, and the quantum origins of the classical, Rev. Mod. Phys. 75: 715, 2003. quant-ph/0105127

Subject code	Subject name	Requirement	ECTS credit
BMETE80AX23	Nonlinear Dynamics	Mid-semester mark	2

Course type	Course code	Course language	Timetable information
Lecture	T0	English	

Subject code	Subject name	Requirement	ECTS credit
BMETE80MD00	Nuclear Physics	Exam	5

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

Required prior knowledge: Basics of classical physics and of electrodynamics, basic concepts of quantum mechanics and statistical physics.Syllabus:1. Manipulating electrically charges particles. Thomson and Millikan experiment. Mass spectroscopy and atomic mass unit (mass-doublet method). Spatial resolution, de Broglie formula. Electrostatic accelerators: Cockroft-Walton, Van de Graaf, Tandem Van de Graaf. Resonance accelerators: linear accelerator, cyclotron, synchrotron. LHC.2. Size of the nucleus, Rutherford’s experiment. Hofstädter experiments. Discovery of the neutron and the composition of the nucleus. Angular momentum and parity.3. Stability of the nucleus, nuclear mass, mass defect. Weizsäcker’s semi-empirical binding energy formula. Types and main characteristics of radioactive decays. Exponential decay law, decay chains. (Radioactive dating.)4. Basic theory of beta decays. Fermi’s Golden Rule, Fermi theory of beta-decay, allowed and forbidden transitions. Fermi and Gamow -Teller transitions. Parity non-conservation.5. Anti-neutrino and neutrino detection (Reines Cowan, and Davis experiments). Solar neutrino puzzle and the neutrino oscillation.6. Basic theory of alpha decays. Transition coefficients and alpha spectroscopy factor. Basic theory of gamma-decays. Classification of decay modes: „electric” and „magnetic” transitions. Selection rules.7. Probabilities of gamma-transitions and Weisskopf-units. Sum rules. Measurements of decay probabilities.8. Nuclear models: Fermi-gas, Shell-model.9. Basics of collective model. Rainwater approximation. Vibrations and rotations.10. Nuclear forces. Learning from the deuteron. Basic ideas of Yukawa theory. Charge independency and isospin.11. Nuclear reactions. Kinematics. Elastic scattering (of neutrons). Microscopic and macroscopic cross sections and their two additivities. Differential cross-sections. Excitation functions.12. Partial-wave approximation, Born approximation, Distorted Wave Born Approximation.13. Mechanism and characteristics of nuclear fission. Nuclear chain reaction and some safety considerations.14. Nuclear fusion and the working principles of fusion devices. JET and ITER.

Subject code	Subject name	Requirement	ECTS credit
BMETE80MFAI	Fusion Devices	Mid-semester mark	4

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

Subject code	Subject name	Requirement	ECTS credit
BMETE80MX00	Nuclear and Reactor Physics Fundamentals	Exam	5

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

Subject code	Subject name	Requirement	ECTS credit
BMETE80NE02	Fusion Devices	Mid-semester mark	4

Course type	Course code	Course language	Timetable information
Laboratory	T1-JEL	English	
Lecture	T0-JEL	English	

Subject code	Subject name	Requirement	ECTS credit
BMETE90AX00	Mathematics A1a - Calculus	Exam	6

Course type	Course code	Course language	Timetable information
Lecture	EN-VIK-0	English	MON:12:15-14:00; TUE:12:15-14:00
Lecture	EN-VBK-0	English	WED:16:15-19:00(KF51 (AUD.MAX)); THU:16:15-17:00(KF51 (AUD.MAX))
Lecture	EN-EMK-0	English	TUE:14:15-16:00(KF88); TUE:14:15-16:00(KF88); WED:16:15-18:00(KF88); WED:16:15-18:00(KF88)
Practice	EN-VIK-1	English	WED:10:15-12:00
Practice	EN-EMK-1	English	MON:16:15-18:00(K373); MON:16:15-18:00(K373)
Practice	EN-EMK-3	English	THU:16:15-18:00(K374); THU:16:15-18:00(K374)
Practice	EN-VBK-1	English	THU:17:15-19:00(KF51 (AUD.MAX))

BUDAPEST UNIVERSITY OF TECHNOLOGY AND ECONOMICS BME FACULTY OF ECONOMIC AND SOCIAL SCIENCES (GTK)Analysis Mathematics A1a (BMETE90AX00) Course desciption: obligatory course-unit (6 contact hours) Real functions, Combining Functions, Trigonometric Functions, Exponential Functions, Inverse Functions and Logarithms, Inverse Trigonometric Functions, Limit of a Function and Limit Laws, One-Sided Limits, Continuity of Functions, Differentiation, Tangents and the Derivative at a Point, The Derivative as a Function, Differentiation Rules, The Chain Rule, Linearization, Applications of Derivatives, Extreme Values of Functions, The Mean Value Theorem, Monotonic Functions and the First Derivative Test, Concavity, Asymptotes of Graphs, Curve Sketching, Indeterminate Forms and L'Hôspital's Rule, Optimization, Antiderivatives, Indefinite Integrals, Techniques of Integration: Using Basic Integration Formulas, Integration by Parts, Substitution Method, Trigonometric Integrals, Trigonometric Substitutions, Integration of Rational Functions (by Partial Fractions and Other Methods), The Definite Integral, The Fundamental Theorem of Calculus, Applications of Definite Integrals: Area Between Curves, Volumes, Areas of Surfaces of Revolution, Arc Length.

Subject code	Subject name	Requirement	ECTS credit
BMETE90AX07	Mathematics A3 for Civil Engineers	Exam	4

Course type	Course code	Course language	Timetable information
Lecture	EN0-EA0	English	WED:08:15-10:00(K373); WED:08:15-10:00(K373)
Practice	EN0-EA1	English	WED:10:15-12:00(K373); WED:10:15-12:00(K373)

Differential geometry of curves and surfaces. Scalar and vector fields. Potential theory. Classification of differential equations. Linear differential equation of the second order. Nonlinear differential equations. Systems of linear differential equations. The concept of probability. Discrete random variables an their distributions. Random variables of continuous distribution. Two-dimensional distributions, correlation and regression. Basic notions of mathematical statistics.

Subject code	Subject name	Requirement	ECTS credit
BMETE90AX09	Mathematics A3 for Electrical Engineers	Exam	4

Course type	Course code	Course language	Timetable information
Lecture	EN0	English	THU:10:15-12:00
Practice	EN1	English	TUE:14:15-16:00

Differential geometry of curves and surfaces. Tangent and normal vector, curvature. Length of curves. Tangent plane, surface measure. Scalar and vector fields. Differentiation of vector fields, divergence and curl. Line and surface integrals. Potential theory. Conservative fields, potential. Independence of line integrals of the path. Theorems of Gauss and Stokes, the Green formulae. Examples and applications. Complex functions. Elementary functions, limit and continuity. Differentiation of complex functions, Cauchy-Riemann equations, harmonic functions. Complex line integrals. The fundamental theorem of function theory. Regular functions, independence of line integrals of the path. Cauchy's formulae, Liouville's theorem. Complex power series. Analytic functions, Taylor expansion. Classification of singularities, meromorphic functions, Laurent series. Residual calculation of selected integrals. Laplace transform. Definition and elementary rules. The Laplace transform of derivatives. Transforms of elementary functions. The inversion formula. Transfer function. Classification of differential equations. Existence and uniqueness of solutions. The homogeneous linear equation of first order. Problems leading to ordinary differential equations. Electrical networks, reduction of higher order equations and systems to first order systems.The linear equation of second order. Harmonic oscillators. Damped and forced oscillations. Variation of constants, the inhomogeneous equation. General solution via convolution, the method of Laplace transform. Nonlinear differential equations. Autonomous equations, separation of variables. Nonlinear vibrations, solution by expansion. Numerical solution. Linear differential equations. Solving linear systems with constant coefficients in the case of different eigenvalues. The inhomogeneous problem, Laplace transform. Stability.

Subject code	Subject name	Requirement	ECTS credit
BMETE90AX18	Mathematics A3 for Chemical Engineers and Bioengineers	Exam	4

Course type	Course code	Course language	Timetable information
Lecture	EN-CA0	English	WED:10:15-12:00(ONLINE)
Practice	EN-CA1	English	THU:10:15-12:00(ONLINE)

Subject code	Subject name	Requirement	ECTS credit
BMETE90AX21	Calculus 1 for Informaticians	Exam	6

Course type	Course code	Course language	Timetable information
Lecture	EN0	English	MON:10:15-12:00; TUE:08:15-10:00
Practice	EN1	English	WED:10:15-12:00

Subject code	Subject name	Requirement	ECTS credit
BMETE90AX33	Mathematics EP1	Exam	4

Course type	Course code	Course language	Timetable information
Lecture	EN0	English	
Practice	EN1	English	

This course covers the elements of single variable calculus and linear algebra. Special emphasis is put on the concepts of linear algebra which are later used by architects in structural design. These are the systems of linear equations, matrices and determinants with their properties. From the elements of calculus, the limit of sequences, the differentiation, the integration and applications belong to the course material.

Subject code	Subject name	Requirement	ECTS credit
BMETE90MX33	Mathematics MSc for Civil Engineers	Exam	3

Course type	Course code	Course language	Timetable information
Lecture	EN0-EA0	English	MON:10:15-12:00(KF88); MON:10:15-12:00(KF88)
Practice	EN0-EA1	English	MON:12:15-14:00(KF88)

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

Course type	Course code	Course language	Timetable information
Lecture	A0	English	

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	
Practice	A1	English	

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	
Practice	A1	English	

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	

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

Subject code	Subject name	Requirement	ECTS credit
BMETE93BG01	Mathematics G1	Exam	6

Course type	**Course code**	**Course language**	**Timetable information**
Lecture	EN0	English	

Subject code	Subject name	Requirement	ECTS credit
BMETE93BG03	Mathematics G3	Mid-semester mark	4

Course type	Course code	Course language	Timetable information
Lecture	EN0	English	
Practice	EN1	English	

Subject code	Subject name	Requirement	ECTS credit
BMETETOP101	Mechanics	Exam	0

Course type	Course code	Course language	Timetable information
Lecture	EN0	English	
Practice	EN1	English	

Principles and concepts of classical physics. Vector and scalar quantities. Motion in one and two dimensions. Projectiles. Newton’s laws. Conservative and dissipative forces. Equilibrium of rigid bodies. Levers, pulleys. Torque, circular motion, angular acceleration, moment of inertia. Linear and angular momentum. Work and energy. Energy of rotational motion, work of spring. Laws of conservation. 2 hours of lectures with demonstrational experiments and problem solving practice 4 hours/week.

Subject code	Subject name	Requirement	ECTS credit
BMETETOP102	Electricity	Exam	0

Course type	Course code	Course language	Timetable information
Lecture	A0	English	
Practice	A1	English	

Fundamental phenomena of electrostatics. Electric charge, field strength. Electric potential and voltage. Electric polarization. Capacitors. Energy of the electric field. Electric current. Electric power. Electric circuits. Magnetic field produced by current. Electromagnetic induction. Self induction. Transformers. Alternating current. Electrical oscillations. Electromagnetic waves. 2 hours of lectures with demonstrational experiments and problem solving practice 4 hours /week.

Subject code	Subject name	Requirement	ECTS credit
BMETETOP117	Engineering Sciences	Mid-semester mark	0

Course type	Course code	Course language	Timetable information
Lecture	EN1	English	TUE:10:15-12:00(K221); TUE:10:15-12:00(K221); WED:10:15-12:00(K221); WED:10:15-12:00(K221)