MATHEMATICS IN ECONOMICS AND FINANCE, UNDERGRADUATE STUDY PROGRAMME, FIRST BOLOGNA CYCLE

COURSE DESCRIPTIONS (MF-17)

COMPULSORY COURSES

COMPULSORY COURSES FOR THE 1ST YEAR OF STUDY

Course name: **ALGEBRA I - MATRIX CALCULUS**
Number of ECTS credits: **6**

Content:
- Vectors, analytic geometry in space.
- Matrices. Types of matrices and basic operations with matrices. Rank of a matrix. Inverse. Systems of linear equations. Matrix interpretation and theorem of solvability. Elementary matrices, Gauss method. Determinants. Cramer's rule.

Course name: **ALGEBRA II - LINEAR ALGEBRA**
Number of ECTS credits: **6**

Content:
- Groups, rings, fields. Ring of polynomials.
- Vector space. Subspaces, linear operators. Linear independence. Basis and dimension of
- vector space.
- Eigenvalues. The characteristic and minimal polynomial.
- Inner product. Orthogonal systems. Gramm-Schmidt process of ortogonalization. Norm. Norm of the matrix and the operator. Normal and related operators.
- Convexity in the vector space.
- Normalized vector spaces as metric spaces. Isometries of R2 and R3.

Course name: **ANALYSIS I - FOUNDATIONS OF ANALYSIS**
Number of ECTS credits: **6**

Content:
- The natural numbers. Rational numbers. Real numbers. Complex numbers.
- The sequence of real numbers. Limits and accumulation points. Cauchy condition. Upper and lower limit. Monotone sequences. Bolzano-Weierstrass theorem.
- Series. The convergence criteria. Absolutely and conditionally convergent series.
- Functions of real variables, even and odd functions, periodicity. Limits of functions, left and right limits. Continuity. Continuous functions on closed intervals limited. Bisection method for finding zeros.
- The elementary functions. Cyclometric functions.

Course name: **ANALYSIS II – INFINITESIMAL CALCULUS**
Number of ECTS credits: **6**

Content:
- Derivative. Mean value theorems. Differentiation of monotone functions. L'Hopital's rule. Higher derivatives. Taylor's formula. Local extrema. Convex and concave functions. Inflection points. Tangent method of finding the zeros.
- The indefinite integral. Definite Integrals. Darboux and Riemann sums. Leibniz-Newton formula. Mean value theorems. Integration methods. Applications of the definite integral in geometry. Improper integral. Numerical integration.
- The logarithm, the number e, and the definition of exponentiation with the real exponent.
- Drawing planar curves.
- Sequences and function series. Power series. Taylor series. Elementary
- complex functions.

Course name: **DISCRETE MATHEMATICS II - COMBINATORICS**
Number of ECTS credits: **6**

Content:
- The principle of the sum, product. Counting pairs. Elementary combinatorics. Assignment. Assignment within the set. The existence of a 1-factor. Assignment between two sets, Hall's theorem. König's theorem, applications. Recursion. Generating functions. Linear recursion with constant coefficients. Applications of combinatorics. Inclusion-exclusion principle. Rook polynomial. Möbius inversion. Partially ordered sets and the Möbius function. Theorem on the inversion. Designs. Finite projective planes. Correction code. Steiner systems. Kirkman schoolgirl problem. Ramsey theorem, proof and application. Polya Theory. Burnside's lemma. Polya's theorem.
- Graphs, examples of graphs. Trees. Basic properties, enumeration of trees. The cheapest tree. Operations on graphs. Product of graphs. Deck graphs and voltage graphs. Graphs and groups. Graph automorphism group. Cayley graphs and Frucht theorem. Symmetric graphs. Planarity and duality. Criterion of planarity. Graph embeddings in other plots. Duality and Euler's theorem. Graph coloring. Coloring vertices. Coloring edges. Chromatic polynomial. Directed graphs. Eulerian digraphs. Tournaments. Markov chains. Connectivity. Menger's and Hall's theorem. Different versions of Menger's theorem and Ford-Fulkerson's theorem. Matroid theory. Definitions. Matroids and graphs. Examples of matroids and applications

Course name: **MATHEMATICAL PRACTICUM I**
Number of ECTS credits: **6**

Content:
- Programs for presentations (eg PowerPoint), spreadsheet (eg Excel)
- Text editors (eg WinEdt, TextPad, Emacs, Auctech, Open Office, ...)
- Introduction to TeX and LaTeX-a (MikTeX, tetex, GSview, Acrobat Reader, ...)
- The basic tools to produce images (pdf, eps), working with the formats of images including images in LaTeX
- Scanning and use of digital cameras.

Course name: **DISCRETE MATHEMATICS I – SET THEORY**
Number of ECTS credits: **6**

Content:
- Introduction to mathematical theory, logic, truth tables, mathematical logic.
- Formal Languages.
- Basic concepts of mathematical logic.
- Methods of recording the sets. The basic relations between sets, the basic operations on sets or families of sets. Power set. Relations. Graphs. Equivalence relations. Partial and linear ordering. Latices and Boolean algebra. Well ordering. Function. Special types of functions. Category.
- Finite and infinite, countable and uncountable sets.
- Cardinal and ordinal numbers. Peano arithmetic, mathematical induction.
- The system of axioms of set theory NBG and ZFC. Axiom of choice. Zorn's lemma.
- Introduction to symbolic computation (Mathematica).

Course name: **MATHEMATICAL TOPICS IN ENGLISH I**
Number of ECTS credits: **6**

Content:
Lectures are given on the most current research topics in the field of mathematics, which may include the following topics
- History of the concept of number
- Number theory
- Algebra
- Analysis
- Famous planning tasks
- Overview of the history of computing
- History of Slovenian mathematics
- Historical development of mathematical concepts

COMPULSORY COURSES FOR THE 2ND YEAR OF STUDY

Course name: **ALGEBRA III - ABSTRACT ALGEBRA**
Number of ECTS credits: **6**

Content:
- Introduction to number theory, Euclidean algorithm, congruences.
- Polynomials o in single variable. Euclidean algorithm. Zeros of polynomials. Solving algebraic equations. Polynomials in several variables. Symmetric polynomials. Fundamental theorem of algebra.
- Grupoids, semigroups and groups. Homomorphisms of groups. Normal subgroups and factor groups. Families of groups. Groups given by generators and relations. Sylow theorems.

Course name: **ANALYSIS III - FUNCTIONS OF MANY VARIABLES**
Number of ECTS credits: **6**

Content:
- Metric spaces. Cauchy-Schwarz inequality. Open and closed sets.
- Compactness and connectedness. Sequences in metric spaces. Cauchy sequences and complete metric spaces. Continuity and uniform continuity. Properties of continuous mappings.

- Functions of several variables. Continuity, partial differentiability. Differential mapping from Rn to Rm. Jacobian matrix. Chain rule of differentiation.
- Higher order partial derivatives. Taylor's formula. Theorem on the locally inverse function and on implicit functions. Local extremal problems, constrained extremal problems.
- Double and multiple integrals. Properties. The conditions on the existence. The introduction of new variables.
- Calculation and application.
- Proper and generalized integrals with parameter. Beta and Gamma functions. Stirling formula.

Course name: **PROBABILITY**
Number of ECTS credits: **6**

Content:
Probability is the starting point for many applications of mathematics in finance and elsewhere. The course will lay the foundation for the treatment of the subject. First the students will be introduced to the idea od probability spaces, the axiomatic foundations of probability, independence and conditional probability. Random variables are the central subject of probability theory. The course will introduce the concepts of distribution, expectation and variance of a random variables. Joint distribution will follow, and concepts like independence, measures of dependence, conditional distributions and conditional expectations will be introduced. In particular martingales will be introduced as one of the central subjects of modern probability theory. Two more important chapters are transformations of random variables like generating functions and characteristic functions, and convergence and approximation of distributions.

Course name: **STATISTICS**
Number of ECTS credits: **6**

Content:
Statistics is one of the most widely used fields of mathematics. The course will start out with simple questions about sampling which, however, lead to fundamental concepts of statistics like estimator, sampling distribution, standard error and confidence interval. This in turn leads to more abstract questions about statistical models, the role of parameters and the question of estimating such parameters. The course will treat methods of parameter estimation and examine the quality of estimators. The chapter on hypothesis testing follows along with the conceptual questions arising from it. The central result here is Wilks's theorem which makes it possible to construct statistical tests. Linear regression is one of the most widely used models in statistics. The course will state the basic assumptions underlying the model, deal with the question of estimating parameters, Gauss-Markov theorem and generalizations of regression such as logit and probit models.

COMPULSORY COURSES FOR THE 3RD YEAR OF STUDY

Course name: **FINANCIAL MATHEMATICS**
Number of ECTS credits: **6**

Content:
Pricing financial instruments is based on a few economic principles and on mathematical models that are derived on the basis of such principles. The subject first introduces the economics basiscs e.g. present value, arbitrage, efficiency of capital markets, equilibrium and optimality.
In the second half mathematical models are introduced and examined. Thier role in pricing financial instruments is investigated, and their relevance to ral capital markets is addressed. The mathematical buildup of models and the derivation of pricing formulae then follows. Fundamental results such as

the fundamental theorem of option pricing are derived and proved. Mathematical tools such as dynamic programming and Bellman equations are proved.

Course name: **STOCHASTIC PROCESSES I**
Number of ECTS credits: **6**

Content:
Stochastic processes are a field of probability important for applications in numerous fields. The starting point for the understanding is the treatment of Markov chains in discrete time. The students will become familiar with concepts like strong Markov property, ergodic properties of Markov chains, reversibility and other. With the introduction of sojourn times we pass on to Markov chains in continuous time which is a step in the direction of continuous time stochastic processes.
Martingales are a central concept in modern probability theory. Examples of martingales will be presented first followed by the two fundamental theorems on optional stopping and the convergence theorem. These two results in turn lead to many results like martingale inequalities, convergence theorems for random sums and similar.
Brownian motion is a fundamental object in stochastic processes in continuous time. The construction question will be treated, path properties examined, the strong Markov property will be presented along with the reflection principle. In the end we will look at a few continuous time martingales related to Brownian motion.

Course name: **MODELLING IN MACROECONOMICS**
Number of ECTS credits: **6**

Content:
Students will become familiar with the key models that are used in macroeconomics. They will understand the assumptions behind these models and be aware of the extent to which these models rest on microeconomic foundations. Students will learn how equilibrium in the macroeconomy is determined, both in the short-run and in the long-run. Moreover, they will learn how various macroeconomic policies affect these equilibria.
The course will make clear that in modern macroeconomic models, aggregate variables like consumption, investment, labour market variables etc., all rest on microeconomic foundations. Such foundations are important to understand how these models work, and they also help in quantifying the effects of different policies and shocks.
Students will cover in greater depth the standard growth model. This model is a backbone of all modern macroeconomic models. Its advantage is that it is micro-founded, is a dynamic model, and it is a general equilibrium model. A good understanding of this model is therefore an entry ticket to understanding a vast majority of modern macroeconomic models.

Course name: **MACROECONOMICS**
Number of ECTS credits: **6**

Content:
Macroeconomic analysis is a fundamental course in Economics where students learn how to analyse the most basic macroeconomic concepts and relations between them. By using mathematical methods they will be able to understand different theoretical approaches in economics and the consequences of the economic policy making.
Course begins with the study of propertes of different forms of production functions followed by static and dynamic analysis of GDP. Using matrix algebra IS-LM model will be investigated. Mathematical and economic properties of Harrod, Domar and Solow growth models are studied extensively and neoclassical growth model is being introduced. However we will discuss only neoclassical growth models which can be solved analyticaly. We will also study the role of expactations in economy by

analyticaly solving models with adaptive and rational expectations. One of the most important segments of macroeconomic analysis is an analysis of business cycles. Keynesian business cycles, Friedman-Lucas model and technological business cycles will be analysed by showing methodological and mathematical differences between the thee concepts. Special emphasis will be given on monetary policy. Topics like quantitative theory of money, Cambridge equation of money demand and relation between Solow growth model and money market will be covered.
Macroeconomic analysis is strongly based on some advanced mathematical methods such as differential and difference equations which will not be discussed mathematicaly rigorously. Insted we will be interested in the application of these methods in macroeconomic analysis.

Course name: **ECONOMETRICS**
Number of ECTS credits: **6**

Content:
"The real world of economics, business, and government is a complicated and messy place. Econometrics helps us to sort out sound ideas from crazy ones and to find quantitative answers to important quantitative questions.
Econometrics opens the window on our complicated world that lets us see the relationships on which people, business, and governments base their decisions." (J. H. Stock and M. W.Watson, Introduction to Econometrics)
This course prepares students for empirical research in economics, and also equips them for specialization in econometric theory, business, and other social sciencis. The course starts with a review of the statistical and probability foundations of econometrics and gives an introduction to regression analysis. More specifically, it covers the following topics: linear and nonlinear regression, omitted variable bias, sample selection, simultaneous causality, regression with panel data, regression with a binary dependent variable, and instrumental variable regression. Econometric theory is supported by numerous empirical examples that equips students, using the statistical software STATA, with essential skills for empirical testing of economic theory.
After the course student will be able to handle large databases, test the relevance of theoretical economic models, "intuitively" look for statistical relations in the data and evaluate the impact of existing policies, develop alternatives, and implement them. These are all skills increasingly demanded by public and financial institutions and businesses worldwide. An absolute must for students who want to successfully compete in the global labor market.

Course name: **FINANCE**
Number of ECTS credits: **6**

Content:
This course will allow students to examine not only the origins and nature of money, but also the institutions and markets that have evolved to enable the exchange of goods and services worldwide.
It will provide an overview of the fundamental principles that form the foundations of money and banking systems. The course covers fundamentals of monetory history, financial markets and institutions, the main instruments of monetary policy, and concludes with a discussion of the theory and implementation of monetary policies. By focusing on the big picture via core principles, students learn the rationale for financial rules and institutional structure so that even when the financial system evolves, students' knowledge will not be out of date. By reading and presenting recent articles from financial journals and through debates on important issues, students will also get familiar with current financial and economic events, and what is more, with the tools mastered during the lectures they should also be able to provide some solutions.

Course name: **FINANCIAL TOPICS IN ENGLISH**
Number of ECTS credits: **6**

Content:
The course is designed to cover various topics in finance. The purpose of the course is to enable students to familiarise themselves with the English terminology used in the fields of finance and economics. Familiarity with the English terminology in these fields is essential for understanding the literature, since the vast majority of the literature in these fields is written in English.
The students obtain a hands-on experience with the key English terms from the literature and their usage. Each lecture is in English and deals with a particular topic from finance, which enables students to get acquainted with the topic itself, the English terminology used in conjunction with that topic, and typical phrases used in discussing that particular topic. The goal of the course is not only to ensure the passive understanding of the terminology, but also to foster the active use of this terminology, both spoken and in writing.

Course name: **MICROECONOMICS**
Number of ECTS credits: **6**

Content:
Microeconomic analysis is a fundamental course in economics where students learn the decison making process on the level of consumers and firms. Students will learn what are the constraints consumers and firms face and how to analyse their decison making by using mathematics. The course is a fundament for further study of economics.
We begin with the analysis of consumer behaviour by formulating his preferences and constraints using mathematics in order to learn how to solve the problem of optimal consumer choice. Then we proceede to discuss the decison making of the firms. We study structure of the cost function, properties of production function and profit function. Again we use mathematics to find the optimal choice for problem of the firm. Next we study the market economy with demad and supply function also properties of market equllibrium are being defined. After the fundamental definitions we move to investigate different market structures, such as perfect competition, monopoly, oligopoly (Cournot, Stackelberg and Bertrand model) and market structure with dominant firm and followers. The analysis of market structures is further upgraded by game theory.
The second part of the course includes the theory of general equillibrium, theory of asymmetric information, modelling exetrnalities into market economy and analysis of public goods and regulations.

Course name: **INTRODUCTION TO NUMERICAL CALCULATIONS**
Number of ECTS credits: **6**

Content:
- Fundamentals of numerical computing. The floating point and rounding errors. Calculations in floating points. Stable computational processes and the problem sensitivity. The total error.
- Non-linear equations. Bisection. Tangent method: derivatives, implicit functions, systems
- nonlinear equations. Secant method. Algebraic equations.
- Systems of linear equations. LU decomposition and Cholesky decomposition. Gaussian elimination. Diagonally dominant and tridiagonal matrices. Problem sensitivity. Aposteriori error estimation. Neumann series and iteratively improvement of the accuracy.
- Eigenvalues. Power method, Inverse power method. Schur and Gershogorin theorem.
- Function approximation. Polynomial interpolation. Divided difference. Hermite interpolation.
- Numerical integration. Integration with polynomial interpolation. Composite rules. Gaussian quadrature formulas. Euler-Maclaurin formula
- Numerical solution of ordinary differential equations. Solving differential equations of the first order. The Taylor series method of obtaining solution. Simple methods, the order of the method. Methods of type Runge-Kutta.

- A linear programming. Convexity and linear inequalities. Simplex algorithm.

Course name: **GAME THEORY**
Number of ECTS credits: **6**

Content:

- The decision problems in strategic situations.
- Basic concepts of game theory: players, moves, income, matrix game with two players.
- Games in normal form: dominating moves, the best answer, Nash balance.
- Important examples of games in normal form: prisoners' dilemma, game of coordination, partnership struggle, Coin game.
- Random decisions: mixed moves, the existence of Nash balance.
- Dynamic games, games in the branched form: strategies, Nash balance, reversible induction, undergames, perfect balance of undergames.
- Important examples of games in a branched form: centipede game, ultimatum game, the game of negotiations, repeated prisoners' dilemma.
- Comparison of decision theory and human decision making: experiments.

Course name: **COMPUTER SCIENCE II**
Number of ECTS credits: **6**

Content:

- Introduction

Introduction to programming languages, concepts of programming languages, Meta-language, Chomski hierarchy, computability, overview of programming language history.

- Lambda calculus

History of λ-calculus, λ-abstraction, definition of λ-calculus, evaluation, substitution, alpha reductions, beta reductions, programming in λ-calculus, Church numbers, recursion, uses of λ-calculus.

- Syntax

Grammars, parsing, parse trees, BNF, grammar definition, operator, priority of operator, asociativity, dangling else, abstract syntax tree, BNF variations.

- Basic structures

Values, basic types, variable declaration, global declaration, local declaration, implementation of variables, symbol tables, name-spaces.

- Functional languages

Mathematical and logic foundations, function expressions, function definition, recursive functions, polymorphism, higher-order functions, examples of functions.

- Imperative languages

Variables, sequential control, structured control, if statement, loops, patterns, function implementation, parameters, activation records, array, functions on arrays.

- Types

Introduction to types, type declaration, products, records, unions, vectors, recursive types, parametrized types, type checking, type inference, examples of use of types.

- Modules

Modules as units of compilation, interface and implementation, separate compilation, language of modules, information hiding, sharing types among modules, functors, examples of module implementations.

- Objects and classes

Introduction to object-oriented languages, object logic, class definition, aggregation, specialization, inheritance, self and super, object initialization, method overloading, dynamic binding, abstract classes, polymorphism, parametrized classes, introspection, exceptions, implementation of classes and objects.

Course name: **COMPUTER SCIENCE I**
Number of ECTS credits: **6**

Content:
Basic building blocks of a computer program (using the syntax of the programming language Java):
- Variables, types and expressions. Basic I/O operations. Decision statements. Control structures. Functions and parameters. Programs. Structural decomposition.

Basic data structures:
- Simple types. Arrays. Records. Characters and strings. Data representation in computer memory. Memory allocation. Linked structures. Stack. Queue. List. Tree.

Algorithms and problem solving:
- What is an algorithm? Problem solving strategies. The role of algoirithms in problem solving. Algorithm implementation strategies. Debugging. Recursion – recursive functions, divide-and-conquer principle, backtracking, implementation of recursion.

Programming languages overview:
- Types of programming languages. Flow control. Functions. Subprograms. Namespaces.

Declarations and types:
- Types. Declarations of types. Safe typing. Type checking. Subtypes. Classes. Polymorphism.

Abstraction mechanisms:
- Data abstractions. Simple types. Composite types. Flow abstractions. Subprograms and functions. Abstract data types. Objects and classes. Patterns. Modules.

Course name: **COMPUTER PRACTICUM**
Number of ECTS credits: **6**

Content:
The faculty network and basic usage rules:
- Description of the faculty computer network, login methods, password changing procedure, e-mail and mailing list usage, access to e-materials.
- OS Linux basics:
- Description of the Linux OS and its Slovenian version – Pingo Linux. BASH shell usage basics.
- Programming language C:
- The syntax of the C programming language. Usage of programming language C to solve example problems.

Course name: **FUNDAMENTALS OF INSURANCE**
Number of ECTS credits: **6**

Content:
Interest rates
- Definitions and basic formulae.
- Present value of cash-flows.
- Expected present value of cash-flows.

Life insurance products
- Life policies.
- Survival models.
- Expected present value of a policy.
- Net premiums.
- Net premium reserves.
- Collective model.

Non-life insurance

- Non-life policies.
- Claim models.
- Premium calculations
- Reserving.
- Panjer recursion.
- Lundberg process.

Reinsurance

- Proportional reinsurance.
- Nonproportional insurance.

Insurance regulation

- Determination of capital.
- Investments.
- Supervision.
- Solvency 2.

Course name: **SEMINAR – FINAL PROJECT PAPER**
Number of ECTS credits: **6**

Content:
The course instructor, together with other teachers of the Department of Mathematics, presents potential thesis arguments, with relevant literature. Students are motivated to search for specific topics that they are interested in, and look for additional literature. Presentation of the final thesis's structure and rules for in-text citations. Describing research methods in mathematics, economics and finance. Final thesis provides a comprehensive overview of the chosen area belonging to the study program of Mathematics in economics and finance, and/or interdisciplinary linkage with other subject areas. Student chooses a topic according to his interests and supervisor suggestions. The topic can be theoretical or empirical, whereby the appropriate research methods must be used. The length and structure of the thesis is exactly defined in the instructions for writing a thesis.

ELECTIVE COURSES

(Read the short descriptions of all elective courses of the study programme. In the table Elective courses you will find the list of the elective courses which were offered in the last two years.)

Course name: **OPERATIONS RESEARCH**
Number of ECTS credits: **6**

Content:
Operations research is a discipline that deals with the application of advanced mathematical analytical methods for modeling various systems and to analyze their characteristics. We will use mathematical methods for modeling financial planing, logistics and for the optimization of networks.

Course name: **STOCHASTIC PROCESSES II**
Number of ECTS credits: **6**

Content:

- Stochastic integral, Itô's Lemma. Girsanov Theorem. Stochastic differential equations. Stochastic optimal control. Applications in mathematical finance.

Course name: **RISK MANAGEMENT**
Number of ECTS credits: **6**

Content:
The course was prepared under the project “Development of quality and excellence culture of the UP”. It was specifically created for students of social and humanistic study programmes, who wish to obtain knowledge on natural sciences.

1. Introduction.
   - The role of insurance companies.
   - Regulatory framework.
   - Definition of risk and the role od risk management.
2. Reserving in life insurance.
   - Typical life contracts.
   - Discounting and equivalence principle.
   - Survival models.
   - Net premiums.
   - Net reserves.
   - Expense loadings.
   - Collective models.
3. Reserving in non-life insurance.
   - Typical non-life contracts.
   - Statistical bases.
   - Pricing.
   - Deterministic models for claim reserves.
   - Stochastic modeling of aggregate claims.
   - Expense loadings.
4. Risk management and mitigation.
   - Capital requirements under Solvency 2.
   - Matching assets and liabilities.
   - Reinsurance.

Course name: **EU ECONOMIC TRENDS**
Number of ECTS credits: **6**

Content:
Content description:

1. Introduction: About E(M)U
   a. Origin (who, when, why)
   b. EU economy in the world
   c. Is there a problem of intergovernmentalism
   d. Fiscal Union: is it feasible?
2. EU growth drivers
   a. Human capital and migration
   b. External balance as a driver for economic growth
   c. Building up a Capital markets union
   d. Sovereign debt and rating agencies
   e. EU TFP
   f. RD, technology and innovation (growth or job disruption?)
   g. The burden of public finance
3. EU challenges
   a. Youth unemployment and an ageing world
   b. Ethics and Islamic finances
4. EU strategies
   a. Brexit and its consequences

b. EU enlargement to SEE
c. Governance and the role of supranational EU: a strategic game play