University of Debrecen

Centre of Arts, Humanities and Sciences

Hungary

Faculty of Science

Applied Mathematics, MSc Program

Modulé	Subject	Hours/week				Examlnation	Credit	
		1	2	3	4			
Theoretical	**Linear Algebra and Applications**	2+0				C	2	
	Appl. of Algebra and Number Theory	2+0				C	2	
Found.	**Applied Analysis**	2+2				C, T	4	
	Appl. of Geometry and Topology	2+2				C, T	4	
	Applied Probability	2+1				C, T	3	
	Appl. of Math. Statistics	2+1				C, T	3	
	Applications of Informatics	0+2				T	2	20
Advanced	**Finite Fields and their Applications**		2+2			C, T	5	
	Applied Graph Theory	2+2				C, T	5	
Professional	**Convex Optimization**		2+2			C, T	5	
	Discrete Optimization		2+2			C, T	5	
Modulé	**Orthogonal Polynomials**		2+0			**c**	3	
	Appl. of Ordinary Diff. Equations		2+1			C, T	4	
	Partial Diff. Equations with Appl.		2+1			C, T	4	
	Stochastic Processes		2+2			C, T	5	
	Theory of Algorithms		2+2			C, T	5	25
Computer	**Data Mining**			2+2		C, T	5	34
	The Math. of WWW and Networks			2+2		C, T	5	
Science	**Complexity Theory**			2+2		C, T	5	
	Design, Analysis and Impl. of Algorithms and Data Structures			3+3		C, T	7	
Modulé	**Cryptography and Data Security**			3+3		C, T	7	
	Theory of Information, Coding and Symmetric Structures			2+2		C, T	5	
Elective	**Applied Combinatorics**				2+2	C, T	5	15
	Artificial Intelligence				2+2	C, T	5	
	Game Theory				2+2	C, T	5	
	Comput. Number Theory, Comput. Algebraié Pr. Packages				0+4	C, T	5	
	Analysis with Computer				0+3	T	3	
	Computer-aided Diff. Geometry				2+2	C, T	5	
	First-Order Logic				3+0	**c**	4	
	Finite Geometries				2+2	C, T	5	
	Quasigroups and Comb. Structures				2+2	C, T	5	
	Lattice Theory				2+0	**c**	3	
	Discrete Tomography				2+0	**c**	3	
	Iterative Fixed Point Theory and its Applications				2+0	**c**	3	
	Extremum Problems				2+1	**c**	4	
	Thesis							20
	Free Optional Courses							6
	Totál Credits							**120**

Subjects

Subject: Linear Algebra and Applications
Classes/week: 2 hour lecture
ECTS Credit Points: 2
Prerequisites: None
Lecturers: István Gaál, DSc; Gábor Nyul, PhD

Topics: Inner product spaces. Normal and unitary transformations, unitary matrices, spectral theorem. Similar matrices and canonical form of polynomial matrices. Minimal polynom of linear transformations and matrices, Cayley-Hamilton theorem. Jordan normal form and its calculation. Eigenvector and root vector. Quadratic forms, Sylvester theorem.

Compulsory/Recommended Readings:
P.R. Halmos: Finite dimensional vector spaces.
H.Anton and R.C.Busby: Contemporary linear algebra, John Wiley & Sons, 2003.

Subject: Applications of Algebra and Number Theory
Classes/week: 2 hour lecture
ECTS Credit Points: 2
Prerequisites: None
Lecturers: Ákos Pintér, PhD; Csaba Rakaczki, PhD

Topics: Algebraic structures, generating systems, factor structures, homomorphism. Group theory: symmetric groups, Lagrange's theorem, normal subgroups, factor groups. Ring theory: ideals and factor rings. Fields and finite fields.
Qudratic congruences, Legendre symbols, reciprocity theorem; binomial congruences of higher degree, primitive root, discrete logarithms (index). Algebraic number theory: algebraic integers, units, norm. Unique prime factorization in special quadratic number fields. Continued fractions and their applications for Pellian equations.

Compulsory/Recommended Readings:
Bódi Béla: Algebra I, Kossuth Egyetemi Kiadó, Debrecen, 1999.
Bódi Béla: Algebra II, Kossuth Egyetemi Kiadó, Debrecen, 2000.
Fuchs László: Algebra, Nemzeti Tankönyvkiadó, Budapest.
Freud Róbert -- Gyarmati Edit: Számelmélet, Nemzeti Tankönyvkiadó, Budapest, 2004.
Erdős Pál -- Surányi János: Válogatott fejezetek a számelméletből, Polygon, Szeged, 1996.
Sárközy András -- Surányi János: Számelmélet feladatgyűjtemény, Nemzeti Tankönyvkiadó, Budapest.
K.H. Rosen: Elementary Number Theory and Its Applications, Addison Wesley, 1985.

Subject: Applied Analysis
Classes/week: 2 hour lecture, 2 hour seminar
ECTS Credit Points: 4
Prerequisites: None
Lecturer: Lajos Molnár, DSc; Mihály Bessenyei, PhD

Topics: Metric spaces: topological notions, sequences, limit and continuity. Functions of bounded variation. Riemann-Stieltjes integral, line integral. Inverse function theorem, implicit function theorem. Conditional extremum problems. Measure theory, Lebesgue integral. Hilbert spaces, orthonormal systems.

Basic concepts of the theory of ordinary differential equations. Linear differential equations and systems of linear differential equations. Elements of numerical analysis.

Compulsory/Recommended Readings:
W. Rudin, Principles of Mathematical Analysis
W. Rudin, Real and Complex Analysis
H.L. Royden, Real Analysis
E.A. Coddington, An Introduction to Ordinary Differential Equations
A. Ralston, A First Course in Numerical Analysis

Subject: Applications of Geometry and Topology
Classes/week: 2 hour lecture, 2 hour seminar
ECTS Credit Points: 4
Prerequisites: None
Lecturers: László Kozma, PhD; Csaba Vincze, PhD

Topics: Vector analysis: differential calculus, vector calculus in space. Space curves, torsion and curvature of curves. The presentation of surfaces, first and second fundamental forms of surfaces. Classical integral theorems. Topics fro topology: The concept of topological and metrical spaces. Sequences and limits. Compactness and connectedness of sets. Fundamental group of spaces.

Compulsory/Recommended Readings:
Janich, Klaus: Vector Analysis, Springer Verlag, 2000.
Bloch. E. D.: A first course in geometric topology and differential geometry, Birkhauser, 1996.

Subject: Applied Probability
Classes/week: 2 hour lecture, 1 hour seminar
ECTS Credit Points: 3
Prerequisites: None
Lecturers: Gyula Pap, DSc; István Fazekas, PhD; Mátyás Barczy, PhD

Topics: Combinatorical probability, sieve formulas, urn models. Conditional probability, Bayes theorem, stochastic independence. Discrete random variables, binomial, negative bi nomial, hypergeometric, Poisson distributions. General notion of random variables and distribution functions. Expectation, variance, median, moments. Important continuous distributions: uniform, exponential, normal, Cauchy, lognormal. Joint distributions, marginal distributions, conditional distributions. Expectation vector, covariance matrix. Multidimensional normal distributions. Convolution, Markov and Tschebyshev inequalities, weak law of large numbers. Stirling formula, Moivre-Laplace theorem. Measure theoretical model of probability theory. Borel-Cantelli lemma. General notion of conditional probability. Series of independent variables. Strong law of large numbers. Basics of characteristic functions. Central limit theorems.

Compulsory/Recommended Readings:
Feller, W.: *An Introduction to Probability Theory and its Applications*, Vol.1. John Wiley & Sons, Inc., New York-London-Sydney 1968.
Graham, R. L., Knuth, D. E., Patashnik, O.: *Concrete Mathematics. A Foundations for Computer Science*. Addison-Wesley Publishing Company, Reading, MA, 1994.
Pap, Gyula: Probability theory 1 and 2, http://www.inf.unideb.hu/valseg/dolgozok/papgy/okt.html
Fazekas, István: Probability theory (in Hungarian) Kossuth Egyetemi Kiadó, Debrecen, 2003.

Subject: Applications of Mathematical Statistics
Classes/week: 2 hour lecture, 1 hour seminar
ECTS Credit Points: 3
Prerequisites: None
Lecturers: István Fazekas, PhD; Endre Iglói

Topics: Basic notions: regression, statistical space, sample, empirical distribution, Glivenko-Cantelli theorem, Kolmogorov-Smirnov theorems, sufficiency, completeness, statistics.
Basic concepts of estimation theory, maximum-likelihood estimator, Fisher information, Rao-Cramer inequality, Rao-Blackwell theorem, Bayesian method, method of moments.
Testing statistical hypotheses. Neyman-Pearson lemma. Confidence intervals. Parametric tests: u-, t-, and F-tests. Linear model. Nonparametric tests: chi-square and Kolmogorov-Smirnov tests. Constructing tests. Asymptotic properties of tests.

Compulsory/Recommended Readings:
Williams, D. Weighing the odds. A course in probability and statistics. Cambridge University Press, Cambridge, 2001.
N.C. Giri, Introduction to Probability and Statistics, Dekker, New York, 1975.
Stoodley, K.D.C. – Lewis, T. – Stainton, C.L.S.: Applied statistical techniques. Ellis Horwood, Chichester, 1980.

Subject: Applications of Informatics
Classes/week: 2 hour seminar
ECTS Credit Points: 2
Prerequisites: None
Lecturers: Attila Bérczes, PhD; István Pink, PhD

Topics: Using program packages in algebra, number theory, analysia, geometry and numerical analysis. Basics of linear programing. Ont he frame of the the course the students will study the use of a program package.

Compulsory/Recommended Readings:
A. Schrijver: Theory of Linear and Integer Programming, Wiley, New York, 1998.
Pethő Attila: Algebraische Algorithmen, Vieweg, 1999.
J. Canon – W. Bosma: Handbook of MAGMA, elektronikusan elérhető segédanyag.
Molnárka Győző, Gergó Lajos, Wettl Ferenc, Horváth András, Kallós Gábor: A Maple V és alkalmazásai, Springer Tudományos Kiadó, 1966.
Juhász Imre: Számítógépi geometria és grafika, Miskolci Egyetemi Kiadó, 1993.
Kurusa Á., Szemők Á.: A számítógépes ábrázoló geometria alapjai, Polygon, 1999.
M. Klincsik, Gy. Maróti: Maple 8 tételben a matematikai problémamegoldás művészetéről, Novadat, Győr, 1995.

Subject: Finite Fields and their Applications
Classes/week: 2 hour lecture, 2 hour seminar
ECTS Credit Points: 5
Prerequisites: Applications of Algebra and Number Theory
Lecturers: Piroska Lakatos, PhD; Szabolcs Tengely, PhD

Topics: The theory of finite fields and its applications in he error-correcting codes and its applications. Algebraic algorithms in the applications of the finite fields.

Compulsory/Recommended Readings:
Emil Kiss, Introduction of Abstract Algebra (Hungarian)
http://www.cs.elte.hu/~ewkiss/bboard/algebrabook
Lidl, R. and Niederreiter, H., Finite Fields , Cambridge, England, Cambridge University Press, 1994.
P. Lakatos. Algebraic coding theory (Hungarian), Lectures notes, Institute of Mathematics, Debrecen 1998.

D. R. Stinson., Cryptography:Theory and Practice, CRC Press, 1995.
A. J. Menezes, P. C. van Oorschot and S. A. Vanstone., The Handbook of Applied Cryptography, CRC Press. 1996. http://www.cacr.math.uwaterloo.ca

Subject: Applied Graph Theory
Classes/week: 2 hour lecture, 2 hour seminar
ECTS Credit Points: 5
Prerequisites: None
Lecturers: Lajos Hajdu, PhD; Sándor Turjányi, dr. Univ.

Topics: k-connected graphs, disjoint trees, increasing the connectedness level. Colouring of graphs and hypergraphs, perfect graphs. The theory of pairing. Embedding of graphs. Strongly regular graphs. The wholeness condition and its applications. Random methods: expected value and second moment method, random graphs, limit function. Extremal combinatorics: classical theorems on extremal sets and extremal graphs.

Compulsory/Recommended Readings:
Bollobás Béla, Random graphs. 2nd ed. Cambridge Studies in Advanced Mathematics. 73. Cambridge: Cambridge University Press. xviii, 498 p. (2001).
Bollobás Béla, Extremal graph theory. Reprint of the 1978 original. Mineola, NY: Dover Publications. xx, 488 p. (2004)
Gross, Jonathan; Yellen, Jay, Graph theory and its applications. 2nd ed.;[B] Discrete Mathematics and its Applications. Boca Raton, FL: Chapman \& Hall/CRC. 779 p. (2006). [ISBN 1-58488-505-X/hbk]
G. Gutin & J. Bang-Jensen, Digraphs: Theory, Algorithms and Applications, Springer (2000) Kocay, William; Kreher, Donald L.Graphs, algorithms, and optimization. [B] Discrete Mathematics and its Applications. Boca Raton, FL: Chapman \& Hall/CRC. xv, 483 p. (2005). [ISBN 1-58488-396-0/hbk]
L. Lovász & M.D. Plummer, Matching Theory (North-Holland 1986)

Subject: Convex Optimization
Classes/week: 2 hour lecture, 2 hour seminar
ECTS Credit Points: 5
Prerequisites: Linear Algebra and Applications
Lecturers: Péter T. Nagy, DSc; Gábor Nyúl, PhD

Topics: Continuous and stochastic optimizations. Altemative theorems, Minkowski-Weyl theorem, pivot and inner point algorithms, ellipsoid method; convex optimization: separation theorems, convex Farkas theorem, Karush-Kuhn-Tucker conditions. Lagrange function and saddle point theorem. Newton's method, inner point algorithm. Basic methods of stochastic programming, applications and practical questions.

Compulsory/Recommended Readings:
Berkovitz: Convexity and Optimization in **E"**, John Wiley, New York, 2002.
Boyd - Vandenberghe: Convex Optimization, Cambridge University Press, Cambridge, 2003.
Prékopa: Stochastic Programming, Kluwer, Dordrecht, 1995.

Subject: Discrete Optimization Classes/week: 2 hour lecture, 2 hour seminar ECTS Credit Points: 5
Prerequisites: Linear Algebra and Applications
Lecturers: Péter T. Nagy, DSc; Gábor Nyul, PhD

Topics: Discrete optimization. Max-flow and min-cut theorem, Egerváry duality theorem, combinatorics of polyhedra, totally dual integrality, matching polyhedra; graph algorithms, Hungarian method, Edmonds-Karp algorithm; algorithmic approach to NP-complete problems: dynamical programming, Lagrange-relaxation, constraints and separation, greedy algorithms; applications and practical problems.

Compulsory/Recommended Readings:
Grötschel – Lovász – Schrijver: Geometric algorithms and combinatorial optimization, Berlin - New York , Springer-Verlag, 1988.
Schrijver: Combinatorial Optimization – Polyhedra and Effeciency, Springer, Berlin, 2003.

Subject: Orthogonal polynomials
Classes/week: 2 hour lecture
ECTS Credit Points: 3
Prerequisites: Applied Analysis
Lecturers: Zsolt Páles, DSc; Zoltán Boros, PhD

Topics: Hilbert spaces, orthonormal systems. Pointwise and uniform convergence of trigonometric and orthogonal polynomial series. Fourier transformation. Basics of approximation theory. Stone's theorem. Bohmamm-Korovkin theorem. Best approximation by polynomials. Jackson's theorems. Interpolation. Spline functions. Approximation by rational functions.

Compulsory/Recommended Readings:
Paál L. Gy.: Ortogonális függvénysorok (Orthogonal series), Tankönyvkiadó, Budapest, 1982.
Szőkefalvi-Nagy B.: Valós függvények és függvénysorok (Real functions and function series), Tankönyvkiadó, Budapest, 1972.
I.P. Natanszon: Konstruktív függvénytan (Constructive theory of functions), Tankönyvkiadó, Budapest, 1952.
N.I. Ahijezer: Előadások az approximáció elméletéről (Lectures on approximation theory), Akadémiai Kiadó, Budapest, 1951.

Subject: Applications of Ordinary Differential Equations
Classes/week: 2 hour lecture , 1 hour seminar
ECTS Credit Points: 4
Prerequisites: Applied Analysis
Lecturers: László Székelyhidi, DSc; Rezső L. Lovas, PhD

Topics: Stability theory. Periodic solutions. Boundary value problems for linear differential equations. The basic problem of the calculus of variation. Euler-Lagrange differential equations. Geometrical methods in mechanics. Lagrange- and Hamilton- systems. Legendre transformation. Euler-Lagrange differential equations, Hamilton-equations. Symmetry and preservation theorems.

Compulsory/Recommended Readings:
V.I. Arnold, Ordinary differential equations (in Hungarian), Műszaki Könyvkiadó, Budapest, 1987.
A. Kósa ., Calculus of variations (in Hungarian), Tankönyvkiadó, Budapest, 1972.
M. de León, P.R. Rodrigues, Methods of differential geometry in analytical mechanics, Elsevier Science, 1989.
R. Abraham, J.E. Marsden, Foundations of mechanics, Benjamin/Cummings, 1978

Subject: Partial Differential Equations with Applications
Classes/week: 2 hour lecture, 1 hour seminar ECTS Credit
Points: 4 Prerequisites: Applied Analysis
Lecturers: Zoltán Boros, PhD; Rezső L. Lovas, PhD

Topics: Basic concepts, elementary methods. Characteristic function, conservation laws. First-order quasilinear equations. Theory of characteristics for first-order equations and Cauchy problems. Classification and canonical transformation of second-order linear equations. Goursat and Cauchy problem for hyperbolic equations. Initial/boundary-value problem for the wave equation, Fourier's method. Initial/boundary-value problem for the heat equation, maximum principle. Cauchy problem for the heat equation, Duhamel's principle. Boundary-value problems for the potential equation. Fixed point theorems with applications.

Compulsory/Recommended Readings:
G. Hellwig: Partial Differential Equations. B.G. Teubner, Stuttgart, 1977.
M. Renardy, R. C. Rogers: An Introduction to Partial Differential Equations. Springer-Verlag, New York, 1993.

Subject: Stochastic Processes
Classes/week: 2 hour lecture, 2 hour seminar
ECTS Credit Points: 5
Prerequisites: Applied Probability
Lecturers: Gyula Pap, DSc; Mátyás Barczy, PhD; Márton Ispány, PhD

Topics: Square integrable processes. Weakly stationary processes, linear filters. Basics of time series analysis. Strongly stationary processes, ergodic theorems. Discrete and continuous time Markov chains and their applications. Itô type stochastic integral, stochastic differential equations, diffusion processes.

Compulsory/Recommended Readings:
Gihman, I. I., Skorohod, A. D.: *Introduction to the Theory of Random Processes*. W. B. Saunders Co., Philadelphia, Pa.-London-Toronto, Ont. 1969.
Karlin, S., Taylor, H. M.: *A First Course in Stochastic Processes*. Academic Press, New York-London 1966.
Karatzas, I., Shreve, S. E.: *Brownian Motion and Stochastic Calculus*, Springer-Verlag, Berlin, Heidelberg, New York, 1991.
Arnold, L.: *Stochastic Differential Equations: Theory and Applications*. Wiley-Interscience [John Wiley & Sons], New York-London-Sydney, 1974.
Pap, Gyula: Stochastic processes, http://www.inf.unideb.hu/valseg/dolgozok/papgy/okt.html

Subject: Theory of Algorithms
Classes/week: 2 hour lecture, 2 hour seminar
ECTS Credit Points: 5
Prerequisites: Applied Graph Theory
Lecturers: Ákos Pintér, PhD; Szabolcs Tengely, PhD

Topics: Ordering and choice, heap, Fibonacci heap. Dynamic programming. Graph algoritms: breadth-first search and dept-first search, spanning trees, shortest paths, Dijkstra's algorithm, Bellman-Ford algorithm, Floyd method for the searching of the shortest path. Streams, maximal streams, minimal cut, Ford-Fulkerson algoritmm, Edmonds-Karp and Dinic algorithms. Search tree, amortized cost, string search. Huffman code, Lempel-Ziv-Welch compression method

Compulsory/Recommended Readings:
Cormen, Thomas H., Leiserson,Charles E., Rivest Ronald L.: Új Algoritmusok, Scolar Kiadó, Budapest 2003.
Lovász L. és Gács P., Algoritmusok, Műszaki Könyvkiadó, Budapest, 1978.

Rónyai L., Ivanyos G., Szabó R.: Algoritmusok,Typotex,Budapest, 1998.
Wilf Herbert S., Algorithms and Complexity (Electronic edition, 1994)

Subject: Data Mining
Classes/week: 2 hour lecture, 2 hour seminar
ECTS Credit Points: 5
Prerequisites: Theory of Algorithms
Lecturer: Márton Ispány, PhD

Topics: Searching frequent itemset. Associacion rules. Correlation analysis. Classification. Decision trees, neural networks, k-NN, Bayesian networks. Kernel method, support vector machines. Dimension reduction. Spectral methods. Imprint based similarity. Clustering. Divisive methods. Hierarchical methods. Density and link based methods. Spectral-clustering. Applications and implemetation.

Compulsory/Recommended Readings:
Berry, M. J. A., Linoff G., Data Mining Technique. For Marketing, Sales and Customer Support, Wiley, New York, 1997.
Devroye, L., Györfi, L., Lugosi, G., A Probabilistic Theory of Pattern Recognition, Springer, Berlin, 1996.
Hastie, T., Tibshirani, R., Friedman, J., The Elements of Statistical Learning. Data Mining, Inference, and Prediction, Springer, New York, 2001.

Subject: The Mathematics of WWW and Networks
Classes/week: 2 hour lecture, 2 hour seminar ECTS
Credit Points: 5 Prerequisites: Applied Graph Theory
Lecturers: Gábor Fazekas, PhD; Sándor Baran, PhD

Topics: Web browsers. Markov chains and random walks on graphs. Theory of search engines. Page Rank and applications. HITS models. Singular decomposition, graph clustering. Graph models (Barabasi). Kleinberg's small-world model. Web page caching, database refreshing. Synchronization and parallelism. Distributed systems and computation.

Compulsory/Recommended Readings:
William Stallings: Data and computer communications (4. ed.), Macmillan Publ. Comp. New York, 1994.
A.S. Tannenbaum: Computer Networks, Fourth Edition, Prentice Hall, Upper Saddle River, 2003.
A.S. Tannenbaum, M.van Steen: Distributed systems: principles and paradigms, Prentice Hall, Upper Saddle River, 2004.
Iványi Antal: Párhuzamos algoritmusok, ELTE Eötvös Kiadó, Budapest, 2005.
Informatikai algoritmusok 1, Szerk.: Iványi Antal, ELTE Eötvös Kiadó, Budapest, 2005.
N.A. Lynch: Osztott algoritmusok, Kiskapu Kft. Budapest, 2002.
Benkő Tamás, Lukácsy Gergely, Szeredi Péter: A szemantikus világháló elmélete és gyakorlata, Typotex , Budapest, 2005.

Subject: Complexity Theory
Classes/week: 2 hour lecture, 2 hour seminar
ECTS Credit Points: 5
Prerequisites: Theory of Algorithms
Lecturers: Pál Dömösi, DSc; Benedek Nagy, PhD

Topics: Computing models, algorithms and lower bounds for usage of resources. Communication games. Finite automata, formal languages. Turing-machines: space and time complexity. Random complexity classes. Pseudo random generators. The polynomial hierarchy. The class PSPACE. PSPACE-completeness. Interactive protocols. Shamir's theorem: IP=PSPACE. Approximation of hard problems. Boole-networks. Parallel algorithms for arithmetic problems, sorting, graphs and linear algebra. Kolmogorov complexity.

Compulsory/Recommended Readings:
Lovász László: Algoritmusok bonyolultsága, egyetemi jegyzet, ELTE, Budapest, 1992.
Papadimitrou, Christos H.: Computational complexity, Addison-Wesley, 1995. Révész, György: Introduction to Formal Languages, McGraw-Hill, New York, 1983. Rónyai Lajos, Ivanyos Gábor és Szabó Réka, Algoritmuselmélet, Typotex, 1998.

Subject: Design, Analysis and Implementation of Algorithms and Data Structures
Classes/week: 3 hour lecture, 3 hour seminar
ECTS Credit Points: 7
Prerequisites: Theory of Algorithms
Lecturers: Attila Pethő, DSc; Attila Bérczes, PhD

Topics: Searching in ordered sets. Sorting. Quicksort. Lower bound for the complexity of sorting. Hashing and sequential serching. The 2-SAT problem.
Decomposition of graphs into threes. Gomory-Hu-threes and their applications. The Steiner-three and the traveling salesman problem. Flows, max flow-min cut theorem. Matching in bipartite graphs. Fast Fourier transformation and its applications.
The disjoint union-whereis data structure. Balanced and self-balancing threes. Dynamical threes. Geometrical data structures: hierarchical searching threes, intervall-threes and pile threes.

Compulsory/Recommended Readings:
D.E. Knuth, The art of computer programming, Vol. 3. Sorting and searching
A.V. Aho, J.E. Hopcroft and J.D. Ullman, Data structures and algorithms, Addison Wesley, reading Mass., 1983.
Jungnickel, Dieter Graphs, networks and algorithms, Algorithms and Computation in Mathematics, 5. Springer-Verlag, Berlin, 2005.
Rónyai Lajos, Ivanyos Gábor és Szabó Réka, Algoritmuselmélet, Typotex, 1998.

Subject: Cryptography and Data Security
Classes/week: 3 hour lecture, 3 hour seminar
ECTS Credit Points: 7
Prerequisites: None
Lecturers: Attila Bérczes, PhD; Gábor Nyul, PhD

Topics: Basics of data security. Anylisya of classical cryptosystems. Simmetric cryptosystems. Block and stream ciphers. Public key cryptography. The RSA algorithm. The Diffie-Hellman key exchange protocol. Digital signatures. Attacks on the RSA. The Rabin cryptosystem, the ElGamal cryptosystem. Elliptic curve cryptography. Cryptographical protocols. Sharing secrets, Zero-knowledge proofs, remote coin-flip. Data protection systems, international and Hungarian pattents and projects. Generating pseudo-random numbers.

Compulsory/Recommended Readings:
Ködmön József: Kriptográfia, Computerbooks, Budapest, 1999.
J. Buchmann: Einführung in die Kryptographie, Springer, 1999.
N. Koblitz: A Course in Number Theory and Cryptography, Springer, 1987.
A. Menezes, P. van Oorschot, and S. Vanstone, Handbook of Applied Cryptography, by CRC Press, 1996.

Subject: Theory of Information, Coding and Symmetric Structures
Classes/week: 2 hour lecture, 2 hour seminar
ECTS Credit Points: 5
Prerequisites: None
Lecturers: Attila Pethő, DSc; Tamás Herendi, PhD

Topics: Entropy, conditional entropy. Mutual information. Maximum of the entropy, Fano-inequality. Entropy of data sources. Lossless source coding. Source coding with prescribed error probability. Voice and image compression. Channel coding, capacity, theorem of Shannon. Error correcting codes, important examples. Bounds for the parameters of codes. Perfect codes and block systems. The Golay-codes. t-sytems, the inequality of Fisher and its variants. Latin squares.

Compulsory/Recommended Readings:
Ash, Robert: Information theory. Interscience Tracts in Pure and Applied Mathematics, No. 19 Interscience Publishers John Wiley & Sons, New York-London-Sydney, 1965.
Csiszár, Imre; Körner, János: Information theory. Coding theorems for discrete memoryless systems. Probability and Mathematical Statistics, Academic Press, Inc. [Harcourt Brace Jovanovich, Publishers], New York-London, 1981.
Reza, Fazlollah M.: An introduction to information theory, McGraw-Hill Electrical and Electronic Engineering Series McGraw-Hill Book Co., Inc., New York-Toronto-London, 1961.
Györfi László, Győri Sándor, Vajda István, Információ és kódelmélet, Typotex Kiadó, 2000.

Subject: Applied Combinatorics
Classes/week: 2 hour lecture, 2 hour seminar
ECTS Credit Points: 5
Prerequisites: None
Lecturers: Lajos Hajdu, PhD; Sándor Turjányi, dr. univ.

Topics: Enumerative combinatorics, random methods, extremal combinatorics, combinatorial optimization and its applications.

Compulsory/Recommended Readings:
Bollobás, Béla, Combinatorics. Set systems, hypergraphs, families of vectors and combinatorial probability. Cambridge etc.: Cambridge University Press. XII, 177 p. (1986).
Bóna, Miklós, Combinatorics of permutations. [B] Discrete Mathematics and its Applications. Boca Raton, FL: Chapman \& Hall/CRC. 383 p. (2004). [ISBN 1-58488-434-7/hbk]
Hajnal Péter, Összeszámlálási problémák., Polygon , Szeged, 1997.
Lawler, Eugene L., Kombinatorikus optimalizálás: hálózatok és matroidok, Műszaki Könyvkiadó, Budapest 1982.
Wilf, Herbert S.Generatingfunctionology. 3rd ed. [B] Wellesley, MA: A K Peters. x, 245 p. (2006). [ISBN 1-56881-279-5/hbk]

Subject: Artificial Intelligence
Classes/week: 2 hour lecture, 2 hour seminar
ECTS Credit Points: 5
Prerequisites: None
Lecturers: Magda Várterész, PhD; Márk Kósa

Topics: Artificial intelligence methods and techniques. Problem representations, state-space representation, examples. State-space graph, graph-search procedures: depth-first, breadth-first. Backtracking, optimal search strategies, heuristics. A and A* algorithms, completeness, monotone restriction. Constructive search algorithms. Local search algorithms: simulated annealing, tabu search,

Hungarian method. Developed search algorithms. Problem-reduction representation and AND/OR graphs. Search procedures for AND/OR graphs, algorithm AO. Two-person, perfect-information games, game trees, winning strategy. Mini-max procedure, alpha-beta pruning procedure. Automated theorem proving and logical programming. Normal forms, prenex form, skolemization. Herbrand's theorem. Substitution, unification. The most general unifiers, unification algorithms. Hilbert systems, natural deduction. The sequent calculus, cut elimination. Semantic tableaux. Resolution, important reolution strategies. Horn-clauses and Prolog..

Compulsory/Recommended Readings:
N. Nilsson, Artificial Intelligence, A New Synthesis, The Morgan Kaufmann Series in Artificial Intelligence, 1998.
S. J. Russel, P. Norvig, Artificial Intelligence, A Modern Approach, Prentice- Hall, 1995.
M. Fitting: First-Order Logic and Automated Theorem Proving, Springer, 2nd edition, 1996.
S. K. Das: Deductive databases and logic programming, Addison Wesley, 1992.
U. Nilsson, J. Maluszinski, *Logic, Programming and Prolog*, 2nd edition, Wiley and Sons, 2000.

Subject: Game Theory
Classes/week: 2 hour lecture, 2 hour seminar
ECTS Credit Points: 5
Prerequisites: Applied Analysis
Lecturer: Attila Gilányi, PhD

Topics: The subject of game theory. Game theoretical models, games in extensive, normal and characteristic function form. Finite games. Fixed point theorems and graph theoretical results applied in game theory. General properties of non-cooperative games. Equilibrium points, the concept of Nash equilibrium, its existence and uniqueness. Two person zero-sum games, matrix games. Basic properties of cooperative games.

Compulsory/Recommended Readings:
K. C. Border, Fixed Point Theorems with Applications to Economics and Game Theory, Cambridge University Press, 1999.
F. Forgó, J. Szép, F. Szidarovszky, Introduction to the Theory of Games, Kluwer Academic Publishers, Dordrecht, Boston, London, 1999.
J. von Neumann, O. Morgenstern, Theory of Games and Economic Behavior, Princeton University Press, Princeton, 1944.
M. J. Osborne, An Introduction to Game Theory, Oxford University Press, New York, 2004.

Subject: Computational Number Theory, Computer Algebraic Program Packages
Classes/week: 4 hour seminar
ECTS Credit Points: 5
Prerequisites: None
Lecturers: Attila Bérczes, PhD; Csaba Rakaczki, PhD

Topics: An overview of the most important mathematical program packages. Fundamental programing tools in MAGMA, PARI and MAPLE (data structure, conditional statements, iterative statements, recursion, functions, procedures). Representation of basic algebraic structures. Defining and handeling curves in the different packages, searching for integral point on curves. Solutions of various types of diophantine equations with the help of program packages.

Compulsory/Recommended Readings:
J. Canon – W. Bosma: Handbook of MAGMA, elektronikusan elérhető segédanyag.
J. Canon -- C. Playoust: An Introduction to Algebraic Programming with MAGMA, elektronikusan elérhető segédanyag.
C. Batut, K. Belabas, D. Bernardi, H. Cohen, M. Olivier -- User's Guide to PARI / GP (version 2.3.1) , elektronikusan elérhető segédanyag.

A: Heck -- Introduction to Maple. Third edition. Springer-Verlag, New York, 2003.

Subject: Analysis with Computer
Classes/week: 3 hour seminar
ECTS Credit Points: 3
Prerequisites: None Lecturer:
Attila Gilányi, PhD

Topics: Solving problems in analysis with computer, determining limits, derivatives, integrals. Exact and numeric solution of differential equations. Conditional optimization.
Displaying functions of one variable and functions of several variables and investigating their properties. Expansion of functions into series, interpolation. Exact and numeric solution of nonlinear equations and systems of equations.

Compulsory/Recommended Readings:
Maple 9, Learning Guide, Waterloo Maple Inc. 2003.
M. B. Monagan, K. O. Geddes, K. M. Heal, G. Labahn, S. M. Vorkoetter, J. McCarron, P. De Marco, Maple 9, Advanced Programming Guide, Waterloo Maple Inc. 2003.

Subject: Computer-aided Differential Geometry
Classes/week: 2 hour lecture, 2 hour seminar
ECTS Credit Points: 5
Prerequisites: None
Lecturer: Zoltán Muzsnay, PhD

Topics: Differential geometry of curves. Computation and visualization of the basic quantities (torsion, curvature) with computer algebra systems. Elements of the theory of surfaces. The investigation of special curves, surfaces, geodesics and curvatures. Elements of the calculus of variations and some geometric problems in physics with Maple.

Compulsory/Recommended Readings:
Gray, S. Salamon, E. Abbena: Modern Differential Geometry of Curves and Surfaces with Mathematica. Studies in Advanced Mathematics 47, Chapman & Hall/CRC, Boca Raton, FL, 2006.
J. Oprea Differential Geometry and its Applications, Prentice Hall, 2004**.**
A. Heck – Introduction to Maple. Third edition. Springer-Verlag, New York, 2003.

Subject: First-Order Logic
Classes/week: 3 hour lecture
ECTS Credit Points: 4
Prerequisites: None Lecturer:
Ágota Figula, PhD

Topics: First-Order Language of mathematical logic. Syntax of first-order languages, semantics of first-order languages. The connection between the syntactic and semantics concepts: satisfaction, completeness. Theorems of Godel. Formal methods: the axioms of arithmetic and set theory.

Compulsory/Recommended Readings:
Ebbinghaus, H.-D., Flum, J., Thomas, W.: Mathematical Logic, Undergraduate Texts in Mathematics, Springer, 1996.
Andras Hajnal, Laszlo Csirmaz: Mathematical Logic, ELTE, Budapest, 1994 in Hungarian.
Albert Dragalin, Szvetlana Buzasi: Introduction in Mathematical Logic, Kossuth Egyetemi Kiad, Debrecen, 2002 in Hungarian.

Subject: Finite Geometries
Classes/week: 2 hour lecture, 2 hour seminar
ECTS Credit Points: 5
Prerequisites: None
Lecturers: Péter T. Nagy, DSc; Ágota Figula, PhD

Topics: Incidence structures. Finite affine and projective geometries. Cyclic planes. Block designes, constructions, existence theorems. Steiner systems. Möbius planes. Quadratic sets, ovals and hyperovals.

Compulsory/Recommended Readings:
Hughes – Piper: Projective planes, Graduate Texts in Mathematics, Vol. 6. Springer-Verlag, New York-Berlin, 1973.
Hughes – Piper: Design theory, Cambridge University Press, Cambridge, 1988.
Dembowski: Finite geometries. Classics in Mathematics. Springer-Verlag, Berlin, 1997.

Subject: Quasigroups and Combinatorial Structures
Classes/week: 2 hour lecture, 2 hour seminar
ECTS Credit Points: 5
Prerequisites: None
Lecturers: Péter T. Nagy, DSc; Ágota Figula, PhD

Topics: Loops, quasigroups, latin squeres. Examples and constructions. Nets, orthogonality of quasigroups. Centrality properties. Commutative Moufang loops. Distributive quasigroups. Related combinatorial structures.

Compulsory/Recommended Readings:
Dénes – Keedwell: Latin Squares and their Applications, English Universities Press, 1974.
Quasigroups and Loops: Theory and Applications. Edited by Chein, Pflugfelder and Smith. Sigma Series in Pure Mathematics, 8., Heldermann Verlag, Berlin, 1990.
Pflugfelder: Quasigroups and Loops: Introduction. Sigma Series in Pure Mathematics, 7. Heldermann Verlag, Berlin, 1990.

Subject: Lattice Theory
Classes/week: 2 hour lecture
ECTS Credit Points: 3
Prerequisites: None
Lecturers: Lajos Hajdu, PhD; Csaba Rakaczki, PhD

Topics: Basic concepts, unimodular transformations, lattice determinant, polar lattice. Lattices and quadratic forms. Convex sets, the theorem of Minkowski, successive minima. Algorithms and applications.

Compulsory/Recommended Readings:
J. W. S. Cassels: An Introduction to the Geometry of Numbers, Springer, 1959.
P. M. Gruber, C. G. Lekkerkerker: Geometry of Numbers, North-Holland Publishing Co., 1987.
H. Cohen: A Course in Computational Algebraic Number Theory, Springer, 1995.
Freud R., Gyarmati E.: Számelmélet, Nemzeti Tankönyvkiadó, 2000.

Subject: Discrete Tomography
Classes/week: 2 hour lecture
ECTS Credit Points: 3
Prerequisites: None Lecturer:
Lajos Hajdu, PhD

Topics: Theoretical problems of discrete tomography. The question of unique reconstruction in the classical case and in case of absorption. The structure of classes of tomographical equivalent sets. Convex- and HV-convex sets. Algorithms and complexity problems.

Compulsory/Recommended Readings:
Discrete Tomography, International Journal of Imaging Systems and Technology 9, No. 2/3, Special Issue, (G. T. Herman and A. Kuba, eds.), 1998.
G. T. Herman and A. Kuba, Discrete Tomography: Foundations, Algorithms and Applications, Birkhäuser, Boston, 1999.
Linear Algebra and its Applications 339, Special issue on Discrete Tomography (A. Del Lungo, P. Gronchi and G. T. Herman, eds.), 2001.

Subject: Iterative Fixed Point Theory and its Applications
Classes/week: 2 hour lecture
ECTS Credit Points: 3
Prerequisites: None
Lecturer: Mihály Bessenyei, PhD

Topics: The fixed point theorem of Banach and its generalizations, iterative fixed point theorems. The stability of the fixed point and its continous dependence. Ekeland's variational principle and the fixed point theorem of Caristi. Tarski's fixed point theorem for partially ordered sets. Interpretations of existence and uniqueness problems as fixed point theorems: Inverse and implicit function theorems; open mapping theorem. Existence and uniqueness theorems for differential equations. Solving nonlinear system of equations. Fractal theory.

Compulsory/Recommended Readings:
E. Zeidler, Nonlinear Functional Analysis and its Applications I-IV, Springer, 1986.
Granas—J. Dugundji, Fixed Point Theory, Springer, 2003.
V. Berinde, Iterative Approximation of Fixed Points, Efemeride, 2002.

Subject: Extremum Problems Classes/week:
2 hour lecture, 1 hour seminar ECTS Credit
Points: 4 Prerequisites: None Lecturer: Zsolt
Páles, DSc

Topics: Classical and modern extremum problems. Fermat1s principle. Descent, admissible, and tangent directions and variations in constrained extremum problems and their determination. Tangent space of nonlinear manifolds. The necessary conditions of Dubovitskii and Milyutin for the extremum in primal form. The dual form of the necessary conditions: first- and second-order Lagrange principle. Dufficient conditions of the optimality.

Compulsory/Recommended Readings:
A. D. Ioffe---V. M. Tihomirov, Theory of Extremal Problems, North-Holland, 1979.
I. V. Girsanov, Mathematical Theory of Extremum Problems, Moszkva, 1970.
Kósa A., Optimumszámítási modellek (Models of optimization problems), Műszaki Könyvkiadó, 1979.