DEPARTMENT OF MATHEMATICS UNDERGRADUATE CURRICULUM

FIRST YEAR

First Semester

MATH 131	Fundamentals of Mathematics I	(3-2)4 / ECTS:7
MATH 151	Calculus I	(4-2)5 / ECTS:8
CENG 111	Concepts in Computer Engineering	(3-0)3 / ECTS:4
PHYS 101	General Physics I	(2-2)3 / ECTS:6
PHYS 111	General Physics Lab. I	(0-2)1 / ECTS:2
ENG 101	Development of Reading and Writing Skills I	(3-0)3 / ECTS:3
		Total Credits:19 **Total ECTS:**30

Second Semester

MATH 132	Fundamentals of Mathematics II	(3-2)4 / ECTS:6
MATH 152	Calculus II	(4-2)5 / ECTS:7
CENG 113	Programming Basics	(3-2)4 / ECTS:6
PHYS 102	General Physics II	(2-2)3 / ECTS:6
PHYS 112	General Physics Lab. II	(0-2)1 / ECTS:2
ENG 102	Development of Reading and Writing Skills II	(3-0)3 / ECTS:3
		Total Credits:20 **Total ECTS:**30

SECOND YEAR

Third Semester

MATH 251	Vector Analysis	(3-2)4 / ECTS:9
MATH 255	Differential Equations	(4-0)4 / ECTS:6
MATH 261	Linear Algebra I	(3-2)4 / ECTS:8
HIST 201	Principles of Atatürk I	(2-0)NC / ECTS:2
TURK 201	Turkish Language I	(2-0)NC / ECTS:2
Non-Technical Elective		(3-0)3 / ECTS:3
		Total Credits:15 **Total ECTS:**30

Fourth Semester

MATH 202	Scientific Computing	(2-2)3 / ECTS:6
MATH 240	Analtical Mechanics	(3-2)4 / ECTS:5
MATH 252	Analysis	(4-0)4 / ECTS:6
MATH 262	Linear Algebra II	(3-2)4 / ECTS:6
HIST 202	Principles of Atatürk II	(2-0)NC / ECTS:2
TURK 202	Turkish Language II	(2-0)NC / ECTS:2
Non-Technical elective		(3-0)3 / ECTS:3
		Total Credits:18 **Total ECTS:**30

THIRD YEAR

Fifth Semester

MATH 301	Dynamical Systems	(3-0)3 / ECTS:6
MATH 355	Partial Differential Equations	(4-0)4 / ECTS:6
MATH 361	Abstract Algebra	(4-0)4 / ECTS:6
MATH 381	Numerical Analysis	(3-2)4 / ECTS:6
Technical elective		(3-0)3 / ECTS:6
		Total Credits:18 **Total ECTS:**30

Sixth Semester

MATH 352	Complex Analysis	(4-2)5 / ECTS:10
MATH 372	Differential Geometry	(3-0)3 / ECTS:8
Technical Elective		(3-0)3 / ECTS:6
Technical Elective		(3-0)3 / ECTS:6
		Total Credits:14 **Total ECTS:**30

FOURTH YEAR

Seventh Semester

MATH 415 Mathematical Research Project I	(2-0)NC / ECTS:15
Technical elective	(3-0)3 / ECTS:6
Technical elective	(3-0)3 / ECTS:6
A Non Technical elective	(3-0)3 / ECTS:3
	Total Credits:9 **Total ECTS:**30

Eighth Semester

MATH 416 Mathematical Research Project II	(2-0)NC / ECTS:15
Technical elective	(3-0)3 / ECTS:6
Technical elective	(3-0)3 / ECTS:6
A Non Technical elective	(3-0)3 / ECTS:3
	Total Credits:9 **Total ECTS:**30

Total Credit: 122
Total ECTS: 240

Technical Elective: Any course from the Departments of Engineering or Science Faculty
A Non Technical Elective: Any course from the Department of General Culture, School of Foreign Languages or Faculty of Architecture

Core Courses

MATH 131 Fundamentals of Mathematics I	(3-2)4 ECTS: 7
MATH 132 Fundamentals of Mathematics II	(3-2)4 ECTS: 6
MATH 151 Calculus I	(4-2)5 ECTS: 8
MATH 152 Calculus II	(4-2)5 ECTS: 7
MATH 202 Scientific Computing	(2-2)3 ECTS: 6
MATH 240 Analytical Mechanics	(3-2)4 ECTS: 5
MATH 251 Vector Analysis	(3-2)4 ECTS: 9
MATH 252 Analysis	(4-0)4 ECTS: 6
MATH 255 Differential Equations	(4-0)4 ECTS: 6
MATH 261 Linear Algebra I	(3-2)4 ECTS: 8
MATH 262 Linear Algebra II	(3-2)4 ECTS: 6
MATH 301 Dynamical Systems	(3-0)3 ECTS: 6
MATH 352 Complex Analysis	(4-2)5 ECTS: 10
MATH 355 Partial Differential Equations	(4-0)4 ECTS: 6
MATH 361 Abstract Algebra	(4-0)4 ECTS: 6
MATH 372 Differential Geometry	(3-0)3 ECTS: 8
MATH 381 Numerical Analysis	(3-2)4 ECTS: 6
MATH 415 Mathematical Research Project I	(2-0)NC ECTS: 15
MATH 416 Mathematical Research Project II	(2-0)NC ECTS: 15

Elective Courses

MATH 303 History Of Mathematical Concepts I	(3-0)3 ECTS: 6
MATH 304 History Of Mathematical Concepts II	(3-0)3 ECTS: 6
MATH 307 Introduction to Graph Theory	(3-0)3 ECTS: 6
MATH 308 Introduction to Combinatorics	(3-0)3 ECTS: 6
MATH 311 Coding theory	(3-0)3 ECTS: 6
MATH 312 Computational mathematics and algorithms	(2-2)3 ECTS: 6
MATH 333 Introduction to Mathematical Modeling	(3-0)3 ECTS: 6
MATH 341 Advanced Mathematics Internship	(0-6)3 ECTS: 6
MATH 342 Mathematics Internship	(0-1)NC ECTS: 6

MATH 366 Number Theory	(3-0)3 ECTS: 6
MATH 368 An Introduction to Mathematical Control Theory	(3-0)3 ECTS: 6
MATH 385 Special Functions of Applied Mathematics	(3-0)3 ECTS: 6
MATH 386 Fluid Dynamics	(3-0)3 ECTS: 6
MATH 401 Quantum Mechanics	(3-0)3 ECTS: 6
MATH 403 Combinatorial Design theory	(3-0)3 ECTS: 6
MATH 404 Quantum Cumputations and Information	(3-0)3 ECTS: 6
MATH 405 Variational Analysis	(3-0)3 ECTS: 6
MATH 406 Mathematics of Public Key Cryptography	(3-0)3 ECTS: 6
MATH 407 Conformal Mappings	(3-0)3 ECTS: 6
MATH 408 Advanced Topics in Graph Theory	(3-0)3 ECTS: 6
MATH 409 Advanced Topics in Combinatorics	(3-0)3 ECTS: 6
MATH 410 Green's functions	(3-0)3 ECTS: 6
MATH 411 Mathematical optimization	(3-0)3 ECTS: 6
MATH 412 Hyperbolic geometry	(3-0)3 ECTS: 6
MATH 413 Linear and Nonlinear Waves	(3-0)3 ECTS: 6
MATH 414 Introduction to Integral Equations	(3-0)3 ECTS: 6
MATH 422 Introduction to Abelian Groups	(3-0)3 ECTS: 6
MATH 450 Scale Invariance and Dimensional Analysis	(3-0)3 ECTS: 6
MATH 451 Mathematics and Technology	(3-0)3 ECTS: 6
MATH 452 Functional Analysis	(3-0)3 ECTS: 6
MATH 453 Introduction to Generalized Functions	(3-0)3 ECTS: 6
MATH 455 Control of Infinite Dimensional Systems	(3-0)3 ECTS: 6
MATH 456 Galois Theory	(3-0)3 ECTS: 6
MATH 481 Differential Equations with Numerical Methods	(2-2)3 ECTS: 6
MATH 482 Numerical Solutions of Linear Integral Equations	(3-0)3 ECTS: 6
MATH 499 Cooperative Education Course	(0-12)6 ECTS: 6

Courses for other departments

MATH 121 Basic Mathematics I	(4-0)4 ECTS:4
MATH 141 Basic Calculus I	(3-2)4 ECTS:5
MATH 142 Basic Calculus II	(3-2)4 ECTS:6
MATH 144 Finite Mathematics	(3-0)3 ECTS:5
MATH 145 Calculus for Engineering and Science I	(4-2)5 ECTS:7
MATH 146 Calculus for Engineering and Science II	(4-2)5 ECTS:8
MATH 255 Differential Equations	(4-0)4 ECTS:6
MATH 265 Basic Linear Algebra	(3-0)3 ECTS:4

Courses Descriptions

MATH 121 Basic Mathematics I **(4-0)4 ECTS:4**
Real Numbers, Circles, Parabolas, Functions and Their Graphs, Trigonometric Functions and Their Inverses, Precise Definition of a Limit, One-Sided Limits, Infinite Limits and Vertical Asymptotes, Continuity, The Derivative, Differentiation Rules Derivatives of Trigonometric Functions, The Chain Rule and Parametric Equations, Implicit Differentiation, Extreme Values of Functions, The Mean Value Theorem, Monotonic Functions and the First Derivative Test, Concavity and Curve Sketching, Optimization Problems, Indeterminate Forms and L'Hopital's Rule, The Definite Integral, The Fundamental Theorem of Calculus, Indefinite Integrals and the Substitution Rule, Area Between Curves.

MATH 131 Fundamentals of Mathematics I **(3-2)4 ECTS:7**
Symbolic logic. Set theory. Cartesian product. Relations. Functions. Injective, surjective and bijective functions. Composition of functions. More about relations: Equivalence relations. Equivalence classes and partitions. Quotient set. Order relations: partial order, total order, well ordering. Mathematical Induction and recursive definitions of functions. Axiom of choice and its equivalents.

MATH 132 Fundamentals of Mathematics II **(3-2)4 ECTS:6**
Cardinality. Equinumerous sets. Finite sets. Countable sets. Uncountable sets. Cardinal numbers. Metric spaces. Open and closed subsets. Closure and interior. Convergence of sequences. Complete spaces. Continuous functions. Compact spaces. Compactness in Rn. Connected and path connected spaces.

MATH 141 Basic Calculus I **(3-2)4 ECTS:5**
Functions. Limits and Continuity. Derivatives. Applications of Derivatives; Mean Value Theorem, Intermediate Value Theorem. Integration. Applications of Integrals; Volmes by slicing, Surface Areas and Arc Lengths.

Transcendental Functions. Integration Techniques; Substitution Rule, Trigonometric integrals, Integration by Parts.

MATH 142 Basic Calculus II **(3-2)4 ECTS:6**
L'Hopital's Rule. Improper Integrals; Tests for Convergence. Sequences and Infinite series; Tests for Convergence. Polar Coordinates. Multivariable Functions and Their Derivatives; Limits, Directional Derivative, Gradient Vector. Double integral, Double Integral in Polar Coordinates.

MATH 144 Finite Mathematics **(3-0)3 ECTS:5**
Linear Systems of Equations, Elementary Operations on a Linear System, Gauss Elimination Method, Matrices, Elementary Operations on a Matrix, Multiplication of Matrices, Transpose, Rank, Elementary Matrices, Inverse of a Matrix, LU-Decomposition of a Matrix, Determinants, Properties of Determinant, Cramer's Rule, Eigenvalues and Eigenvectors, Cayley-Hamilton Theorem and Applications, Linear Combination of Vectors, Subspaces, Linear Independence and Basis, Theorem of Bases, Linear Programming, Geometrical Approach to Linear Programming Problems, The Duality Principle, The Simplex Method with Mixed Constraints, Graphs, Graph Modeling and Applications, Paths, Cycles, and Trees, Subgraphs. Graph Operations, Graph Isomorphism.

MATH 145 Calculus for Engineering and Science I **(4-2)5 ECTS:7**
Functions; preliminaries. Limits and continuity. Differentiation. Applications of Derivatives; Extreme values of functions, the mean value teorem, monotonic functions and the 1st derivative test, concavity and curve sketching, optimization problems, indeterminate forms and L'Hopital's rule, antiderivatives. Integration; estimating with finite sums, the definite integral, the fundamental theorem of calculus, the substitution rule. Applications of Definite Integrals. Transcendental functions. Techniques of Integration. Conic sections and polar coordinates.

MATH 146 Calculus for Engineering and Science II **(4-2)5 ECTS:8**
Infinite sequences and series, power series, Taylor and Maclaurin series. Vectors and the geometry of space; the dot product, the cross product, lines and planes in space, cylinders and quadric surfaces. Vector-valued functions and motion in space. Partial derivatives; functions of several variables, limits and continuity in higher dimensions, directional derivatives and gradient vectors, extreme values and saddle points, Lagrange multipliers. Multiple integrals; double integrals, double integrals in polar form, triple integrals in rectangular, cylindrical and spherical coordinates, substitutions in multiple integrals. Integration in vector fields; line integrals, vector fields, path independence, Green's theorem, surface area and surface integrals, Stokes' theorem, the Divergence theorem.

MATH 151 Calculus I **(4-2)5 ECTS:8**
Functions, limit and derivative of a function of a single variable, A thorough discussion of the basic theorems of differential calculus: Intermediate value, extreme value, and the Mean Value Theorems, applications: Graph sketching and problems of extrema.

MATH 152 Calculus II **(4-2)5 ECTS:7**
The Riemann Integral, Mean Value Theorem for integrals, Fundamental Theorem of Calculus, Techniques to evaluate anti-derivative, families, various geometric and physical applications. Sequences, improper Integrals, infinite series of constants, power series and Taylor's series with applications.

MATH 202 Scientific Computing **(2-2)3 ECTS:6**
Introduction to Scientific Computing, Data Visualization, Symbolic Computation, Linear Systems, Interpolation and Curve Fitting, Numerical Differentiation and Integration, Ordinary Differential Equation.

MATH 240 Analytical Mechanics **(3-2)4 ECTS:5**
The equations of motion. Generalized coordinates. The principle of least action. Relativity principle. The Lagrangian for a free particle. Conservation laws. Energy. Momentum. Centre of mass. Angular momentum. Integration of the equations of motion. Motion in one dimension. The reduced mass. Motion in a central field. Small oscillations. Free oscillations in one dimension. Forced oscillations. Damped oscillations. Motion of a rigid body. Angular velocity. The inertia tensor. Angular momentum of a rigid body. Eulerian angles. Euler's equations. The canonical equations. Hamilton's equations. The Routhian. Poisson brackets. The action. Canonical transformations. Liouville's theorem. The Hamilton- Jacobi equation.

MATH 251 Vector Analysis **(3-2)4 ECTS:9**
Vector Differential Calculus: Curves in Parametric Form-tangent, norm, arc length parameter. Fields. Gradient. Directional Derivative. Divergence. Curl. . Vector Integral Calculus: Line Integrals. Mass, Work, Flow, Circulation . Line Integrals Independent of Path. Conservative Fields and Potentials. Surfaces and Surface Area. Metric on the Surface. Surface Integrals. Fundamental Theorems of Vector Calculus: Green's Theorem. Stokes' Theorem. Gauss (Divergence) Theorem.

MATH 252 Analysis **(4-0)4 ECTS:6**
Continuos Functions. Uniform Continuity. Sequences and Series of Functions. Pointwise and Uniform Convergence. Bolzano-Wieirstrass Theorem. Riemann Integrability. Fuctions of Several Variables. Limits and Continuity. Derivatives of Composite Fuctions. Jacobian Matrix. Implicit Functions and Implicit Function Theorems. Maxima and Minima of Functions of Several Variables. Lagrange Multipliers Method. Construction of the Lebesque Measure. Measure Spaces. Measurable Functions. Simple functions Integration. Comparison with

the Riemann Integral.

MATH 255 Differential Equations **(4-0)4 ECTS:6**
First order equations and various applications. Second order linear equations. Higher order linear differential equations. Power series solutions: ordinary and regular singular points. The Laplace transform: solution of initial value problems. Systems of linear differential equations: solutions by operator method, by Laplace transform. Fourier Series and boundary value problems.

MATH 261 Linear Algebra I **(3-2)4 ECTS:8**
Matrices. Elementary Row Operations. Systems of Linear Equations. Gauss-Jordan Elimintaion Method. Square Matrices. Determinants. Invertible Matrices. Vector Spaces. Subspaces. Linear Independence. Basis and Dimension. Linear Transformations. Algebra of Linear Transformations. Isomorphism. Representation of Linear Transformations by Matrices. Linear Functionals. Algebra of Polynomials. Lagrange Interpolation. Prime Factorization of Polynomials.

MATH 262 Linear Algebra II **(3-2)4 ECTS:6**
Eigenvalues and Eigenvectors of Linear Operators (matrices). Characteristic and Minimal Polynomials. Diagonalization of Matrices. Triangular Form of a Linear Operator. Cayley-Hamilton Theorem. Direct-Sum Decomposition. Invariant Subspaces. The Primary Decomposition Theorem. Jordan Normal Form. Inner Product Spaces. Linear Functionals. Adjoint of a Matrix. Self-Adjoint, Unitary and Normal Operators. Orthogonal Projections. Spectral Theorem for Self-Adjoint, Unitary and Normal Operators. Bilinear and Quadratic Forms.

MATH 265 Basic Linear Algebra **(3-0)3 ECTS:4**
Matrices, determinants and systems of linear equations. Gaussian elimination. LU Decomposition. Vector spaces; subspaces, sum and direct sums of subspaces. Linear dependence, bases, dimension. rank and nullity, change of basis, canonical forms, inner product, Gram- Schmidt orthogonalization process, QR decomposition. Eigenvalues, eigenvectors, diagonalization, similarity. Quadratic Forms. Complex vector spaces, Complex eigenvalues, Unitary and Hermitian Matrices. Least-squares.

MATH 301 Dynamical Systems **(3-0)3 ECTS:6**
Harmonic oscillators. Conservative force fields. Central force fields. Linear systems with constant coefficients and real and complex eigenvalues. Exponentials of operators. Canonical forms of operators. Sinks and sources. Hyperbolic flows. The fundamental theorem. Existence and uniqueness. Continuity of solutions. Stability. Liapunov functions. Gradient systems. The Poincaré-Bendixson theorem. Periodic attractors. Classical mechanics.

MATH 303 History of Mathematical Concepts I **(3-0)3 ECTS:6**
Origins of number and geometry. Egypt and Mesopotamia. Ionia and Pithagoreans. The Heroic Age. Paradoxes of Zeno. The Age of Plato and Aristotle. Euclid of Alexandria. Elements. Archimedes. Apollonius of Perga. The Conics. The Arithmetical of Diophantus. China and India. Ramanujan. Algebra and arabs. Europe in the Middle Ages. Solution of a qubic equation.

MATH 304 History of Mathematical Concepts II **(3-0)3 ECTS:6**
The Renaissance. Cardano. Solution of qubic equation. Complex numbers. Invention of logarithms. Fermat and Descartes. Analytic geometry. Number theory. Probability. The limit concept. Newton and Leibnitz. The Principia. Probability and infinite series. Development of calculus. Age of Euler. D'Alembert. Lagrange. Monge. Laplace. Gauss and Cauchy. Noneuclidean geometry. Lobachevskiy. Abel, Jacobi, Galois. Projective geometry. Riemannian geometry. Felix Klein. Analysis. Riemann. Mathematical physics. British Algebra. Algebraic geometry. Poincare and Hilbert. Topology. Aspect of Twentieth Century.

MATH 307 Introduction to Graph Theory **(3-0)3 ECTS:6**
Graph terminology; adacency and incidence matrices; isomorphism; handshake lemma; diameter; regular graphs; matchings; planar graphs; chromatic number; hamiltonian cycles; stable sets and cliques; Euler tours; connectivity and components

MATH 308 Introduction to Combinatorics **(3-0)3 ECTS:6**
Counting methods and techniques; pigeonhole principle; generating functions; sum and product lemmas; formal power series; binomial theorem; recurrence relations and their solutions; binary strings; integer partitions

MATH 311 Coding theory **(3-0)3 ECTS:6**
Fundamental definitions; generator and parity check matrices; syndrome decoding; BCH and cyclic codes; Read-Solomon codes

MATH 312 Computational mathematics and algorithms **(2-2)3 ECTS:6**
Algorithms on integers; polynomial algorithms; Fast Fourier Transform, primality testing and integer factorization; algorithms on matrices; geometric algorithms; graphs algorithms

MATH 333 Introduction to Mathematical Modelling **(3-0)3 ECTS:6**
Modelling with discrete dynamical systems. The modelling process, proportionality and geometric similarity. Model fitting. Experimental modelling. Simulation modelling. Discrete probability modelling. Discrete

optimization modelling, linear programming and numerical search methods. Dimensional analysis and similitude. Graphs of functions as models. Modelling with systems of differential equations. Continuous optimization modelling. Project.

MATH 341 Advanced Mathematics Internship **(0-6)3 ECTS:6**
It is a technical elective mathematics course during which the student performs research at an industrial research laboratory or at a university. The consent of the student's advisor in
the Mathematics Department is required for enrollment in this course. The minimum workload is 150 hours. At the end of the internship, the student will prepare a report based on
the research performed and the results obtained.

MATH 342 Mathematics Internship **(0-1)NC ECTS:6**
An elective mathematics course during which the student performs research at an industrial research laboratory or at a university. The minimum workload is 150 hours.

MATH 352 Complex Analysis **(4-2)5 ECTS:10**
Algebra of complex numbers. Polar representation. Analyticity. Cauchy- Riemann equations. Power series. Elementary functions. Mapping by elementary functions. Linear fractional transformations. Line integral. Cauchy-Theorem. Cauchy integral formula. Taylor's Series. Laurent series. Residues, Residue theorem. Improper integrals. Conformal mapping. Integral formulas of the Poisson type. The Schwarz-Christoffel Transformation.

MATH 355 Partial Differential Equations **(4-0)4 ECTS:6**
First order equations; linear, quasilinear and nonlinear equations. Classification of second order linear partial differential equations, canonical forms. The Cauchy problem for the wave equation. Dirichlet and Neumann problems for the Laplace equation, maximum principle. Heat equation on the strip.

MATH 361 Abstract Algebra **(4-0)4 ECTS:6**
Groups and subgroups. Cosets. Theorem of Lagrange. Homomorphisms. Factor groups. Rings, fields and integral domains. Rings of polynomials. Factor rings. Ideals. Prime and maximal ideals. Unique factorization domains. Euclidean domains. Principal ideal domains. Field extensions. Finite fields.

MATH 366 Number Theory **(3-0)3 ECTS:6**
Pythagoren Triples. Sums of Higher Powers and Fermat's Last Theorem. Divisibility and Greatest Common Divisor. Factorization and Fundamental Theorem of Arithmetic. Congurences, Powers, Fermat's Little Theorem and Euler's Formula. Chinese Remainder Theorem. Prime Numbers, Counting Primes. Mersenne Primes and Perfect Numbers. Powers, Roots and Codes. Primality Tests. Euler's Phi Function and Sums of Divisors. Primitive Roots and Indices. Which Numbers are Sums of Two Squares. Continued Fractions, Square Roots and Pell's Equation. Generating Functions. Sums of Powers. Cubic curves and Elliptic Curves.

MATH 368 An Introduction to Mathematical Control Theory **(3-0)3 ECTS:6**
State Space Fundamentals, Reachability and Controllability, Detectability and Observability, Minimal Realizations, BIBO and Asymptotic stability, Design of Linear State Feedback
Control Laws, Observers and Dynamic Feedback

MATH 372 Differential Geometry **(3-0)3 ECTS:8**
General concepts of geometry. Coordinates in Euclidean space. Riemannian metric. Pseudo-Euclidean space and Lobachevsky geometry. Flat curves. Space curves. The theory of surfaces in three-dimensional space. The concept of area. Curvature. The second fundamental form. Gaussian curvature. Invariants of a pair of quadratic forms. Euler's theorem. Complex analysis and geometry. Conformal transformations. Isotermal coordinates. The concept of a manifold. Geodesics.

MATH 381 Numerical Analysis **(3-2)4 ECTS:6**
Convergence, stability, error analysis and conditioning. Solving systems of linear equations: The LU and Cholosky factorization, pivoting, error analysis in Gaussian elimination. Matrix eigenvalue problem, power method, orthogonal factorizations and least squares problems. Solutions of nonlinear equations. Bisection, Newton's, secant and fixed point iteration methods.

MATH 385 Special Functions of Applied Mathematics **(3-0)3 ECTS:6**
Gamma and Beta functions. Pochhammer's symbol. Hypergeometric series. Hypergeomet-ric differential equation; ordinary and con-fluent hypergeometric functions. Generalized hypergeometric functions; the contiguous function relations. Orthogonal polynomials. Bessel function; the functional relationships, Bessel's differential equation. Orthogonality of Bessel functions.

MATH 386 Fluid Dynamics **(3-0)3 ECTS:6**
The ideal fluid. Irrotational flow. The vorticity equation. Steady flow past a wing. The equations of viscous flow. The diffusion of vorticity. Flow with circular stream lines. The convection and diffusion of vorticity. Waves. Surface waves. Dispersion, group velocity. Surface tension effects. Effects of finite depth. Sound waves. Classical Aerofoil Theory. Velocity potential and stream function. Method of images. Milne-Thompson's Circle theorem. Complex potential. Conformal mapping. Blasius' theorem. The Kutta- Juokowsli lift theorem. D'Alembert's paradox. Vortex motion. Kelvin's circulation theorem. The Helmholtz vortex theorems. Navier Stokes Equations. Very viscous flow.

MATH 401 Quantum Mechanics **(3-0)3 ECTS:6**
Fundamental concepts. Kets, Bras, and operators. Measurements, observables. Uncertainty relations. Position and momentum space. Quantum dynamics. Time evolution and Schrödinger equation. The Schrödinger and Heisenberg picture. Simple harmonic oscillator. Schrödinger's wave equation. Propagators and Feynman path integral. Potentials and gauge transformations. Rotations and angular momentum. Spin. Rotation group. The density operator. Identical particles. Quantum statistics. Symmetries in quantum mechanics. Scattering theory.

MATH 403 Combinatorial Design Theory **(3-0)3 ECTS:6**
An overview of combinatorial design theory, main constructions and theorems. Relations with finite affine and projective spaces, as well as error correcting codes.

MATH 404 Quantum Computations and Information **(3-0)3 ECTS:6**
Introduction to classical computation. Information and entropy. Introduction to quantum mechanics. Postulates of quantum mechanics. EPR paradox. Bell's inequalities. Quantum computation. The qubit. The Bloch sphere. The circuit model of quantum computation. Qubit gates. Controlled gates and entanglement generation. Universal quantum gates. Unitary errors. Function evaluation. The density operator. Von Neuman entropy. Entanglement measure. The quantum Fourier transform. Shor's algorithm. Quantum communication.

MATH 405 Variational Analysis **(3-0)3 ECTS:6**
The Euler-Lagrange equation. First integrals. Geodesics. Minimal surface of revolution. Several dependent variables. Isoperimetric problems. Fermat's principle. Dynamics of particles. The vibrating string. The Sturm-Liouville problem. The vibrating membrane. Theory of elasticity. Quantum mechanics. The principles of Feynman and Schwinger in Quantum mechanics. Variational principles in hydrodynamics.

MATH 406 Mathematics of Public Key Cryptography **(3-0)3 ECTS:6**
An in depth study of public-key cryptography and number-theoretic problems related to the efficient and secure use of public-key cryptographic schemes.

MATH 407 Conformal Mappings **(3-0)3 ECTS:6**
Analytic functions. Geometrical interpretation. Conformal transformations. Mobius transformations. Christofel-Schwarz conformal transformations. Conformal metric and geometry. Boundary value problems. Electrostatics and hydrodynamics.

MATH 408 Advanced Topics in Graph Theory **(3-0)3 ECTS:6**
Connectivity and Menger's theorem; embeddings of graphs and Kuratowski's theorem; network flows; crossing number; structure of k-chromatic graphs; Ramsey theory; extremal graph theory; probabilistic methods and random graphs; eigenvalues and eigenvectors of graphs.

MATH 409 Advanced Topics in Combinatorics **(3-0)3 ECTS:6**
Bijections, decompositions; composition and differentiation lemmas; algebra of formal power series; strings on finite alphabets; integer partitions; Ferrehs graph and Durfee square; Lagrange implicit function theorem; topics in lattices and posets.

MATH 410 Green's Functions **(3-0)3 ECTS:6**
Dirac's delta function. Generalized functions and properties. ODE and PDE with delta potential. Green's functions for ODE. Green's functions for wave, heat and Laplace equations. Klein-Gordon and Helmholz equations. Boundary value problems.

MATH 411 Mathematical Optimization **(3-0)3 ECTS:6**
Concepts in optimization; modeling restrictions with linear constraints; convex sets, polyhedra and extreme points; simplex method; duality; sensitivity; topics in flows, integer programs and nonlinear optimization.

MATH 412 Hyperbolic geometry **(3-0)3 ECTS:6**
Hyperbolic plane. The Mobius group. Conformality. Length and distance. Isometries. Planar models hyperbolic plane. Lobachevsly model. Poincare disk model. Klein model. Applications.

MATH 413 Linear and Nonlinear Waves **(3-0)3 ECTS:6**
Linear and nonlinear oscillators. Linear dispersive waves. Nonlinear waves. Solitary waves. Korteweg-de Vries equation. Solitons.

MATH 414 Introduction to Integral Equations **(3-0)3 ECTS:6**
Classification of integral equations. Solution of an integral equation. Relation between differential and integral equations. Fredholm integral equations. Volterra integral equations. Methods for solving integral equations. Integro-differential equations: basic concepts and solution methods. Integral equations with singular kernels, Abel's problem. Nonlinear Fredholm and Volterra integral equations.

MATH 415 Mathematical Research Project I **(2-0)NC ECTS:15**
To introduce the student ot mathematical research. Student conducts independent research under the supervision of a faculty member, and presents his findings as a report.

MATH 416 Mathematical Research Project II **(2-0)NC ECTS:15**
To further the mathematical research ability of the student. Student conducts independent research under the supervision of a faculty member, and presents his findings as a report and as a presentation.

MATH 422 Introduction to Abelian Groups **(3-0)3 ECTS:6**
Abelian groups. Quotient groups. Isomorphism theorems. Torsion part of the group. Decomposition of torsion groups into direct sum of primary groups. Divisibility. Injective groups. Structure of divisible groups. Projective groups. Free groups. Existence of epimorphisms from a projective groups and of monomorphisms into injective groups. Pure subgroups. Basic subgoups. Bounded pure subgroups. Classification of torsion-free groups of rank one.

MATH 450 Scale Invariance and Dimensional Analysis **(3-0)3 ECTS:6**
Dimensional analysis, similarity and modeling. Self-similar solutions. Group of transformations. Stability. Fractals and self-similarity. Applications to hydrodynamics. Renormalization group.

MATH 451 Mathematics and Technology **(3-0)3 ECTS:6**
Positioning on Earth and in Space: GPS. Friezes and mosaics: symmetry groups and transformations. Robotic motion. Saving and loans. Image compression: fractals and attractors. Science flashes.

MATH 452 Functional Analysis **(3-0)3 ECTS:6**
Metric Spaces, Normed and Banach Linear Spaces, Inner Product and Hilbert Spaces, Linear Operators on Normed Spaces, Bounded and Compact Linear Operators, Spaces of Linear Operators, Linear Functionals on Normed Spaces. Bounded Linear Operators on Inner Product Spaces, Bounded Linear Functionals. Adjoint of a Bounded Operator, Self-Adjoint, Unitary and Normal Operators. Spectral Properties of Bounded and Compact operators, Unbounded Operators.

MATH 453 Introduction to Generalized Functions **(3-0)3 ECTS:6**
Heaviside function and Delta-sequences. Test functions. Linear functionals and definition of a distribution (generalized function). Regular and singular distributions. Algebraic operations on distributions: linear change of variables, product of a distribution by a function. Analytic operations on distributions: derivative of a distribution. Transformation properties of Dirac-delta distribution. Schwartz space and tempered distributions: definitions and basic properties. Fourier transform of distributions. Convolution. The concept of generalized solution of a differential equation. Applications to Differential equations: Fundamental solutions and Green's functions.

MATH 455 Control of Infinite Dimensional Systems **(3-0)3 ECTS:6**
Controllability and observability of PDEs (using back-stepping methods).

MATH 456 Galois Theory **(3-0)3 ECTS:6**
Cubic and quartic equations. Cardan's Formulas. Symmetric polynomials. Discriminant. Roots of polynomials. The Fundamental Theorem of Algebra. Extension fields. Minimal polynomials. Adjoining elements. Degree of a field extension. Finite extensions. The tower theorem. Algebraic extensions. Simple extensions. Splitting fields, their uniqueness up to isomorphism. Normal extensions. Separable extensions. Fields of characteristic 0 and fields of characteristic p. The Primitive Element Theorem. Galois group. Galois group of splitting fields. Permutation of the roots. Examples of Galois groups. Abelian equations. Galois extensions. The Fundamental Theorem of Galois Theory. Solvability by radicals. Solvable groups. Cyclotomic extensions. Regular polygons and roots of unity. Impossibility of some geometric constructions using just straightedge and compass. Finite fields.

MATH 481 Differential Equations with Numerical Methods **(2-2)3 ECTS:6**
Initial and Boundary Value Problems. Heat Equation. Wave Equation. Elliptic PDE problems. Reaction-Convection-Diffusion Problems. Upwind and Centred Approximation Method. Poisson equation in 2D. Explicit and Implicit methods.

MATH 482 Numerical Solution of Linear Integral Equations **(3-0)3 ECTS:6**
Compact operator. The Fredholm alternative. Degenerate kernel methods. Projection methods. The Nyström method. Global approximation methods on smooth surfaces. Solution of integral equations on the unit sphere.

MATH 499 Cooperative Education Course **(0-12)6 ECTS:6**
Within the scope of this course, students will receive introductory courses during the first two weeks of the semester covering the topics of learning outcomes and objectives of the cooperative education and evaluation of the work experience. Following this, students are installed to the jobs where they are obliged to work two days a week. Students daily summarize what is done in a journal and provide a report by the end of the semester which they also have to present and defend in front of the jury.

0.4.