Study Plan for the Bachelor's Degree in Mathematics

The Bachelor's Degree in Mathematics is awarded upon the fulfillment of the following requirements:

1. The conditions as specified in the regulations for awarding the Bachelor's Degree at Yarmouk University No. (2) for the year 1991 and its amendments issued in accordance with the bylaws of awarding academic degrees and diplomas at Yarmouk University No. 76 for the year 1976.
2. University course requirements as specified in the above mentioned regulations (27 credit hours).
3. Faculty course requirements as specified in the study plan for the Bachelor's Degree in the Faculty of Science (21 credit hours).
4. Department course requirements (86 credit hours):

I. **Single Major** (86 credit hrs.):

(1) Obligatory courses (62 credit hrs.):
Phys.102, Math.102, Math.201, Math.203, Math.204, Math.241, Math.251, Math.261, Math.281, Math.291, Math.301, Math.311, Math.312, Math.321, Math.341, Math.342, Math.343, Math.362, Math.465, Math.483, Math.491, Stat.111.

(2) Elective courses (24 credit hrs.):

a – (18 credit hrs.) (At least 12 credit hours of 400 level courses) chosen from:
Math.351, Math.352, Math.353, Math.365, Math.371, Math.382, Math.401, Math.403, Math.411, Math.412, Math.413, Math.421, Math.442, Math.445, Math.446, Math.451, Math.452, Math.461, Math.462, Math.463, Math.464, Math.466, Math.471, Math.481, Math.482, Math. 492.

b – (6 credit hrs.) chosen from:
Math.499A, Math.499B, Math.499C, Phys.103, Phys.105, Phys.202, Stat.105, Stat.201, Stat.211, Chem.102, Bio.102, Geo.102, Env.101B, CS.130, CIS.103, MIS.120.

Table (1)
Single Major Credit Hours

Requirements	Obligatory	Elective	Total
University	21	6	27
Faculty	21	-	21
Department	62	24	86
Total	104	30	134

II. Major / Minor (86 credit hrs.).

(1) Major (in Mathematics) (65 credit hrs.):

a – Obligatory courses (51 credit hrs.):
Phys.102, Math.102, Math.201, Math.203, Math. 204, Math.241, Math.251, Math.261, Math.281, Math.301, Math.311, Math.312, Math. 321, Math.342, Math.343, Math.362, Math.465.

b – Elective courses (14 credit hrs.) (At least 6 credit hours of 400 level courses) chosen from:
Math.291, Math.341, Math.351, Math.352, Math.353, Math.365, Math.371, Math.382, Math.401, Math.403, Math.411, Math.412, Math.413, Math.421, Math.442, Math.445, Math.446, Math.451, Math.452, Math.461, Math.462, Math.463, Math.464, Math.466, Math.471, Math.481, Math.482, Math.483, Math.491, Math. 492, Math. 499A, Math.499B, Math.499C, Phys. 105, Stat. 105, Stat.111.

(2) Minor (21 credit hrs.) in any of the Departments of the Faculty of Science, the Departments of the Faculty of Information Technology and Computer Sciences, and the Departments of the Faculty of Economics and Administrative Sciences according to the minor course listing of each Department.

Table (2)
Major / Minor Credit Hours

Requirements	Obligatory	Elective	Total
University	21	6	27
Faculty	21	-	21
Department	51	14	65
Minor	21		21
Total	114	20	134

III. Minor in Mathematics (21 credit hrs.):

(1) Obligatory courses (15 credit hrs.): Math.102, Math.201, Math.203, Math.241, Math.251.

(2) Elective courses (6 credit hrs.) chosen from:
Math.204, Math.261, Math.281, Math.301, Math.311, Math.312, Math.321, Math.341, Math.342, Math.343, Math..362.

Table (3)
The Significance of Second Digit

No.	Title	No.	Title
0	Calculus, Differential Equations	5	Logic, Foundation of Mathematics and History of Mathematics.
1	Mathematical Analysis: Real, Complex, and Functional	6	Geometry, Topology, Graph Theory
2	Numerical Analysis	7	Applied Mathematics
3	----------	8	Control Theory & Dynamical Systems
4	Algebra and Number Theory	9	Mathematics software packages, Research Project, Seminar, and Special Topics

Table (4)
Courses Offered by the Department of Mathematics for the Bachelor's Degree in Mathematics

No.	Course No.	Course Title	Credit Hours	Prerequisites
1.	Math 099	General Mathematics	3	---
2.	Math.101	Calculus (1)	3	----
3.	Math.102	Calculus (2)	3	Math.101
4.	Math. 141	Applied Mathematics for information systems (IT Students)	3	Math.101
5.	Math.152	Discrete Mathematics (for IT & Hijjawi Engineering students)	3	Math.101
6.	Math.201	Intermediate Analysis (1)	3	Math.102
7.	Math.203	Ordinary Differential Equations (1)	3	Math.102
8.	Math.204	Special Functions and Fourier Analysis	3	Math.203
9.	Math.206	Mathematics for Chemistry Students	3	Math.102
10.	Math.212	Engineering Mathematics (for Hijjawi Engineering Technology students)	3	Math.203
11.	Math.241	Linear Algebra (1)	3	Math.101
12.	Math.251	Set Theory	3	Math.102
13.	Math.261	Euclidean Geometry - A Modern Approach	3	Math.251
14.	Math.281	Linear Programming and Game Theory	3	Math.241
15.	Math.291	Mathematics Software Packages	1	Math.251
16.	Math.301	Partial Differential Equations (1)	3	Math.204
17.	Math.311	Real Analysis (1)	3	Math.251
18.	Math.312	Complex Analysis (1)	3	Math.201, Math.251
19.	Math.321	Numerical Analysis (1)	3	Math.241

Table (4) (Continued)

20.	Math.322	Numerical Analysis (For IT. Students)	3	CS.101
21.	Math.341	Linear Algebra (2)	3	Math.241
22.	Math.342	Abstract Algebra (1)	3	Math.251
23.	Math.343	Theory of Numbers	3	Math.251
24.	Math.351	History of Mathematics (1)	3	Math.251
25.	Math.352	Fuzzy Sets and its Applications	3	Math.251 or Math.152
26.	Math.353	Mathematical Logic	3	Math.251
27.	Math.362	Topology (1)	3	Math.251
28.	Math.365	Projective Geometry	3	Math.251
29.	Math.371	Tensor Analysis and Continuum Mechanics	3	Math.204
30.	Math.382	Mathematical Modeling	3	Math.241
31.	Math.401	Partial Differential Equations (2)	3	Math.301
32.	Math.403	Ordinary Differential Equations (2)	3	Math.203
33.	Math.411	Real Analysis (2)	3	Math.203
34.	Math.412	Complex Analysis (2)	3	Math.312
35.	Math.413	Functional Analysis	3	Math.311
36.	Math.421	Numerical Analysis (2)	3	Math.203, Math.321
37.	Math.442	Abstract Algebra (2)	3	Math.342
38.	Math.445	Applied Algebra	3	Math.342
39.	Math.446	Applied Linear Algebra	3	Math.241
40.	Math.451	History of Mathematics (2)	3	Math.251
41.	Math.452	Philosophy of Mathematics	3	Math.251
42.	Math.461	Algebraic Geometry	3	Math.342
43.	Math.462	Topology (2)	3	Math.362
44.	Math.463	Graph Theory	3	Math.251
45.	Math.464	Algebraic Topology	3	Math.342, Math.362
46.	Math.465	Differential Geometry	3	Math.201
47.	Math.466	Differential Topology	3	Math.362
48.	Math.471	Mathematical Principles of the Theory of Relativity	3	Math.204, Math. 342
49.	Math.481	Control Theory	3	Math.311
50.	Math.482	Calculus of Variation	3	Math.371
51.	Math.483	Combinatorial Mathematics	3	Math.241
52.	Math. 491	Seminar	1	Math. 251
53.	Math.492	Special Topics	3	Math.251
54.	Math.499A	Research Project	1	Dept. approval
55.	Math.499B	Research Project	2	Dept. approval
56.	Math.499C	Research Project	3	Dept. approval

- *Math.206 can not be counted together with Math. 201.*
- *Math. 281 can not be counted together with Stat. 274 or MIS 241.*
- *Math. 322 can not be counted together with Math. 321.*
- *Math. 465 is equivalent to Math. 361.*
- *Math. 483 is equivalent to Math. 383.*

Guidance Plan for Mathematics Students

First Year

First Semester		Second Semester	
Course Number	Credit Hours	Course Number	Credit Hours
Math. 101	3	Math. 102	3
Phys. 101	3	Phys. 102	3
Obligatory Course/ Faculty	3	Cs. 101	3
Obligatory Course/ University	3	Obligatory Course/ Faculty	3
Obligatory Course/ University	3	Elective Course/ University	3
Total	15	Total	15

Second Year

First Semester		Second Semester	
Course Number	Credit Hours	Course Number	Credit Hours
Math. 201	3	Math. 251	3
Math. 203	3	Math. 204	3
Math. 241	3	Math. 281	3
Obligatory Course/ University	3	Stat. 111	3
Obligatory Course/ Faculty	3	Elective Course/ Department	3
Obligatory Course/ Faculty	3	Elective Course/ Department	3
Total	18	Total	18

Third Year

First Semester		Second Semester	
Course Number	Credit Hours	Course Number	Credit Hours
Math. 261	3	Math. 312	3
Math. 291	1	Math. 342	3
Math. 301	3	Math. 341	3
Math. 311	3	Math. 362	3
Math. 321	3	Elective Course/ Department	3
Elective Course/ University	3	Obligatory Course/ University	3
Total	16	Total	18

Fourth Year

First Semester		Second Semester	
Course Number	Credit Hours	Course Number	Credit Hours
Math. 343	3	Math. 491	1
Math. 365	3	Elective Course/ Department	3
Math. 483	3	Elective Course/ Department	3
Elective Course/ Department	3	Elective Course/ Department	3
Obligatory Course/ University	3	Elective Course/ Department	3
Obligatory Course/ University	3	Obligatory Course/ University	3
Total	18	Total	16

Course Description of the
Department of Mathematics Courses for the Bachlor's Degree

Math. 099 - General Mathematics **(3 credit hrs.)**
The Real Number System, Inequalities, The Cartesian Plane and the Distance Formula, Linear and Quadratic Functions and Their Graphs, Composite and Inverse Functions. Polynomial and Rational Functions, Polynomial Division and Synthetic Division, Rational Zeros of Polynomial Functions. Exponential, Logarithmic, Trigonometric and Inverse Ttrigonometric Functions and their Graphs. The Limit of a Function, Properties of Limits, Continuity, Limits at Infinity. Definition of the Derivative, Rules of Differentiation, Applications of the Derivative, The Chain Rule, Implicit Differentiation, Derivatives of Trigonometric, Exponential and Logarithmic Functions. The Definite Integral, The Basic Properties of Integral, The Fundamental Theorem of Calculus, Some Applications of Integrals, The Area Between Two Curves.

Math. 101 - Calculus (1) **(3 credit hrs.)**
Limits and continuity. Derivatives. Rules of differentiation. Tangent and normal lines. Related rates. The mean value theorem of differentiation and its applications, indeterminate forms ($0/0, \infty/\infty$) and L'Hospital's rule, vertical and horizontal asymptotes local extrema, concavity, and curve sketching. The definite integral, the fundamental theorem of calculus, the indefinite integral. Applications of the definite integral: Area, solids of revolutions, and volumes using cylindrical shells. The transcendental functions: The general exponential and logarithmic functions.

Math. 102 - Calculus (2) **(3 credit hrs.)**
Hyperbolic functions, inverse functions of trigonometric and hyperbolic functions. Techniques of integration: Integration by parts, trigonometric substitutions, partial fractions, quadratic expressions. Plane curves and polar coordinates: Parametric equations, tangent lines, area in polar coordinates, surface of revolution, and improper integrals. Sequences and infinite series: convergence and divergence, positive term series, alternating series, absolute and conditional convergence. Power series: Differentiation and integration, Taylor series.

Math. 141 - Applied Mathematics for information systems (IT Students) **(3 credit hrs.)**
Logic and Boolean algebra: (Truth tables), Arithmetic progressions, compounding, compound interest applications, Linear functions (Slope, intercept graphing, application), Linear systems and their application, Matrix (basics, matrix operation), Applications and case studies in information systems.

Math. 152 - Discrete Mathematics (For I.T Students) **(3 credit hrs.)**
Logic, Methods of proof. Boolean algebra. Sets, Relations, Functions, ordered relations. Counting principles. Mathematical induction. Recursive relations. Permutations, Graphs and trees.

Math. 201 - Intermediate Analysis (1) **(3 credit hrs.)**
Vectors in IR^2 and IR^3: Lines and planes. Functions of several variables: Limits and continuity. Partial differentiation. Chain rule. Gradient and tangent planes. Extrema of functions of two variables. Lagrange multipliers.,. Vector-valued functions: The calculus of vector-valued functions. Space curves, curvature, tangential and normal components of acceleration. Quadratic surfaces. Double integrals with applications. Triple integrals in cylindrical and spherical coordinate systems with applications. Jacobian of transformations. Line integrals. Green's theorem.

Math. 203 - Ordinary Differential Equations (1) (3 credit hrs.)
Introduction and classification, solutions of first order differential equations and their applications, (Growth and decay problems and linear motion problems), solutions of higher order linear differential equations and their applications (Spring problem and projectile problems), series solutions of differential equations near ordinary points. Laplace transforms.

Math. 204 - Special Functions and Fourier Analysis (3 credit hrs.)
Series solutions near regular singular points (Bessel functions), Legendre and associated Legendre functions, Fourier series, Fourier transform , integral Fourier transform, Beta and Gamma functions.

Math. 206 - Mathematics for Chemistry Students (3 credit hrs.)
Vectors in IR^2 and IR^3: Vector algebra, dot product, cross product. Vector calculus. Applications. Functions of several variables: partial differentiation, gradient, extreme-value problems. Applications. Evaluations of double and triple integrals: area, volume, the mass of a plate, … etc. First ordinary differential equations: Linear separable, homogeneous, exact equations. Applications. Second order differential equations: power series method and some other methods. Bessel function. Partial differential equations: separation of variables and some applications. Matrices and linear transformations: matrix algebra, determinants, the eigen-value problem.

Math. 212 - Engineering Mathematics (for Hijjawi Engineering Technology Students) **(3 credit hrs.)**
Vector differential calculus, gradient of a scalar field, divergence field, curl of a vector field, vector integral calculus, integral theorems, line integral, Green's theorem, divergence theorem, Stokes's theorem, Fourier analysis, complex Fourier series, Fourier integrals, Fourier sine and cosine transforms.

Math. 241 - Linear Algebra (1) (3 credit hrs.).
Systems of linear equations, Gaussian elimination, Matrices and matrix arithmetic. The inverse of a matrix. Determinants, evaluating determinants, properties of determinants, Cramer's rule. Vector spaces, subspaces, linear dependence, bases and dimension, row and column spaces, null space, rank and nullity. Eigenvalues and eigenvectors, diagonalization. Linear transformations, kernel and range.

Math. 251 – Set Theory (3 credit hrs.)
Mathematical Logic, methods of proof. The concept of sets, relations, equivalence relation, order relation, functions. Finite and infinite sets, denumerable and nondenumerable sets. Cardinal numbers and their arithmetics. The Schroeder-Bernstein theorem. The axiom of Choice and some of its equivalent forms(especially Zorn's lemma).

Math. 261 - Euclidean Geometry - A Modern Approach (3 credit hrs.)
Euclid's and Hilbert's axioms of Euclidean geometry. Triangle and circle geometry (including theorems of Ceva, Menelaus, Morley, Napoleon,…). 3-dimensional geometry. Examples of Non-Euclidean geometry (finite geometries).

Math. 281 - Linear Programming and Game Theory **(3 credit hrs.)**
The linear programming model; The simplex method (general problem, Basic feasible solutions, theory of simplex method, the simplex tableau, artificial variables, redundant systems, a convergence proof, Linear programming and convex); Duality (definition of the dual problem, interpretations, the duality theorem, the complementary slackness theorem, dual simplex algorithm); Sensitivity analysis (matrix representation of the simplex algorithm, changes in the objective function, addition of a new variable, changes in constant term column vector, addition of a constraint); Integer programming (Models with integer programming formulations, Geomory's cutting plane algorithm, a branch and bound algorithm); The transportation problem (a distribution problem, the transportation problem applications).

Math. 291 - Mathematics Software Packages **(1 credit hrs.)**
Introduction to mathematical Softwares: Matlab, Mathematica, and Maple, commands in Matlab to solve elementary problems in Calculus and Linear Algebra that include vectors, matrices, basic functions, and basic operations. M-files and programming in Matlab including loops and conditions. Plotting in 2-D and 3-D, solving linear systems, commands in Mathematica and Maple to solve different symbolic Calculus and Linear Algebra problems. Building up symbolic manipulation and programming in Mathematica and Maple.

Math. 301 - Partial Differential Equations (1) **(3 credit hrs.)**
Classification of partial differential equations, comparison with ordinary differential equations, Heat equation: Steady state temperatures insulated Bar, convection, sturm-Liouville problems, Eigenfunction expansion, finite, semi-Infinite and infinite Rod, Error function, Fourier and Laplace transforms. The wave equation: vibrating string, D'Alembert's solutions on finite vibrating string and beam, semi-infinite, infinite Domains; Fourier transforms (sine and cosine transforms). Potential equation: in a rectangle, a slot and a disk.

Math. 311 – Real Analysis (1) **(3 credit hrs.)**
Metric spaces-analysis point of view: definition of a metric, the concepts of neighborhood, limit points, interior points, open sets, closed sets, perfect sets, closure of a set, compact sets and their elementary properties including Heine-Borel theorem, finite intersection property, and the main characterization of compact sets in Euclidean spaces, connected sets. Sequences: Limit of sequences, subsequences and sub sequential, Cauchy sequences, Monotone sequences (in IR), upper and lower limits. Continuity: Limits of functions, Continuous functions, continuity and compactness, uniform continuity, continuity and connectedness, monotonic functions, convex functions, and extension theorems. Differentiable function (in IR) and the Mean Value Theorem. Riemann Stieltjes Integral and its existence.

Math. 312 - Complex Analysis (1) **(3 credit hrs.)**
Complex number system. Analytic functions: Cauchy Riemann Equations. Polar coordinates and Harmonic functions. Elementary functions: Exponential, Logarithmic and trigonometric functions and their inverses. Integrals: Cauchy-Goursat theorem and Cauchy integral formula. Series: convergence, residues and poles.

Math. 321 - Numerical Analysis (1) **(3 credit hrs.)**
Introduction, error analysis, numerical solution of equations in one variable, interpolation and polynomial approximation, numerical differentiation and integration, orthogonal polynomials and least squares approximation.

Math. 322 - Numerical Analysis (For I.T. Students). **(3 credit hrs.)**
Error analysis, numerical solution of equations in one variable, numerical solutions of linear systems: iterative methods, interpolation and polynomial approximation, numerical differentiation and integration.

Math. 341 - Linear Algebra (2) **(3 credit hrs.)**
Matrix representations of linear transformation. Change of basis, similarity, characteristic and minimal polynomials of a linear operator. Cayley-Hamilton theorem, eigenvalues, eigenvectors and diagonalization, canonical forms. Inner product spaces. Orthogonality, orthonormal bases, change of bases. Gram-Schmidt orthogonalization process. Normal, orthogonal and unitary operators. Jordan and rational forms. Linear functionals and the dual spaces.

Math. 342 - Abstract Algebra (1) **(3 credit hrs.)**
Binary operations. Groups, subgroups, cyclic subgroups and direct product of groups. Permutation groups. Cyclic groups. Group homomorphisms and isomorphisms. Classification of cyclic groups. Cosets and Lagrange's theorem. Normal subgroups and factor groups. The fundamental theorem of group homomorphisms (statement). Rings, integral domains and fields. Some non-commutative examples. The field of quotients of an integral domain. Ideals and quotient rings. Prime and maximal ideals. Homomorphisms of rings.

Math. 343 - Theory of Numbers **(3 credit hrs.)**
Unique factorization in Z. Linear Diophantine equations. Congruences. Linear congruences. Fermat's, Euler's and Wilson's theorems. Euler's function. The divisors of an integer. Perfect numbers. Quadratic congruences. (Statement of) the quadratic reciprocity law. Pythagorean triplets. Infinite descent and the case $n = 4$ of Fermat's last theorem. Sums of two and of four squares. Pell's equation.

Math. 351 - History of Mathematics (1) **(3 credit hrs.)**
A brief historical introduction of ancient Mathematics (Indian, Egyptian, Babylonian) through its main mathematical operations. Greek Mathematics The school of Pythagoras, Euclid and his system of axioms. A brief biography of selected Greek mathematicians as Pythagoras, Euclid, Archimedes, Ptolemy, etc. Mathematics of the world of Islam, its main contributions and salient characteristics. A concise biography of selected Arab and Moslem mathematicians as Al-Khowarizmi, Thabit Bin Qurrah, Omar Al-Khayyam, and AL-Bayrouni etc, along with selected topics from their writings, such as the Algebra of Khowarizmi, the determination of Qibla of Bayrouni, and Al-Khayyam and his geometric method of solving cubic equations.)

Math. 352 - Fuzzy Sets and Its Applications **(3 credit hrs.)**
Review (set theory). Fuzzy sets. Operations on fuzzy sets. Fuzzy relations. Fuzzy graph and fuzzy relations. Fuzzy logic. Applications on fuzzy logic.

Math. 353 - Mathematical Logic **(3 credit hrs.)**
Soundness and completeness, predicate logic, interpretation, satisfaction and truth. Equality, completeness and consistency of models. Gödel's theorem.

Math. 362 - Topology (1) **(3 credit hrs.)**
Topological spaces: Open sets, closed sets, closure, interior and boundary of a set, cluster points and the derived set, isolated points. Relative topology and subspaces. Bases. Finite product of topological spaces. Continuous functions, open functions, closed functions, homeomorphism, T_0, T_1 and T_2 spaces, connected and compact spaces.

Math. 365 - Projective Geometry **(3 credit hrs.)**
Perspectivity, Projectivity, Cross ratio as a projective property, Pappus theorem, Desargues two triangles theorem. Harmonic sets. Axioms for the projective plane. Theorems of Pascal and Brianchon. Coordinate system and projective transformations. The conics.

Math. 371 - Tensor Analysis and Continuum Mechanics **(3 credit hrs.)**
Tensor analysis, strain tensor, stress tensor. Relations between stress and strain tensors (elastic, plastic materials). Constitutive equations for fluids, gases and liquids. Viscoelastic materials.

Math. 382 - Mathematical Modeling **(3 credit hrs.)**
Introduction, mathematical classification of Models, constraints and terminology on Models, modeling process, population dynamics models for single species, stability analysis of growth models, Fishing management models, scaling variables, bifurcation analysis of the ODE $y' = f(y, c)$; saddle-node, transcritical and Pitchfork bifurcations, models from science and finance, Newton's law of cooling or heating, Chemical Kinetic reactions, modeling by systems of equations, modeling interacting species; model building, different types of interactions models.

Math. 401 - Partial Differential Equations (2) **(3 credit hrs.)**
Heat, wave and potential equations in infinite domains (two and three dimensions), interior Dirichlet problem for a circle, Dirichlet problems in an annulus, spherical harmonies. A nonhomogenous Dirichlet problem, systems of partial differential equations, existence and uniqueness theorems.

Math. 403 - Ordinary Differential Equations (2) **(3 credit hrs.)**
Series solutions of second order ordinary linear differential equations: Review of series solutions near ordinary and singular points, series solution near regular singular points, Bessel's equations, systems of first order linear order ordinary differential equations: Introduction, review on matrix functions, uncoupled systems, diagonal systems, using diagonalization to solve systems of first order ordinary differential equations, exponential of matrices, the fundamental theorem of linear systems, linear systems in the plane (phase plane portraits), complex eigenvalues, multiple eigenvalues, nonhomogeneous linear systems, nonlinear differential equations and stability: Autonomous systems and stability, almost linear systems, the fundamental theorem of nonlinear systems, competing species, Predator-Prey equations, Liapunov's theory for stability, periodic solutions and limit cycles.

Math. 411 - Real Analysis (2) **(3 credit hrs.)**
Sequences of functions: Convergence and uniform convergence; Approximation theorems (Stone, Weierstrass theorems). Series of functions: Absolute and uniform convergence, Cauchy criterion, Weierstrass M-test, Dirichlet test and Abel test. Differentiation in $\Re^p$: Chain Rule and Mean-Value theorem, inverse and implicit function theorems.

Math. 412 - Complex Analysis (2) **(3 credit hrs.)**
Residues and Poles: Evaluation of improper real integrals. Improper integrals involving sines and cosines. Definite integrals involving sines and cosines. Integration through a Branch cut. Logarithmic residues and Rouche's theorem. Mapping by elementary functions. Conformal mappings and transformations of harmonic functions. Singularities and the argument principle.

Math. 413 - Functional Analysis **(3 credit hrs.)**
Linear spaces. Normed and Banach spaces. Concrete examples of normed and Banach spaces as $\Re^{\infty}$, C, $\Re^{n}$,C^{n},l^{p}, l^{∞}, C_{0}, C[a, b]. Incomplete normed spaces. Bounded linear operators. Spaces of bounded linear operators. Equivalent norms. Finite dimensional normed spaces and compactness. Bounded linear functionals. Dual spaces and the form of some dual spaces. Hilbert spaces: Definition, parallelogram Law, relation with Banach spaces, orthogonal of vectors.

Math. 421 - Numerical Analysis (2) **(3 credit hrs.)**
Numerical solutions of linear systems: iterative methods, numerical solutions of nonlinear systems, numerical solution of ordinary differential equations, approximating eigenvalues.

Math. 442 - Abstract Algebra (2) **(3 credit hrs.)**
The fundamental theorem of ring homomorphisms. Rings of polynomials. Division algorithm, ideal structure and unique factorization in the ring of polynomials over a field. Principal ideal domain and unique factorization domains. Euclidean domains and the ring of Gaussian integers. Field extensions. Algebraic elements and their irreducible polynomials. Finite fields.

Math. 445 - Applied Algebra **(3 credit hrs.)**
Boolean algebras and transistor gates. Crystallographic groups. Burnside's method of enumeration and applications to necklace problems and coloring polyhedra, finite-state machines, error-correcting codes. Cryptology.

Math. 446 - Applied Linear Algebra **(3 credit hrs.)**
QR Factorization. Householder and Givens rotations. Least squares solutions and singular value decomposition. Classical Jacobi method, cyclic Jacobi method, fast givens, QR and QZ methods. Steepest decent, conjugate gradient iterations, Chebycheve iterations, GRMRES methods. Lanczos iterative schemes.

Math. 451 - History of Mathematics (2) **(3 credit hrs.)**
Mathematics in the medieval and in the renaissance eras with emphases on the effect of Arab and Muslim Mathematicians on Europe in a precise and well documented historical context. Mathematics of the 16^{th} to the 19^{th} centuries through the study of selected mathematicians. Selected topics from well known master pieces of the Mathematics literature such as Newton's principia, Laplace's celestial Mechanics etc. A detailed history of selected topics like: Calculus, Number Theory, Group Theory, Rings, Fields, Set theory, Fourier series etc.

Math. 452 - Philosophy of Mathematics **(3 credit hrs.)**
The axiomatic method, sets and infinite sets, the axiom of choice and equivalent statements, discussion of the paradoxes, Hilbert's proof.

Math. 461 - Algebraic Geometry **(3 credit hrs.)**
Plane curves: Plane conics, A^2, homogeneous coordinates, IP^2. Parameterizations of curves, classification of conics in IP^2. Cubics and associated groups, curves and their genus. Affine varieties: Affine varieties and the Nullstellstellensatz. Noetherian rings, Hilbert basis theorem, Algebraic sets, Zariski topology. Rational maps. Applications: Projective varieties and birational equivalence, tangent spaces, lines on cubic surfaces.

Math. 462 - Topology (2) **(3 credit hrs.)**
Local bases, first countable spaces. Second countable spaces, separable spaces. Connected spaces and their properties, components, locally connected spaces, path- wise connected. Compact spaces and their properties, compactness in R^n, countably compact spaces. Metric spaces, metric topologies, equivalent metrics, continuity and uniform continuity of functions on metric spaces, compactness of metric spaces.

Math. 463 - Graph Theory **(3 credit hrs.)**
Basic concepts of graph theory. Isomorphisms of graphs, connected graphs, complement and self complement graphs, line graphs (Krausz Theorem, Van Rooji and wilf theorem, Beineke theorem), graph decomposition, graph labeling (magic graphs, graceful trees, rosa's theorem), Eulerian graphs, Hamiltonian graphs (Dirac theorem, Ore theorem, Bondy-Chevatal theorem, Chevatal theorem), planar graphs (Drawing in the plane, Dual graphs, Euler's formula, Kuratowski's theorem, Grinberg's theorem), thickness and crossing number, chromatic number and chromatic polynomials..

Math. 464 - Algebraic Topology **(3 credit hrs.)**
Homotopy, homotopy of path, fundamental group, covering spaces, simply connected spaces, the fundamental group of the circle. The fundamental group of the punctured plane, the fundamental group of S^n, the fundamental group of surfaces, the fundamental group of product spaces, Van Kampen theorem, Homotopy type and homotopy equivalence of spaces, deformation retracts, essential and inessential maps, Maps of spheres into S^n , Brouwer Fixed Point Theorem, Borsuk Theorem.

Math. 465 - Differential Geometry **(3 credit hrs.)**
Curves, Curvature and torsion, Frenet equations. Intrinsic equations of a curve. Fundamental existence and uniqueness theorem. The concept of a surface. First fundamental form: Arc length, area, and angle. Second fundamental form. Normal curvature. Principal curvatures and directions. Gaussian and mean curvatures. Introduction to intrinsic.

Math. 466 - Differential Topology **(3 credit hrs.)**
Definition and examples on n-manifolds, Orientable and non-orientable manifolds, Sub-manifolds, Compact and connected 2-manifolds, Classification of compact surfaces, triangulation of compact surfaces, Manifolds with boundary, noncompact surfaces.

Math. 471 - Mathematical Principles of the Theory of Relativity **(3 credit hrs.)**
Physical background. The principle of relativity, light as electromagnetic waves, affine spaces, space-time, orthogonal groups, semi-orthogonal groups, Galilean space-time, Galilean group, Lorentz transformations. The Lorentz group. Minkowski's space time, relativistic mechanics. Selected topics, e.g., relativity and projective geometry or introduction to general relativity.

Math. 481 - Control Theory **(3 credit hrs.)**
System dynamics and differential equations, transfer functions and block diagrams, state - space formation, transient and steady state response analysis, stability, controllability and observability. Introduction to optimal control, optimal control with unbounded continuous controls, bang - bang control. Applications.

Math. 482 - Calculus of Variation **(3 credit hrs.)**
Variational problems with fixed boundaries, variational problems with movable boundaries and natural boundary conditions. Variational problems with constraints. Direct methods for variational problems.

Math. 483 - Combinatorial Mathematics **(3 credit hrs.)**
Permutations; Combinations, selections and the binomial coefficients, the pigeonhole principle, the inclusion-exclusion principle, generating functions, recursions (homogenous and inhomogeneous recurrence, recurrence relations and generating functions), definition of graphs and subgraph, Handshaking lemma, examples in graphs (paths, cycles, complete, bipartite), trees (properties of trees, spanning trees, minimum spanning trees, shortest path, Prüfer encoding, Cayley theorem).

Math. 491 - Seminar **(1 credit hr.)**
The subject of this course is endorsed by the instructor.

Math. 492 - Special Topics **(3 credit hrs.)**
The subject of this course is endorsed by the instructor.

Math. 499A – Research Project **(1 credit hrs.)**
The subject of this course is endorsed by the department council.

Math. 499B – Research Project **(2 credit hrs.)**
The subject of this course is endorsed by the department council.

Math. 499C – Research Project **(3 credit hrs.)**
The subject of this course is endorsed by the department council.