Courses Offered for Incoming Students
by the Faculty of Natural Sciences of BME

Parameters: CODE, lectures / practical lectures / laboratory / f= term mark, v = exam / ECTS credit points, semester

1. Basis Courses for Engineer Students

Physics 1i – Mechanics and Thermodynamics
BMETE11AX03, 3/1/0/v/4, spring

Kinematics. The laws of motion. Work and energy. Potential energy. Linear momentum and collisions. Rotation of a rigid object about a fixed axis. Angular momentum. Kepler's laws of planetary motion. Static equilibrium. Accelerating frames. Oscillatory motion. Waves. Elasticity and fluid mechanics. Temperature. Heat and the 1st law of thermodynamics. The kinetic theory of gases. Heat engines, entropy and the 2nd law of thermodynamics.

Physics 2i – Electrodynamics, Optics and Introductory Quantum Mechanics
BMETE11AX04, 3/1/0/v/4, fall

Electric fields. Gauss' law. Electric potential. Capacitance and dielectrics. Current and resistance, direct current circuits. Magnetic fields. Faraday's law. Inductance. Special relativity, kinematics and dynamics. Light and optics. Interference of light waves. Diffraction and polarization. Lasers and holography. Introduction to quantum physics. Quantum mechanics.

Physics A2 – Electrodynamics and Applications
BMETE15AX02, 2/0/0/v/2, spring

Properties of electric charges. Insulators and conductors. Coulomb's law. The electric field. Superposition. Electric field lines of forces. The electric flux. Gauss's law. Examples: the electric field of some specific charge distributions. The electric field inside and outside of conducting materials. Work and the electric potential. Capacitance and dielectrics. The electric current in various media. Microscopic interpretation of current density and resistivity. Classical and differential Ohm's law. Resistance and energy dissipation. Resistance and temperature. Low temperature behavior of conductors. Footprints of quantum mechanics: residual resistivity, superconductors, semiconductors. Batteries, electromotive force, internal resistance. Wheatstone bridge. Strain gauge. Magnetic fields. The Lorentz law. Sources of magnetic fields. The non-existence of magnetic monopoles. The Biot-Savart law. Ampere's law. Examples: the magnetic field of some specific current distributions. Forces acting on current carrying conductors. Torque, magnetic moment, spin. Electric motor. The microscopic structure of ferromagnets. Faraday's law of induction. Generators, transformers. Inductance, self-inductance. Energy stored in magnetic fields. Displacement current, generalized Ampere's law. Maxwell's equations of the electromagnetic field. Electromagnetic waves. Properties of radio, infrared, visible, ultraviolet, X-ray and gamma radiation. Thermal radiation. Heat conduction. Heat convection. Infrared camera. Measurement of humidity. Solar cells.

Physics A3 – Atomic Physics
BMETE15AX03 2/0/0/v/2, fall

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. Schrödinger 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.

Nuclear Energy and Sustainable Development
BMETE809008, 2/0/0/f/3, spring

In different countries in the world there are different approaches to sustainable development, environmental protection, energy supply and nuclear energy. The possible ways of socio-economical development, sustainability, role of traditional energy sources, renewable and nuclear energy are being heavily discussed in many countries by stakeholders. The lecture will give an overview on current challenges of energy supply, and possible development strategies. The most important topics to be discussed during the semester are the followings: Definition of sustainable development; different international programs, intentions and conventions; trends and structure of energy production and consumption, their role in sustainable development. Traditional energy resources, security of energy supply, the role of different resources in economical development and economical independence; the role of energy production in environmental pollution. Climate change, global warming, Kyoto protocol. Comparison of fossil-, renewable- and nuclear energy production; comparison of different energy technologies from the perspective of environmental, economical impact, security of energy supply; the role of renewable and nuclear energy in energy mix. Development of nuclear energy technologies, basics of nuclear reactors; health effects of ionizing radiation. Nuclear energy systems, nuclear fuel cycle; treatment and disposal of radioactive wastes; environmental impact of nuclear power plants. Nuclear safety; discussion of nuclear accidents (Chernobyl, Fukushima, TMI). Application of nuclear technologies outside the power industry (medical, agricultural, other applications).

Nuclear- and Neutron Physics
BMETE80AE00, 3/1/0/f/4, fall

Main characteristics of the atomic nucleus. Atomic number, mass number, size, mass, binding energy. Semi-empirical binding energy formula. Radioactivity and its relation to the binding energy. Alpha- beta- and gamma-decay. Exponential decay law and half life. Radioactive decay series, radioactive equilibrium. Radioactive dating. Interaction of ionizing radiation with matter. Ionizing power and range of electrically charged particles. Bethe-Bloch equation, Bragg-peak. Interaction of gamma-photons with matter: photo-effect, Compton-scattering, pair-production. Exponential attenuation law. Interaction of neutrons with matter. Nuclear reactions. Particle flux and cross-section. Energy balance of nuclear reactions, exothermic and endothermic reactions, activation energy and energy threshold. Nuclear reaction mechanisms: potential scattering, direct reactions, compound nucleus reactions. Nuclear resonances. Main properties of neutron-induced nuclear reactions. Energy-dependence of neutron-induced nuclear reactions. Elastic scattering of neutrons, slowing down of neutrons. Moderator properties. Two ways of nuclear energy production: nuclear fusion and nuclear fission. The fission process and its characteristics. Energy balance. Fission products and fission neutrons. Prompt neutrons and delayed neutrons. Fundamentals of nuclear chain reaction. Effective neutron multiplication factor. Critical, super-critical and sub-critical systems. Chicago pile, the first critical assembly. Exponential experiment. Short overview of the nuclear reactor types. The nuclear fusion process. The plasma state of the matter. Fusion in the stars and in the Sun. Terrestrial fusion, Lawson criteria. Two ways towards fusion energy: the inertial fusion and the magnetic confined plasma. The Tokamak principle. The ITER.

Mathematics A2a – Vector Functions
BMETE90AX02, 4/2/0/v/6, spring

Solving systems of linear equations: elementary row operations, Gauss-Jordan- and Gaussian elimination. Homogeneous systems of linear equations. Arithmetic and rank of matrices. Determinant: geometric interpretation, expansion of determinants. Cramer's rule, interpolation, Vandermonde determinant. Linear space, subspace, generating system, basis, orthogonal and orthonormal basis. Linear maps, linear transformations and their matrices. Kernel, image, dimension theorem. Linear transformations and systems of linear equations. Eigenvalues, eigenvectors, similarity, diagonalizability. Infinite series: convergence, divergence, absolute convergence. Sewuences and series of functions, convergence criteria, power series, Taylor series. Fourier series: axpansion, odd and even functions. Functions in several variables: continuity, differential and integral calculus, partial derivatives, Young's theorem. Local and global maxima / minima. Vector-vector functions, their derivatives, Jacobi matrix. Integrals: area and volume integrals.

Mathematics A3 for Civil Engineers
BMETE90AX07, 2/2/0/v/4, fall

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 and their distributions. Random variables of continuous distribution. Two-dimensional distributions, correlation and regression. Basic notions of mathematical statistics.

Mathematics A3 for Mechanical Engineers
BMETE90AX10, 2/2/0/f/4, fall

Classification of differential equations. Separable ordinary differential equations, linear equations with constant and variable coefficients, systems of linear differential equations with constant coefficients. Some applications of ODEs. Scalar and vector fields. Line and surface integrals. Divergence and curl, theorems of Gauss and Stokes, Green formulae. Conservative vector fields, potentials. Some applications of vector analysis. Software applications for solving some elementary problems.

Mathematics A3 for Electrical Engineers
BMETE90AX09, 2/2/0/v/4, fall

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.

Mathematics A4 – Probability Theory
BMETE90AX08, 2/2/0/f/4, fall

Notion of probability. Conditional probability. Independence of events. Discrete random variables and their distributions (discrete uniform distribution, classical problems, combinatorial methods, indicator distribution, binomial distribution, sampling with/without replacement, hypergeometrical distribution, Poisson distribution as limit of binomial distributions, geometric distribution as model of a discrete memoryless waiting time). Continuous random variables and their distributions (uniform distribution on an interval, exponential distribution as model of a continuous memoryless waiting time, standard normal distribution). Parameters of distributions (expected value, median, mode, moments, variance, standard deviation). Two-dimensional distributions. Conditional distributions, independent random variables. Covariance, correlation coefficient. Regression. Transformations of distributions. One- and two-dimensional normal distributions. Laws of large numbers, DeMoivre-Laplace limit theorem, central limit theorem. Some statistical notions. Computer simulation, applications.

Linear Algebra
BMETE91AX31, 3/1/0/v/4, fall and spring

Vectors in 2- and 3-dimensions, R^n, linear combination, linear independence. Vector spaces. Solving system of linear equations by elimination. Matrices, column space, nullspace, rank, basis and dimension, the four fundamental subspaces. Matrix operations, inverse of matrices, LU-decomposition. Linear transformations, matrices of linear transformations, change of basis. Determinant as a multilinear function, as a sum of products, by cofactor expansion. Inner product, orthogonalization, QR-decomposition, least squares and data fitting. Eigenvalues, diagonalization, orthogonal diagonalization, spectral decomposition. Complex and real matrices, symmetric matrices, positive definite matrices, quadratic forms. Singular Value Decomposition and other matrix decompositions. Jordan canonical form. Applications in mathematics (derivative as a linear transformation, solving differential equations...) Applications in engineering (graphs and networks, Markov matrices, Fast Fourier Transform, data mining.)

Numerical Methods for Engineers
BMETE91AX30, 1/1/0/f/2, fall and spring

Basic notions of numerical computations (types of errors, error propagation). Fundamentals of metric spaces, Banach's fixed point theorem. Iterative methods for solving nonlinear equations and their convergence properties (regula falsi, Newton's method, successive approximation). Extreme value problems (e.g., gradient method for nonlinear systems of equations). Systems of linear equations (some iterative methods, least square solution for over- and underdetermined systems). Orthogonal systems of functions (dot product for functions, orthogonal polynomial systems for different dot products, Chebyshev- and Legendre polynomials). Interpolation and approximation of functions (by polynomials, by orthogonal system of functions). Numerical differentiation and integration (Gauss quadratures).

2. Additional Courses

Nobel Prize Physics in Everyday Application
BMETE11AX14, 2/0/0/v/2, fall

Scope: The amazing and explosive development of technology is our everyday experience in various fields of life from informatics and medicine. It is less well known how this development is supported by scientific research. As an example a notebook computer applies numerous Nobel Prize awarded ideas, like the integrated circuits (2000), semiconducting laser (2000), liquid crystal display (1991), CCD camera (2009), GMR sensor of the hard disk (2007) and several further achievements from earlier days of quantum mechanics and solid state physics. The course is intended to give insight to a range of amazing everyday applications that are related to various Nobel Prizes with a special focus on recent achievements. The topics below are reviewed at a simplified level building on high school knowledge of physics. Syllabus: Textbook applications from the early days of Nobel prizes: wireless broadcasting, X-rays, radioactivity, etc. Optics in everyday application: lasers, CCD cameras, optical fibers, liquid crystal displays, holography. Quantum physics: from atom models to quantum communication. Measurements with utmost precision: application of Einstein's theory of relativity in GPS systems, atomic clocks, Michelson interferometry, etc. Nuclear technology from power plants to medical and archeological applications. Advanced physics in medicine: magnetic resonance imaging, computer tomography and positron emission tomography. Semiconductors from the first transistor to mobile communication. Fundamental tools of nanotechnology (scanning probe microscopes, electron beam lithography, etc.) Spintronics from the discovery of electron spin to everyday application in data storage devices. Exotic states of solids in everyday application: superconducting magnets and levitated trains. Towards „all carbon electronics”: envisioned and already realized applications of grapheme.

Nobel Prize Physics in Everyday Application – Laboratory Exercise
BMETE11AX15, 0/0/2/f/2, winter

Introduction (safety regulations, basic knowledge about the measurement apparatus, data evaluation and data processing). Measurement of submicron displacements with a Michelson interferometer. Investigation of liquid crystal display working principle. Investigation of spin-valve magnetic sensors/exploring the atomic nature of matter in an STM-like setup (to be specified later). Nuclear power plant simulator exercise. Extended visit to the training reactor.

Laser Physics
BMETE12MX00, 3/1/0/v/4, fall

Maxwell-equations and electromagnetic waves. Fundamentals of quantum mechanics, Schrödinger-equation, particle in a potential box, H atom, He atom, molecules. Electron states in solids, conductors, insulators and semiconductors. Fundamentals of statistical physics. Theory of laser oscillation. Interaction of photons with atoms, line-broadening mechanisms, coherent amplification, optical resonator, conditions of continuous wave and transient laser oscillation. Properties of laser beams. Laser types. Laser applications.

Physics 3 – Modern Physics
BMETE11MX01, 3/1/0/v/5, spring

The course covers introduction to two disciplines: Quantum Mechanics and Solid State Physics. After the semester students should be able to understand the basic principles behind these two disciplines and solve some simple problems. This will contribute to the understanding of the workings of modern electronics and nanotechnology.

Hungarian Mathematics in the Progress of the World
BMETE93AX12, 2/0/0/v/2, fall and spring

The Hungarian mathematics (along with theoretical physics) has been an important player in the world's technical development during the last centuries. In the fifteenth century Regiomontanus (a mathematics professor of Hungary) started trigonometry and a modern astronomy which led to the Copernican revolution. In the sixteenth century, Dürer (whose father was a Magyar) started descriptive geometry. In the early nineteenth century Bolyai created a brand new geometry. During the first half of the twentieth century some Magyars (namely Teller, Szilárd, and Von Neumann) helped the computations in the United States to create nuclear weapons. Another Hungarians (Kármán and Szebehely) made very important calculations for appropriate flying of airplanes and spaceships. In mathematical optimization theory the Hungarian names Farkas, König, Vonneumann, Egerváry are very well-known. In numeric mathematics and in computer science, the famous mathematicians Riesz, Fejér, Erdös, and Lovász are all from Hungary. This course will constitute of separate lectures linked together. Different weeks will be devoted to different subjects. The best lecturers of mathematics at our university will be asked the give the separated lectures with a lot of figures, photos, and plenty of examples, explanations and nice stories. At the end of the semester the students will fill in a multiple-choice test to get a grade. During the semester some homework assignments will also be to do.

Mathematics M1 – Differential Equations and their Numerical Methods
BMETE90MX46, 4/2/0/v/8, spring

Ordinary differential Equations. Well-posedness of initial value problems. Various types of stability. Stability of equilibria and Liapunov functions. Phase space analysis near equilibria and periodic orbits. The loss of stability in parametrized families of equations. Explicit/implicit Euler and Runge-Kutta methods. Comparing explicit and approximate dynamics, error estimate between exact and approximate solutions. Retarded equations. Partial differential equations. The standard initial and boundary value problems of mathematical physics. Separation of variables. Fourier series as coordinate representation in Hilbert space. The method of finite differences for the heat equation: error estimate and the maximum principle.

Global Optimization
BMETE93MM00, 3/1/0/f/5, spring

Different forms of global optimization problems, their transformation to each other, and their reduction to the one-dimensional problem. Classifications of the global optimization problems and methods. Lagrange function, Karush–Kuhn–Tucker theorem, convex and DC programming. Multi-start and stochastic methods for global optimization, their convergence properties and stopping criteria. Methods based on Lipschitz constant, and their convergence properties. Branch and Bound schema, methods based on interval analysis, automatic differentiation. The DIRECT method and its properties. Projected gradient method, penalty and barrier function methods for constrained problems. Powell method and Nelder and Mead method for non-differentiable objective functions. Multi-objective optimization.

Linear Programming
BMETE93MM01, 3/1/0/v/5 fall

System of linear equations: solution and solvability. Gauss-Jordan elimination method. System of linear inequalities. Alternative theorems, Farkas lemma and its variants. Solution of system of linear inequalities using pivot algorithms. Convex polyhedrons. Minkowski-, Farkas- and Weyl-theorems. Motzkin-theorem. Primal-dual linear programming problems. Feasible solution set of linear programming problems. Basic solution of linear programming problem. Simplex algorithm. Cycling, anti-cycling rules: Bland's minimal index rule. Lexicographic simplex method. Lexicographic dual simplex method. Two phase simplex method. Revised simplex method. Sensitivity analysis. Decomposition methods: Dantzig-Wolfe. Interior point methods of linear programming problems. Self-dual linear programming problem. Central path and its uniqueness. Computation of Newton-directions. Analytical center, Sonnevend-theorem. Dikin-ellipsoid, affine scaling primal-dual interior point algorithm and its polynomial complexity. Tucker-model, Tucker theorem. Rounding procedure. Khachian's ellipsoid algorithm. Karmarkar's potential function method. Special interior point algorithms.

"Mathematica" with Applications
BMETE927206, 0/0/2/f/3, fall

The goal of the course is to provide an introduction to the mathematical program package "Mathematica". Its numerical, symbolic and graphic capabilities are shown together with tools to create interactive documents, animation etc. Elements of programming paradigms such as functional, procedural, pattern matching and recursive programming are shown. The student has to submit homeworks regularly, and to create an engineering application of the program and to present it in a lecture at the end of the semester. The interested student should have a look at the following website: http://demonstrations.wolfram.com

Geometry of Curves, Surfaces and Transformations for Engineers
BMETE94AX11, 2/0/0/v/2, spring

Curves: parametrization, parametrized curves, regular curves, arc length, curvature, torsion, fundamental theorem of the local theory of curves, Frenet formulas, global properties of plane curves: the isoperimetric inequality and the four-vertex theorem. Regular surfaces: changes of parameter, differential functions on surfaces, tangent plane, first fundamental form, orientation of surfaces, second fundamental form, Gauss map, Meusnier theorem, Rodrigues theorem, principal curvatures, Gaussian curvature, Minkowskian curvature, Euler formula, Dupin indicatrix, conformal map, equations of compatibility.

Operations Research
BMETE90MX50, 3/1/0/v/5, spring

The course is concerned with operations research models in the economy. It also provides the necessary theoretical background for developing solutions of the problems arising in the field of operational research. It teaches the use of modeling languages, optimization packages in operations research. Economic models resulting in linear programming problems (e.g. portfolio selection problem). Different forms of the linear programming problems. Graphical solution. Recollection of results from linear algebra. Elementary basis transformation, basic solution. The simplex method for the normal form of the linear programming problems. Possibility of alternative optimal solutions. Unbounded problems. The dual problem. Meaning of the dual problem. Duality theorems. Two phase simplex algorithm. The dual of a general linear programming problem. The theorem of complementarity. Economic interpretation shadow prices. Balanced transportation problem. Simplex tableau of the transportation problem. The dual problem. Optimality criterion. The non-balanced problem. Prohibitive tariffs. Complex transportation problem. The assignment problem. Network models: shortest path problem. Basic models of network programming: maximal flow, minimal spanning tree. Critical Path Method (CPM), network design. Integer linear programming models. The branch and bound method. Inventory models. Applications of the scheduling theory. Firm allocation models. Seminars: The use of Excel solver. Modeling languages: GAMS, AMPL. Solvers: XpressMP, CPLEX. Mixed programming problems.

Child Language
BMETE47MC12, 2/2/0/v/5, fall

The subject of the course is the question of how young children acquire their first language. What is it that allows all typically developing human beings to learn the abstract complex system of human language in the absence of explicit instruction? How can we explain the apparent independence of the process of language acquisition from the development of other human cognitive functions? The lab sessions will allow the students to gain some hands-on experience in designing experiments to study child language and in analyzing corpus data. The seminars introduce methods used in psycholinguistic research. We would also like to draw attention to potential methodological confounds and to teach students how to chose the method that fits their research question and target population best. The course will also give a general introduction to designing and running experiments, as well as analyzing the results and drawing conclusions. The review of methods will include methods used in studies of the mental lexicon (naming, picture selection, phoneme and category monitoring, lexical decision, etc.) studies of sentence processing (off-line and online), priming, and methods used in language acquisition research. We will also talk about working with natural language samples and databases, and give a thematic overview. Topics: The stages of language development. Human language and individual languages. The theoretical problems of language acquisition: input sparseness, no negative evidence, incomplete or erroneous input. Theoretical solutions to the problems. Empirical evidence. Language acquisition under atypical circumstances. Models of language acquisition. Computational models of language acquisition.

3. Special Courses in Mathematics

Random Matrix Theory and Its Physical Applications
BMETE15MF10, 2/0/0/v/3, fall

Random matrix theory provides an insight of how one can achieve information relatively simply about systems having very complex behavior. The subject based on the knowledge acquired in quantum mechanics and statistical physics together with some knowledge of probability theory provides an overview of random matrix theory. The Dyson ensembles are defined with their numerous characteristics, e.g. the spacing distribution, the two-level correlation function and other quantities derived thereof. Then the thermodynamic model of levels is obtained together with several models of transition problems using level dynamics. Among the physical applications the universality classes are identified in relation to classically integrable and chaotic systems. The problem of decoherence is studied as well. Then the universal conductance fluctuations in quasi-onedimensional disordered conductors are investigated. Other models are investigated: the disorder driven Anderson transition and the random interaction model of quantum dot conductance in the Coulomb-blockade regime. We use random matrix models to investigate chirality in two-dimensional and Dirac systems and the normal-superconductor interface. The remaining time we cover problems that do not belong to strictly physical systems: EEG signal analysis, covariance in the stock share prize fluctuations, mass transport fluctuations, etc.

Descriptive Geometry
BMETE90AX06, 1/2/0/v/3, fall

Mutual positions of spatial elements. Orthogonal projections in Monge's representation, auxiliary projections. Intersection of polygons and polyhedra. True measurements of segments and angles. Perpendicular lines and planes. Projection of the circle. Representation of rotational surfaces and their intersections with a plane. Axonometric view. Construction of the helix.

Commutative Algebra and Algebraic Geometry
BMETE91MM01, 3/1/0/f/5, fall

Closed algebraic sets and their coordinate rings, morphisms, irreducibility and dimension, Hilbert Nullstellensatz, the correspondence between radical ideals and subvarieties of affine space. Monomial orders, Gröbner bases, Buchberger algorithms, computations in polynomial rings. From regular functions to rational maps, local rings, fundamentals of sheaf theory, ringed spaces. Projective space and its subvarieties, homogeneous coordinate ring, morphisms, the image of a projective variety is closed. Geometric constructions: Segre and Veronese embeddings, Grassmann varieties, projection from a point, blow-up. Dimension of affine and projective varieties, hypersurfaces. Smooth varieties, Zariski tangent space, the Jacobian condition. Hilbert function and Hilbert polynomial, examples, computer experiments. Basic notions of rings and modules, chain conditions, free modules. Finitely generated modules, Cayley-Hamilton theorem, Nakayama lemma. Localization and tensor product. Free resolutions of modules, Gröbner theory of modules, computations, Hilbert syzygy theorem.

Fourier Analysis and Function Series
BMETE92MM00, 3/1/0/v/5, fall

Completeness of the trigonometric system. Fourier series, Parseval identity. Systems of orthogonal functions, Legendre polynomials, Haar and Rademacher systems. Introduction to wavelets, wavelet orthonormal systems. Fourier transform, Laplace transform, applications. Convergence of Fourier series: Dirichlet kernel, Dini and Lischitz convergence tests. Fejer's example of divergent Fourier series. Fejer and Abel-Poisson summation. Weierstrass-Stone theorem, applications. Best approximation in Hilbert spaces. Müntz theorem on the density of lacunary polynomials. Approximations by linear operators, Lagrange interpolation, Lozinski-Harshiladze theorem. Approximation by polynomials, theorems of Jackson. Positive linear operators Korovkin theorem, Bernstein polynomials, Hermite-Fejer operator. Spline approximation, convergence, B-splines.

Dynamic Programming in Financial Mathematics
BMETE93MM14, 2/0/0/v/3, fall

Optimal strategies, discrete models. Fundamental principle of dynamic programming. Favourable and unfavourable games, brave and cautious strategies. Optimal parking, planning of large purchase. Lagrangean mechanics, Hamilton-Jacobi equation. Viscous approximation, Hopf-Cole transformation, Hopf-Lax infimum-convolution formula. Deterministic optimal control, strategy of optimal investment, viscous solutions of generalized Hamilton-Jacobi equations. Pontryagin's maximum principle, searching conditional extreme values in function spaces. Optimal control of stochastic systems, Hamilton-Jacobi-Bellman equation.

Differential Geometry and Topology
BMETE94MM00, 3/1/0/v/5, fall

Smooth manifolds, differential forms, exterior derivation, Lie-derivation. Stokes' theorem, de Rham cohomology, Mayer–Vietoris exact sequence, Poincaré-duality. Riemannian manifolds, Levi–Civitá connection, curvature tensor, spaces of constant curvature. Geodesics, exponential map, geodesic completeness, the Hopf–Rinow theorem, Jacobi fields, the Cartan–Hadamard theorem, Bonnet's theorem.

Mathematical Modelling Seminar 1
BMETE95MM01, 2/0/0/f/1, fall

The aim of the seminar to present case studies on results, methods and problems from applied mathematics for promoting the spreading of knowledge and culture of applied mathematics, moreover the development of the connections and cooperation of students and professors of the Mathematical Institute, on the one hand, and of personal, researchers of other departments of the university or of other firms, interested in the applications of mathematics. The speakers talk about problems arising in their work. They are either applied mathematicians or non-mathematicians, during whose work the mathematical problems arise. An additional aim of this course to make it possible for interested students to get involved in the works presented for also promoting their long-range carrier by building contacts that can lead for finding appropriate jobs after finishing the university.

Statistical Program Packages 2
BMETE95MM09, 0/0/2/f/2, fall

The goal of the course is to provide an overview of contemporary computer-based methods of statistics with a review of the necessary theoretical background. How to use the SPSS (Statistical Package for Social Sciences) in program mode. Writing user's macros. Interpretation of the output data and setting the parameter values accordingly. Definition and English nomenclature of the displayed statistics. Introduction to the S+ and R Program Packages and surveying the novel algorithmic models not available in the SPSS (bootstrap, jackknife, ACE). Practical application. Detailed analysis of a concrete data set in S+.

Limit- and Large Deviation Theorems of Probability Theory
BMETE95MM10, 3/1/0/v/5, spring

Limit theorems: Weak convergence of probability measures and distributions. Tightness: Helly-Ptohorov theorem. Limit theorems proved with bare hands: Applications of the reflection principle to random walks: Paul Lévy's arcsine laws, limit theorems for the maximum, local time and hitting times of random walks. Limit theorems for maxima of i.i.d. random variables, extremal distributions. Limit theorems for the coupon collector problem. Proof of limit theorem with method of momenta. Limit theorem proved by the method of characteristic function. Lindeberg's theorem and its applications: Erdős-Kac theorem: CLT for the number of prime factors. Stable distributions. Stable limit law of normed sums of i.i.d. random variables. Characterization of the characteristic function of symmetric stable laws. Weak convergence to symmetric stable laws. Applications. Characterization of characteristic function of general (non-symmetric) stable distributions, skewness. Weak convergence in non-symmetric case. Infinitely divisible distributions: Lévy-Hinchin formula and Lévy measure. Lévy measure of stable distributions, self-similarity. Poisson point processes and infinitely divisible laws. Infinitely divisible distributions as weak limits for triangular arrays. Applications. Introduction to Lévy processes: Lévy-Hinchin formula and decomposition of Lévy processes. Construction with Poisson point processes (a la Ito). Subordinators and Lévy processes with finite total variation, examples. Stable processes. Examples and applications. Large deviation theorems: Introduction: Rare events and large deviations. Large deviation principle. Computation of large deviation probabilities with bare hands: application of Stirling's formula. Combinatorial methods: The method of types. Sanov's theorem for finite alphabet. Large deviations in finite dimension: Bernstein's inequality, Chernoff's bound, Cramer's theorem. Elements of convex analysis, convex conjugation in finite dimension, Cramer's theorem in R^d. Gartner-Ellis theorem. Applications: large deviation theorems for random walks, empirical distribution of the trajectories of finite state Markov chains, statistical applications. The general theory: general large deviation principles. The contraction principle and Varadhan's lemma. large deviations in topological vector spaces and function spaces. Elements of abstract convex analysis. Applications: Schilder's theorem, Gibbs conditional measures, elements of statistical physics.

Multivariate Statistics with Applications in Economy
BMETE95MM18, 2/0/0/f/2, spring

Multivariate central limit theorem and its applications. Density, spectra and asymptotic distribution of random matrices in multivariate statistics (Wishart-, Wigner-matrices). How to use separation theorems for eigenvalues and singular values in the principal component, factor, and correspondence analysis. Factor analysis as low rank representation, relations between representations and metric clustering algorithms. Methods of classification: discriminatory analysis, hierarchical, k-means, and graph theoretical methods of cluster analysis. Spectra and testable parameters of graphs. Algorithmic models, statistical learning. EM algorithm, ACE algorithm, Kaplan—Meier estimates. Resampling methods: bootstrap and jackknife. Applications in data mining, randomized methods for large matrices. Mastering the multivariate statistical methods and their nomenclature by means of a program package (SPSS or S+), application oriented interpretation of the output data.

Nonparametric Statistics
BMETE95MM20, 2/0/0/v/3, fall

Density function estimation. Distribution estimation, L1 error. Histogram. Estimates by kernel function. Regression function estimation. Least square error. Regression function. Partition, kernel function, nearest neighbour estimates. Empirical error minimization. Pattern recognition. Error probability. Bayes decision rule. Partition, kernel function, nearest neighbour methods. Empirical error minimization. Portfolio strategies. Log-optimal, empirical portfolio strategies. Transaction cost.

Biostatistics
BMETE95MM25, 0/2/0/f/3, fall

Introduction to epidemiology. Classical epidemiological study designs. Predictive models. Multivariate logistic regression. Survival analysis. Biases in epidemiological studies. Examples, Case studies, usage of SAS software.

Time Series Analysis with Applications in Finance
BMETE95MM26, 2/0/0/f/3, fall

White noise and basic ARMA models, lag operators and polynomials, auto- and crosscorrelation, autocovariance, fundamental representation, state space representation, predicting ARMA models, impulse-response function, stationary ARMA models, Wold Decomposition, vector autoregression (VAR): Sims and Blanchard-Quah orthogonalization, variance decomposition, VARs in state space notation, Granger causality, spectral representation, spectral density, filtering, spectrum of the filtered series, constructing filters, Hodrick-Prescott filter, random walks and unit root time series, cointegration, Beveridge-Nelson decomposition, Bayesian Vector Autoregression (BVAR) models, Gibbs Sampling, coding practice and application to financial and macroeconomic data.