

**University of Debrecen
Faculty of Science and Technology
Institute of Mathematics**

MSc Program

APPLIED MATHEMATICS

Applied mathematics MSc

Basics

Students having a BSc degree in Mathematics are granted exemption from these subjects. Students having degree in other subjects have to put in a credit-acceptance form. The Institute of Mathematics will decide what basic subjects the students will have to learn.

Code	Subject	Credit	Hours/week		Examination	Prerequisites	Semester
			Theory	Practice			
TTMME0101	Introduction to modern algebra	3	2		C	TTMMG0101(p)	1
TTMMG0101	Introduction to modern algebra	2		2	T		1
TTMME0202	Operation research	3	2		C	TTMMG0202(p)	1
TTMMG0202	Operation research	2		2	T		1
TTMME0301	Selected topics in geometry	3	2		C	TTMMG0301(p)	1
TTMMG0301	Selected topics in geometry	2		2	T		1
TTMME0401	Probability theory	3	2		C	TTMMG0401(p)	1
TTMMG0401	Probability theory	2		2	T		1

Advanced prof module

Code	Subject	Credit	Hours/week		Examination	Prerequisites	Semester
			Theory	Practice			
	Basic information	0		1	A		1
TTMME0104	Graph theory and applications	3	2		C	TTMMG0104(p)	1
TTMMG0104	Graph theory and applications	2		2	T		1
TTMME0106	Algorithms in mathematics	3	2		C	TTMME0104 TTMMG0106(p)	2
TTMMG0106	Algorithms in mathematics	2		2	T	TTMME0104	2
TTMME0205	Convex optimization	3	2		C	TTMMG0205(p)	1
TTMMG0205	Convex optimization	2		2	T		1
TTMME0107	Discrete optimization	3	2		C	TTMMG0107(p)	2
TTMMG0107	Discrete optimization	2		2	T		2
TTMME0207	Applications of ordinary differential equations	3	2		C	TTMMG0207(p)	3
TTMMG0207	Applications of ordinary differential equations	2		2	T		3
TTMME0204	Partial differential equations	3	2		C	TTMMG0204(p)	4
TTMMG0204	Partial differential equations	2		2	T		4
TTMME0402	Stochastic processes	3	2		C	TTMMG0402(p)	2
TTMMG0402	Stochastic processes	2		2	T		2
TTMME0403	Multivariate analysis	3	2		C	TTMMG0403(p)	3
TTMMG0403	Multivariate analysis	2		2	T		3
TTMME0404	Option pricing	3	2		C	TTMMG0404(p)	1
TTMMG0404	Option pricing	2		2	T		1
TTMME0405	Financial mathematics I.	3	2		C	TTMMG0405(p)	2
TTMMG0405	Financial mathematics I.	2		2	T		2
TTMME0901	Introduction to finance	5	2	2	C		1
TTMME0902	Microeconomics	5	2	2	C		2
TTMME0904	Econometrics	4	2	1	C	TTMME0403(p)	3
TTMME0905	Financial accounting	5	2	2	C		4
TTMME0208	Game theory	3	2		C	TTMMG0208(p)	4

TTMMG0208	Game theory	2		2	T		4
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Elective courses

The required credits points of elective subjects depend on how many subjects are accepted from the Basics. (The student has to learn subjects from elective courses for the same amount of credit points that is accepted from the Basics.)

Code	Subject	Credit	Hours/week		Examination	Prerequisites	Semester
			Theory	Practice			
TTMME0903	Macroeconomics	5	2	2	C	TTMME0902	3
TTMME0407	Insurance mathematics	3	2		C		2/4
TTMME0406	Financial mathematics II.	3	2		C	TTMME0405	3
TTMME0303	Finite geometries and coding theory	3	2		C	TTMMG0303(p)	2/4
TTMMG0303	Finite geometries and coding theory	2		2	T		2/4
TTMME0206	Fourier series	4	2	1	C		3

Thesis, free optional courses

Code	Subject	Credit	Hours/week		Examination	Prerequisites	Semester
			Theory	Practice			
TTMMG0701	Thesis 1.	10			T		3
TTMMG0702	Thesis 2.	10			T	TTMMG0701	4
	Free optional courses	6					

Subjects

Basics

TTMME0101, TTMMG0101

Introduction to modern algebra

2+2 classes/week, 3+2 credit, C+T

Lecturer: Dr. Horváth Gábor

Prerequisites: none

Sylow's theorems. Semidirect product. Maximal subgroups of p-groups are normal of index p. Characteristic subgroup, commutator. Solvable groups and their basic properties. Alternating group is simple if acting on at least 5 points. Free groups, generators, relations, Dyck's theorem. Necessary and sufficient condition for a ring to be a unique factorization domain, ascending and descending chain conditions. Field of fractions. Artinian and Noetherian rings, Hilbert's basis theorem. Algebras, minimal polynomial over algebras, Frobenius's theorem. Splitting field, existence, uniqueness, algebraic closure existence, uniqueness. Normal extensions, extensions of perfect fields are simple. Galois theory. Fundamental theorem of algebra. Compass and ruler constructions. Theorem of Abel and Ruffini, Casus Irreducibilis is unavoidable for degree three polynomials.

TTMME0202, TTMMG0202

Operation research

2+2 classes/week, 3+2 credit, C+T

Lecturer: Dr. Mészáros Fruzsina

Prerequisites: none

Problems reducible to linear programming tasks. Extreme points of convex polyhedra, simplex algorithm and its geometry, sensitivity analysis. Duality. Transportation and assignment model, network models. Special linear programming models.

Compulsory/Recommended Readings:

Ronert Vanderbei: Linear Programming, Foundations and Extensions, Kluwer Academic Publishers, 1998.

Dimitris Bertsimas, John Tsitsiklis: Introduction to Linear Optimization, Athena Scientific Series in Optimization and Neural Computation, 1997.

TTMME0301, TTMMG0301

Selected topics in geometry

2+2 classes/week, 3+2 credit, C+T

Lecturer: Dr. Kozma László

Prerequisites: none

Differentiable curves. Curvature, torsion. The fundamental theorem of curves. Surfaces in the Euclidean space. Fundamental form of surfaces. Normal curvature, principal curvatures, principal directions. Variational problem of arc-length. Geodesics. Geodesic curvature. Minimizing property of geodesics. Axioms of affine and projective planes. Projective completion of an affine plane. Duality. Vector space model of projective planes, homogenous coordinates. Perspectivities (central projections) and projectivities. Cross ratio of four points or lines, Pappus-Steiner theorem. Desargues's theorem and Pappus's theorem. Complete quadrilateral, complete quadrangle, harmonic sets of points and lines. Collineations, fundamental theorem of projective geometry. The parallel postulate, the development of hyperbolic geometry. The Cayley-Klein model of hyperbolic geometry, Poincaré disk model and upper half-plane model. Description of congruences. Spherical geometry: measuring distance on the sphere, spherical triangles. Elliptic metric.

Compulsory/Recommended Readings:

Wolfgang Kühnel: Differential Geometry: Curves – Surfaces – Manifolds, AMS, 2006.

H. S. M. Coxeter: Projective Geometry, Springer, 1974.

Patrick J. Ryan: Euclidean and non-Euclidean geometry: an analytical approach, Cambridge, 1986.

TTMME0401, TTMMG0401

Probability theory

2+2 classes/week, 3+2 credit, C+T

Lecturer: Dr. Fazekas István

Prerequisites: none

Probability, random variables, probability distributions. Asymptotic theorems of probability theory.

Compulsory/Recommended Readings::

A. N. Shiryaev: Probability, Springer-Verlag, Berlin, 1984.

Advanced prof module

TTMME0104, TTMMG0104

Graph theory and applications

2+2 classes/week, 3+2 credit, C+T

Lecturer: Dr. Nyul Gábor

Prerequisites: none

Multiply connected graphs: Menger's theorems, edge-disjoint spanning trees. Graph colourings: chromatic number, greedy vertex colouring, Brooks' theorem, Mycielski construction, perfect graphs, chromatic polynomial, chromatic index, Vizing-theorem. Independence and covering: Gallai's theorems, König's theorem, Hall's theorem, perfect matchings in bipartite and in arbitrary graphs, augmenting path method. Extremal graph theory: Mantel's theorem, Turán's theorem. Friendship theorem, strongly regular graphs. Planar graphs, crossing number. Directed paths and cycles in directed graphs, tournaments.

Compulsory/Recommended Readings::

J. A. Bondy, U. S. R. Murty: Graph Theory, Springer, 2008.

TTMME0106, TTMMG0106

Algorithms in mathematics

2+2 classes/week, 3+2 credit, C+T

Lecturer: Dr. Bérczes Attila

Prerequisites: TTMME0104

Representing graphs, breadth-first search and depth-first search, finding minimal spanning trees: Kruskal's, Prim's and Boruvka's algorithms. The Bellman-Ford-algorithm. Dijkstra's algorithm. Structure of shortest paths: Floyd-Warshall-algorithm. Transitive closure of directed graphs, Johnson's algorithm on sparse graphs. Representing polynomials: discrete and fast Fourier-transformation. Number theoretical algorithms: Euclidean algorithm, operations with residue classes, Chinese remainder theorem. Computing powers. Prime tests, factorizing integers. Random prime tests, Agrawal–Kayal–Saxena prime test. Pollard's rho-algorithm.

Compulsory/Recommended Readings::

Herbert S. Wilf: Algorithms and Complexity, electronic edition, 1994.

TTMME0205, TTMMG0205

Convex optimization

2+2 classes/week, 3+2 credit, C+T

Lecturer: Dr. Bessenyei Mihály

Prerequisites: none

Hull operations and their representations. The Stone–Kakutani separation theorem. Algebraic interior and algebraic closure. The intersection of the algebraic closure of complementary convex sets; separation of convex sets by linear functions. The Dubovickij–Miljutin theorem and its consequences. The Bernstein–Doetsch theorem for linear functions; the topological form of the separation theorems. Convex and sublinear functions; the maximum theorem and its consequences. Subgradient and directional derivative of convex functions. Rules of calculus. The Bernstein–Doetsch theorem for convex functions. Distance function, tangent cone, normal cone. The minimum of convex conditional extremum problems; primal and dual conditions. The convex Fermat principle. Penalty function. The Karush–Kuhn–Tucker theorem and its consequence. Slater condition and Slater theorem.

Compulsory/Recommended Readings::

T. R. Rockafellar: Convex Analysis, Princeton University Press, Princeton, N. J., 1970.

J. M. Borwein and A. S. Lewis: Convex Analysis and Nonlinear Optimization, CMS Books in Mathematics, Springer, New York, 2006.

TTMME0107, TTMMG0107

Discrete optimization

2+2 classes/week, 3+2 credit, C+T

Lecturer: Dr. Nyul Gábor

Prerequisites: none

Theoretical background of discrete optimization problems. Totally unimodular matrices, integer linear programming, Hoffman-Kruskal theorem. Assignment problem, quadratic assignment problem, set covering problem, Chinese postman problem, travelling salesman problem, Steiner-tree problem, bin packing problem. Max flow–min cut problem, Ford-Fulkerson theorem, Edmonds-Karp theorem. Greedy algorithm for downward closed family of sets, matroids.

Compulsory/Recommended Readings::

Bernhard Korte, Jens Vygen: Combinatorial Optimization, Springer-Verlag, 2006.

Dieter Jungnickel: Graphs, Networks and Algorithms, Springer-Verlag, 2008.

Vijay V. Vazirani: Approximation Algorithms, Springer-Verlag, 2001.

TTMME0207, TTMMG0207**Applications of ordinary differential equations****2+2 classes/week, 3+2 credit, C+T****Lecturer: Dr. Novák-Gselmann Eszter****Prerequisites: none**

Autonomous systems of differential equations and their phase spaces. Stability of differential equations, the theorems of Lyapunov, the direct method of Lyapunov. Boundary value problems and eigenvalue problems. Green function. Existence and uniqueness theorems. Maximum and minimum principles. Nonlinear boundary value problems. Sturm-Liouville eigenvalue problems. Rotationally symmetric elliptic problems. Diffeomorphisms and their symmetries. The application of the one-parameter symmetry group to integration of equations. Calculus of variations, the Euler–Lagrange differential equations, the invariance of the Euler–Lagrange differential equations, the canonical form of the Euler–Lagrange differential equations, the first integrals of the Euler–Lagrange differential equations. The Noether theorem. The principle of stationary action.

Compulsory/Recommended Readings::

B. Dacorogna, Introduction to the Calculus of Variations, 2nd ed., London: Imperial College Press, 2008.

A. D. Ioffe, V. M. Tihomirov, Theory of Extremal Problems, Studies in Mathematics and its Applications, 6. North-Holland Publishing Co., Amsterdam-New York, 1979.

W. Walter, Gewöhnliche Differentialgleichungen - Eine Einführung, 7. Auflage, Springer, 2000.

TTMME0204, TTMMG0204**Partial differential equations****2+2 classes/week, 3+2 credit, C+T****Lecturer: Dr. Fazekas Borbála****Prerequisites: none**

Examples in physics. First order equations: homogeneous linear equations, quasilinear equations and Cauchy problems for general equations. Higher order equations, the Cauchy–Kovalevskaya theorem. One, two and three dimensional wave equation. Inhomogeneous wave equation. Poisson equation, Green functions, harmonic functions, maximum principle. Initial value problem for the Laplace and Poisson equations. The heat conduction equation. Sobolev spaces, weak solutions.

Compulsory/Recommended Readings::

V. I. Arnold: Lectures on Partial Differential Equations, Springer, Berlin, 2004.

TTMME0402, TTMMG0402**Stochastic processes****2+2 classes/week, 3+2 credit, C+T****Lecturer: Dr. Barczy Mátyás****Prerequisites: none**

General notion of conditional expected value, discrete and continuous time Markov chains, discrete time martingals, Wiener processes, stochastic integration with the Wiener process (Itô integral), Itô's formula, stochastic differential equations, diffusion processes.

Compulsory/Recommended Readings::

I. Karatzas, S. E. Shreve: Brownian Motion and Stochastic Calculus, Springer-Verlag, 1991.

N. Shiriyayev: Probability, 2nd edition, Springer-Verlag, 1995.

S. M. Ross: Introduction to Probability Models, 10th edition, Academic Press, 2009.

TTMME0403, TTMMG0403**Multivariate analysis**

2+2 classes/week, 3+2 credit, C+T

Lecturer: Dr. Baran Sándor

Prerequisites: none

Multivariate sample and its properties, principal component analysis, factor analysis, canonical correlation analysis, methods of statistical classification, cluster analysis, multidimensional scaling.

Compulsory/Recommended Readings::

A. J. Izenman: Modern Multivariate Statistical Techniques. Regression, Classification and Manifold Learning, Springer, 2008.

N. H. Timm: Applied Multivariate Analysis, Springer, 2002.

B. Everitt, T. Hothorn: An Introduction to Applied Multivariate Analysis with R, Springer, 2011.

K. V. Mardia, J. T. Kent, J. M. Bibby: Multivariate Analysis, Academic Press, 1982.

TTMME0404, TTMMG0404

Option pricing

2+2 classes/week, 3+2 credit, C+T

Lecturer: Dr. Gáll József

Prerequisites: none

The students get to know about the fundamental derivatives and their roles, the fundamentals of the mechanism of derivatives markets, the principles of pricing derivatives, the principle of arbitrage-freeness and how to apply it, some classical models and problems and methods related to their fitting and applications.

TTMME0405, TTMMG0405

Financial mathematics I.

2+2 classes/week, 3+2 credit, C+T

Lecturer: Dr. Barczy Mátyás

Prerequisites: none

Discrete time models of shares markets and options pricing, risk measures, coherent measures, Value at Risk, Expected Shortfall, operational risk and its models based on composite distributions. Markowitz-type mean-variance portfolio analysis, CAPM.

Compulsory/Recommended Readings::

Harry H. Panjer: Operational Risk: Modeling Analytics, Wiley, 2006.

Musiela, M. and Rutkowski, M.: Martingale Methods in Financial Modeling, Springer-Verlag, Berlin, Heidelberg, 2005.

TTMME0901

Introduction to finance

2+2 classes/week, 5+0 credit, C

Lecturer: Dr. Gáll József

Prerequisites: none

Basic notions of finances and financial markets, time value of money, methods of calculating present value, other fundamental financial statements, financial statement frauds based on financial and market data, bonds and shares and basic methods of the pricing, internal rate of return, elementary questions on investment.

TTMME0902**Microeconomics****2+2 classes/week, 5+0 credit, C****Lecturer: Dr. Kapás Judit****Prerequisites: none**

Fundamental principles of microeconomics. Methodology of microeconomical analysis: modelling, comparative statics, optimization, marginal analysis. Central problems of microeconomics. The mechanism of market: analysis of demand and supply. Interventions of government into the market: price control, taxation. Modelling of consumer decision. Preference ordering, utility theory, types of preference. Budget set. Optimization of consumption, individual demand. Applications of demand theory, elasticities. Production theory. The microeconomical concept of corporational perception, the corporation as decision maker. Entrepreneur, owner, manager. Profit maximization as main goal. Terms. Short and long term production function. Factor demand, marginal product and increment. Competitive industry: commodity prices over short and long term. Well-being of society: consumer and producer surplus. Monopolist behaviour: profit maximization of pure monopoly, analysis of effects on well-being.

TTMME0904**Econometrics****2+1 classes/week, 4+0 credit, C****Lecturer: Dr. Balogh Tamás László****Prerequisites: TTMME0403 (p)**

Topics of econometrics, fields of interest. Introduction to the R. Single and multivariate regression models: the OLS estimate, goodness-of-fitting, indices, hypothesis testing. Autocorrelation, multicollinearity. Dummy and truncated variables. Simultaneous econometrics models. Error of variables. Analysis of panel data. Basic notions in time series analysis. Case studies.

TTMME0905**Financial accounting****2+2 classes/week, 5+0 credit, C****Lecturer: Dr. Tóth Kornél****Prerequisites: none**

Notion of public accountancy. Steps in the accounting process. Accounting system, practice of public accountancy. International Financial Reporting Standards (IFRS). The content of financial statements and their presentation.

TTMME0208, TTMMG0208**Game theory****2+2 classes/week, 3+2 credit, C+T****Lecturer: Dr. Boros Zoltán****Prerequisites: none**

The normal form of non-cooperative games. The notion and existence of Nash equilibrium. The best response mapping. Fixed point theorems in game theory. Analysis of finite games, strictly dominated strategies, bimatrix representation of finite two-person games. Application of the game theoretic approach to simple market models (duopolium, oligopolium). Mixed extension of finite games. Two-person zero-sum games, matrix games. Games in extensive form. Combinatorial games, Grundy's games, Grundy numbering. Cooperative games, the value of the coalition. Nash's model of bargaining.

Compulsory/Recommended Readings::

J. H. Conway: On Numbers and Games, Academic Press, 1976.

Martin J. Osborne: An Introduction to Game Theory, Oxford University Press, 2003.

Elective courses**TTMME0903****Macroeconomics****2+2 classes/week, 5+0 credit, C****Lecturer: Dr. Czeglédi Pál****Prerequisites: TTMME0902**

Central problems in macroeconomics. Principles of measuring aggregates: economic cycle and the GDP, nominal and real GDP, applications of GDP, the GDP-deflator and the consumer price index, measuring unemployment. Economy in the long run: equilibrium of the goods market, equilibrium of the factor market and the distribution of income, theories of natural unemployment. Importance of money and inflation: the functions of money and the money supply, quantity theory of money, money demand, costs of inflation. Short run models of economy: the keynesian cross, the IS-LM model, models of aggregate supply and aggregate demand. Relation between short term and long term deductions: the expectations-augmented Philips curve and the Friedman and Modigliani-type theory of consumption functions.

TTMME0407

Insurance mathematics

2+0 classes/week, 3+0 credit, C

Lecturer: Dr. Barczy Mátyás

Prerequisites: none

Notion of insurance, classification of insurances, classical non-life insurance models, methods for determining total loss, related regression and statistical questions. Pricing. Life and reinsurances, annuity calculation, pricing of life insurances.

Compulsory/Recommended Readings::

Straub, Erwin: Non-life Insurance Mathematics, Springer-Verlag, 1980.

Mikosch, Thomas: Non-life Insurance Mathematics, Springer, Berlin, Heidelberg, New York, 2006.

TTMME0406

Financial mathematics II.

2+0 classes/week, 3+0 credit, C

Lecturer: Dr. Gáll József

Prerequisites: TTMME0405

Utility theory, expected utility, axioms and criticism in related literature. Risk aversion and its measuring, optimal portfolios. Continuous time shares and interest-rate models, analysis of arbitrage-freeness, pricing of shares, bonds and interest-rate derivatives.

Compulsory/Recommended Readings::

Musiela, M. and Rutkowski, M.: Martingale Methods in Financial Modeling, Springer-Verlag, Berlin, Heidelberg, 2005.

Björk, T.: Arbitrage Theory in Continuous Time, Oxford University Press, Oxford/New York, 1998.

Brigo, D. and Mercurio, F.: Interest Rate Models - Theory and Practice: With Smile, Inflation and Credit, Springer, Berlin, Heidelberg New York, 2006.

TTMME0303, TTMMG0303

Finite geometries and coding theory

2+2 classes/week, 3+2 credit, C+T

Lecturer: Dr. Szilasi Zoltán

Prerequisites: none

Finite incidence structures: projective and affine planes, Galois geometry. Combinatorial properties of finite projective planes. Arcs and ovals. Finite projective planes and algebraic structures. Finite projective and affine planes over a field. Examples of combinatorial point sets on finite projective plane. Further incidence structures: block design and Steiner-system. Applications of finite geometry in coding theory.

Compulsory/Recommended Readings::

A. Beutelspacher: Projective Geometry – From Foundations to Applications, Cambridge, 1998.

J. W. P. Hirschfeld: Projective Geometries Over Finite Fields, Oxford, 1998.

D. R. Hughes, F. C. Piper: Projective Planes, Springer, 1973.

S. E. Payne: Topics in Finite Geometry, 2007.

TTMME0206

Fourier series

2+1 classes/week, 4+0 credit, C

Lecturer: Dr. Gát György

Prerequisites: none

The interpolation theorems of Marcinkiewicz, classical and complex trigonometric systems, the theorems of Weierstrass, the density of trigonometric polynomials, the Riemann-Lebesgue lemma, Dirichlet kernels, Fejér

kernels, norm convergence of Fejér means, the Calderon-Zygmund decomposition, Hilbert operator, Fejér-Lebesgue theorem, the Dini and the Lipschitz criteria for convergence, the norm convergence of Fourier partial sum operators, Fourier series with respect to Walsh systems.

Compulsory/Recommended Readings::

N. K. Bary: A Treatise on Trigonometric Series, Elsevier, 2014.

A. Zygmund, Trigonometric Series Vol I., Cambridge University Press, 2002.