BS SCHEME OF STUDIES MATHEMATICS

DEPARTMENT OF MATHEMATICS

GCWUF

2019

Govt. College Women University Faisalabad
Department of Mathematics

Scheme of Studies BS Mathematics Four Years Degree Program
2019

Semester I

Course Code	Title of the Course	Credit Hours	Page #
Major Course			
MTH-301	Calculus I	4(4-0)	6
MTH-303	Elements of Set Theory and Mathematical Logic	3(3-0)	7
Minor Course			
ENG-321	English I (Language in Use)	3(3-0)	
ICT-321	Introduction to Computers	3(2-1)	
PST-321	Pakistan Studies	2(2-0)	
PHY-301	Mechanics I	3(3-0)	
Total		**18(17-1)**	

Semester II

Course Code	Title of the Course	Credit Hours	
Major Course			
MTH-302	Calculus II	4(4-0)	8
MTH-304	Discrete Mathematics	3(3-0)	9
Minor Course			
ENG-322	English II (Academic Reading And Writing)	3(3-0)	
ICT-323	Introduction to Programming	3(2-1)	
ISL-408	Islamic Studies	2(2-0)	
PHY-302	Mechanics II	3(3-0)	
Total		**18(17-1)**	

SemesterIII

Course Code	Title of the Course	Credit Hours	Page #
Major Course			
MTH-401	Calculus III	4(4-0)	10
MTH-403	Metric Spaces and Group Theory	3(3-0)	11
ECO-301	Principles of Micro Economics	3(3-0)	
STA-320	Introduction to Statistical Theory	3(3-0)	

ENG-421	English III (Communication Skills)	3(3-0)	
Total		**16(16-0)**	

Semester IV

Course Code	**Title of the Course**	**Credit Hours**	**Page #**
Major Course			
MTH-402	Affine and Euclidean Geometry	4(4-0)	12
MTH-404	Linear Algebra	3(3-0)	13
MTH-406	Ordinary Differential Equations	3(3-0)	14
Minor Course			
PSY-301	Introduction to Psychology	3(3-0)	
ARB-308	Arabic Language	3(3-0)	
CHM-300	Environmental Sciences	1(1-0)	
Total		**17(17-0)**	

Semester V

Course Code	**Title of the Course**	**Credit Hours**	**Page #**
Major Course			
MTH-501	Topology	3(3-0)	15
MTH-503	Differential Geometry	3(3-0)	16
MTH-505	Real Analysis I	3(3-0)	17
MTH-507	Algebra I	3(3-0)	18
MTH-509	Vector and Tensor Analysis	3(3-0)	19
MTH-511	Complex Analysis I	3(3-0)	20
Total		**18(18-0)**	

Semester VI

Course Code	**Title of the Course**	**Credit Hours**	
Major Course			
MTH-502	Partial Differential Equations	3(3-0)	21
MTH-504	Classical Mechanics	3(3-0)	22
MTH-506	Complex Analysis II	3(3-0)	23
MTH-508	Real Analysis II	3(3-0)	24
MTH-510	Functional Analysis	3(3-0)	25
MTH-512	Algebra II	3(3-0)	26
Total		**18(18-0)**	

Semester VII

Course Code	Title of the Course	Credit Hours	Page #
Major Course			
MTH-601	Numerical Analysis I	3(3-0)	27
MTH-603	Number Theory	3(3-0)	28
MTH-605	Mathematical Statistics I	3(3-0)	29
MTH-629	Seminar	1(0-1)	
Elective Courses (2 courses out of following)			
MTH-607	Advanced Group Theory	3(3-0)	30
MTH-609	Methods of Mathematical Physics	3(3-0)	31
MTH-611	Quantum Mechanics I	3(3-0)	32
MTH-613	Fluid Mechanics I	3(3-0)	33
MTH-615	Advanced Topology	3(3-0)	34
MTH-617	Algebraic Topology	3(3-0)	35
MTH-619	Continuous Groups	3(3-0)	36
MTH-621	Rings and Modules	3(3-0)	37
MTH-623	Special Theory of Relativity	3(3-0)	38
MTH-625	Operations Research	3(3-0)	39
MTH-627	Software Packages	3(2-1)	40
Total		16(15-1)	

Semester VIII

Course Code	Title of the Course	Credit Hours	
Major Course			
MTH-602	Mathematical Statistics II	3(3-0)	41
MTH-604	Advanced Set Theory	3(3-0)	42
MTH-606	Numerical Analysis II	3(3-0)	43
MTH-630	Special Problem	1(0-1)	
Elective Courses (3 Courses or 1 Course and (Project/ Thesis/ Internship)) from the following			
MTH-608	Theory of Modules	3(3-0)	44
MTH-610	Algebraic Number Theory	3(3-0)	45
MTH-612	Category Theory	3(3-0)	46
MTH-614	Galois Theory	3(3-0)	47
MTH-616	Probability Theory	3(3-0)	48
MTH-618	Theory of Elasticity	3(3-0)	49
MTH-620	Electromagnetism	3(3-0)	50
MTH-622	Quantum Mechanics II	3(3-0)	51
MTH-624	Theory of Optimization	3(3-0)	52
MTH-626	Measure Theory	3(3-0)	53
MTH-628	Combinatorics	3(3-0)	54
MTH-634	Fluid Mechanics II	3(3-0)	55

MTH-636	Integral Equations	3(3-0)	56
MTH-638	Graph Theory	3(3-0)	57
MTH-631	Project	6(0-6)	
MTH-632	Internship	6(0-6)	
MTH-633	Thesis	6(0-6)	
		19(18-1)	

Program	Award	Duration	Semester	Credit Hours
Bachelor of Sciences	BS Mathematics	4Years	8 Semesters	140

SEMESTER I

Course Title **Calculus-I**
Course Code **MTH-301**
Credit Hours **4(4-0)**

AIMS AND OBJECTIVES:

Calculus serves as the foundation of advanced subjects in all areas of mathematics. This is the first course of Calculus. The objective of this course is to introduce students to the fundamental concepts of limit, continuity, differential and integral calculus of functions of one variable.

THEORY:

Lines and systems of equations, Nonlinear systems: at least one quadratic equation.
Limits and continuity: Functions, limit of a function. Graphical approach. Properties of limits. Theorems of limits. Limits of polynomials, rational and transcendental functions. Limits at infinity, infinite limits, one-sided limits. Continuity.
Derivatives. Definition, techniques of differentiation. Derivatives of polynomials and rational, exponential, logarithmic and trigonometric functions.The chain rule. Implicit differentiation. Rates of change innatural and social sciences. Related rates. Linear approximations anddifferentials. Higher derivatives, Leibnitz's theorem.Applications of derivatives: Increasing and decreasing functions. Relative extrema and optimization. First derivative test for relativeextrema. Convexity and point of inflection. The second derivative test for extrema. Curve sketching. Mean value theorems. Indeterminate forms and L'Hopitals rule. Inverse functions and their derivatives. Integration: Anti derivatives and integrals. Riemann sums and the definite integral. Properties of Integral. The fundamental theorem of calculus. The substitution rule.

RECOMMENDED BOOKS:

1. A. Kaseberg. 2004. Intermediate Algebra. 3rd Edition. Thomson-Brooks/Cole.
2. F. A. Jr., E. Mendelson, Schaum's Outline of Calculus. Latest Edition. McGraw Hill Inc.
3. G. B. Thomas Jr., M. D. Weir, J. R. Hass, F. R. Giordano. Thomas's Calculus. Latest Edition. Pearson Education.
4. H. Anton, I. Bivens, S. Davis. Calculus. Latest Edition. John Wiley & Sons, Inc.
5. M. Liebeck. 2011. A Concise Introduction To Pure Mathematics, 3rd Edition. CRC Press.

Course Title **Elements of Set Theory and Mathematical Logic**
Course Code **MTH-303**
Credit Hours **3(3-0)**

AIMS AND OBJECTIVES:

Everything mathematicians do can be reduced to statements about sets, equality and membership which are basics of set theory. This course introduces these basic concepts. The course aims at familiarizing the students with cardinals, relations and fundamentals of propositional and predicate logics.

THEORY:

Set theory: Sets, subsets, operations with sets: union, intersection, difference, symmetric difference, Cartesian product and disjoint union.
Functions: graph of a function. Composition; injections, surjections, bijections, inverse function.
Computing cardinals: Cardinality of Cartesian product, union. Cardinality of all functions from a set to another set. Cardinality of all injective, surjective and bijective functions from a set to another set. Infinite sets, finite sets. Countable sets, properties, examples (Z, Q). R is not countable. R, RxR, RxRxR have the same cardinal. Operations with cardinal numbers. Cantor-Bernstein theorem.
Relations: Equivalence relations, partitions, quotient set; examples, parallelism, similarity of triangles. Order relations, min, max, inf, sup; linear order. Examples: N, Z, R, P(A). Well ordered sets and induction. Inductively ordered sets and Zorn's lemma.
Mathematical logic: Propositional Calculus. Truth tables. Predicate Calculus.

RECOMMENDED BOOKS:

1. D. Smith, M. Eggen, R. S. Andre. 2001. A Transition to Advanced Mathematics. 7^{th} Edition. Brooks/Cole.
2. M. Liebeck. 2011. A Concise Introduction to Pure Mathematics. 3^{rd} Edition. CRC Press.
3. N. L. Biggs. 2002. Discrete Mathematics, 2^{nd} Edition. Oxford University Press.
4. P. R. Halmos, Naive Set Theory, New York, Van Nostrand.
5. R. Garnier, J. Taylor. 2010. Discrete Mathematics. 3^{rd} Edition. CRC Press.

SEMESTER II

Course Title **Calculus-II**
Course Code **MTH-302**
Credit Hours **4(4-0)**

AIMS AND OBJECTIVES:

This is second course of Calculus. As continuation of Calculus I, it focuses on techniques of integration and applications of integrals. The course also aims at introducing the students to infinite series, parametric curves and polar coordinates.

THEORY:

Techniques of integration: Integrals of elementary, hyperbolic, trigonometric, logarithmic and exponential functions. Integration byparts, substitution and partial fractions. Approximate integration.Improper integrals. Gamma functions.
Applications of integrals: Area between curves, average value. Volumes. Arc length. Area of a surface of revolution.Applications toEconomics, Physics, Engineering and Biology.
Infinite series: Sequences and series. Convergence and absolute convergence. Tests for convergence: divergence test, integral test, pseries test, comparison test, limit comparison test, alternating seriestest, ratio test, root test. Power series. Convergence of power series. Representation of functions as power series. Differentiation and integration of power series. Taylor and McLaurin series.
Approximations by Taylor polynomials. Conic section, parameterized curves and polar coordinates. Curves defined by parametric equations. Calculus with parametric curves: tangents, areas, arc length. Polar coordinates. Polar curves, tangents to polar curves. Areas and arc length in polar coordinates.

RECOMMENDED BOOKS:

1. A. Kaseberg. 2004. Intermediate Algebra. 3rd Edition. Thomson-Brooks/Cole.
2. F. A. Jr., E. Mendelson, Schaum's Outline of Calculus. Latest Edition. McGraw Hill Inc.
3. G. B. Thomas Jr., M. D. Weir, J. R. Hass, F. R. Giordano. Thomas's Calculus. Latest Edition. Pearson Education.
4. H. Anton, I. Bivens, S. Davis. Calculus. Latest Edition. John Wiley & Sons, Inc.
5. M. Liebeck. 2011. A Concise Introduction To Pure Mathematics, 3rd Edition. CRC Press.

Course Title: **Discrete Mathematics**
Course Code: **MTH-304**
Credit Hours: **3(3-0)**

AIMS AND OBJECTIVES:

Discrete Mathematics is study of distinct, un-related topics of mathematics; it embraces topics from early stages of mathematical development and recent additions to the discipline as well. The present course restricts only to counting methods, relations and graphs. The objective of the course is to inculcate in the students the skills that are necessary for decision making in non-continuous situations.

THEORY:

Counting methods: Basic methods: Product, inclusion-exclusion formulae , Permutations and combinations, Recurrence relations and their solutions , Generating functions , Double counting, Applications, Pigeonhole principle , Applications. Relations: Binary relations, n-ary relations, Closures of relations , Compositions of relations Inverse relations. Graphs: Graph terminology, Representation of Graphs, Graphs isomorphism, Algebraic methods: the incidence matrix , connectivity , Eulerian and Hamiltonian paths , Shortest path problem , Trees and spanning trees Complete graphs and bivalent graphs.

RECOMMENDED BOOKS:

1. A. Tucker. 2002. Applied Combinatorics. John Wiley & sons. Inc. New York.
2. B. Kolman, R. C. Busby , S. C. Ross, 2008. Discrete Mathematical Structures. 5th Edition. Prentice-Hall of India , New Delhi.
3. K. H. Rosen, 2007. Discrete Mathematics and Its Applications, 6th Edition. McGraw-Hill.
4. K.A. Ross, C. R. B. Wright. 2003. Discrete Mathematics, Prentice Hall, New Jersey.
5. N. L. Biggs. 2002. Discrete Mathematics, 2nd Edition. Oxford University Press.
6. R. Diestel, 2010. Graph Theory. 4th Edition . Springer-Verlag . New York.

SEMESTER III

Course Title **Calculus-III**
Course Code **MTH-401**
Credit Hours **4(4-0)**

AIMS AND OBJECTIVES:

This is third course of Calculus and builds up on the concepts learned in first two courses. The students would be introduced to the vector calculus, the calculus of multivariable functions and double and triple integrals along with their applications.

THEORY:

Vectors and analytic geometry in space, Vector-valued functions: Vector-valued functions and space curves. Derivatives and integrals of vector valued functions. Arc length. Curvature, normal and binormal vectors.
Multivariable functions and partial derivatives: Functions of several variables. Limits and Continuity. Partial derivatives, Composition and chain rule. Directional derivatives and the gradient vector. Implicit function theorem for several variables. Maximum and minimum values. Optimization problems. Lagrange Multipliers.
Multiple integrals: Double integrals over rectangular domains and iterated integrals. Non-rectangular domains. Double integrals in polar coordinates. Triple integrals in rectangular, cylindrical and spherical coordinates. Applications of double and triple integrals. Change of variables in multiple integrals.
Vector calculus: Vector fields. Line integrals. Green's theorem. Curl and divergence. Surface integrals over scalar and vector fields. Divergence theorem. Stokes' theorem.

RECOMMENDED BOOKS:

1. A. Kaseberg. 2004. Intermediate Algebra. 3rd Edition. Thomson-Brooks/Cole.
2. F. A. Jr., E. Mendelson, Schaum’s Outline of Calculus. Latest Edition. McGraw Hill Inc.
3. G. B. Thomas Jr., M. D. Weir, J. R. Hass, F. R. Giordano. Thomas’s Calculus. Latest Edition. Pearson Education.
4. H. Anton, I. Bivens, S. Davis. Calculus. Latest Edition. John Wiley & Sons, Inc.
5. M. Liebeck. 2011. A Concise Introduction To Pure Mathematics, 3rd Edition. CRC Press.

Course Title: **Metric Spaces & Group Theory**
Course Code: **MTH-403**
Credit Hours: **3(3-0)**

AIMS AND OBJECTIVES:

This course aims to introduce the basic ideas of metric spaces and group theory.

THEORY:

Metric Spaces: Definition and various examples of metric spaces, Holder’s inequality, Cauchy-schwarz and Minkowski’s inequality, Open and closed balls, Neighborhoods, Open and closed sets, Interior, Exterior and boundary points, Limit points, Closure of a set, Convergence in metric spaces, Cauchy sequences, Continuity in metric spaces.
Group Theory: Binary operations, Definition, Examples, formation of groups and applications, Subgroups, Subgroup lattice, Order of group, Order of an element, Abelian groups, Cyclic groups, Cosets, Lagrange’s theorem and its applications, Permutations, Permutability of permutations, Cyclic permutations, Even and odd permutations, Symmetric groups, Alternative groups.

RECOMMENDED BOOKS:

1. Micheal, O. Searcoid. 2007. Metric Spaces. Springer.
2. E. Kreyszig. 1978. Introduction to Functional Analysis with Applications, John Wiley and Sons.
3. W.A. Sutherland. 1975. Introduction to Metric and Topological Spaces. Clarendon Press
   Oxford.
4. E.T. Copson. 1968. Metric Spaces. Cambridge University, Press.
5. G.F. Simmons. 1963. Introduction to Topology and Modern Analysis. McGraw Hill Company.
6. I.N. Herstein. 1964. Topics in Algebra. Xerox Publishing Company.
7. Vivek Sahai and Vikas Bist. 1999. Algebra. Narosa Publishing House.
8. P.B. Bhattacharya, S.K. Jain and S.R. Nagpaul. 1986. Basic Abstract Algebra. C.U.P.

SEMESTER IV

Course Title: **Affine and Euclidean Geometry**
Course Code: **MTH-402**
Credit Hours: **4(4-0)**

AIMS AND OBJECTIVES:

To familiarize mathematics students with the axiomatic approach to geometry from a logical, historical, and pedagogical point of view and introduce them with the basic concepts of Affine Geometry, Affine spaces and Platonic Ployhedra.

THEORY:

Vector Spaces and Affine Geometry: Co linearity of three points , ratio AB/BC , Linear combinations and linear dependent set versus affine combinations and affine dependent sets , Classical theorems in affine geometry : Thales , Menelaus , Ceva , Desargues , Affine subspaces , affine maps , Dimension of a linear subspace and of an affine subspace . Euclidean Geometry: Scalar product , Cauchy-Schwartz inequality : norm of a vector , distance between two points, angles between two non-zero vectors , Pythagoras theorem , parallelogram law , cosine and sine rules , Elementary geometric loci .Orthogonal Transformations :Isometries of plane (four types), Isometries of space (six types) , Orthogonal basis. Platonic polyhedral :Euler theorem on finite planar graphs , Classification of regular polyhedra in space Isometries of regular polygons and regular polyhedra .

RECOMMENDED BOOKS:

1. E. G. Rees. 2004. Notes on Geometry. Springer.
2. H. W. Eves , Fundamentals of Modern Elementary Geometry, Jones and Bartlett Publishers
3. M. A. Armstrong, Groups and Symmetry, Springer
4. S. Stahl, 2007. A Gateway to Modern Geometry: The Poincare Half-Plane. 2nd Edition. Jones and Bartlett International Publishers. Inc. United States.

Course Title: **Linear Algebra**
Course Code: **MTH-404**
Credit Hours: **3(3-0)**

AIMS AND OBJECTIVES:

Linear algebra is the study of vector spaces and linear transformations. The main objective of this course is to help students learn in rigorous manner, the tools and methods essential for studying the solution spaces of problems in mathematics, engineering, the natural sciences, and social sciences and develop mathematical skills needed to apply these to the problems arising within their field of study; and to various real world problems.

THEORY:

System of Linear Equations, Gauss-Jordan method , Gaussian elimination.
Determinants: Permutations of order two and three and definitions of determinants of the same order , Computing of determinants, Definition of higher order determinants , Properties , Expansion of determinants
Vector Spaces: Definition and examples , subspaces , Linear combination and spanning set , Linearly independent set , Finitely generated vector spaces , Bases and dimension of a vector space, Operations on subspaces , Intersections , sums and direct sums of subspaces , Quotient spaces.
Linear Mappings: Definitions and examples , Kernel and image of a linear mapping , Rank and nullity Reflections , Projections and homotheties , Change of basis , Eigen values and Eigen vectors , Theorem of Hamilton-Cayley.
Inner Product Spaces: Definitions and examples , Properties , Projection , Cauchy inequality , Orthogonal and Orthonormal basis , Gram-Schmidt Process , Diagonalization.

RECOMMENDED BOOKS:

1. D. Dummit, R. M. Foote, 2003. Abstract Algebra. 3rd Edition. Wiley.
2. H. Anton, C. Rorres. 2010. Elementary Linear Algebra : Applications Version. 10th Edition. John Wiley & Sons.
3. T. M. Apostol, 2014. Calculus (Volume 2: Multi-Variable Calculus and Linear Algebra, with Applications to Differential Equations and Probability). 2nd Edition. John Wiley & Sons.
4. S. Lang, 2004. Linear Algebra. 3rd Edition. Springer-Verlag.
5. S. Friedberg, A. Insel . 2003. Linear Algebra, 4th Edition. Pearson Education. Canada

Course Title: **Ordinary Differential Equations**
Course Code: **MTH-406**
Credit Hours: **3(3-0)**

AIMS AND OBJECTIVES:

To introduce students to the formulation, classification of differential equations and existence and uniqueness of solutions. To provide skill in solving initial value and boundary value problems. To develop understanding and skill in solving first and second order linear homogeneous and nonhomogeneous differential equations and solving differential equations using power series methods.

THEORY:

Introduction and formulation of differential equations. First order ordinary differential equations: formation and solution of differential equations, Separable variables, Exact Equations, Homogeneous Equations, Linear equations, integrating factors. Some non-linear first order equations with known solution, differential equations of Bernoulli and Ricaati type, Clairaut equation, Modeling with firt order ODEs, Basic theory of systems of first order linear equations, Homogeneous linear system with constant coefficients, Non homogeneous linear system. Second and higher order linear differential equations: Initial value and boundary value problem, Homogeneous and non- homogeneous equations, Superposition principal, Homogeneous Equations with constant coefficient, Linear independence and Wronskian, Non-homogeneous Equations, undetermined coefficients method, variation of parameters, Cauchy-Euler equation, Modeling.
Sturm-Liouville problems: Introduction to Eigen value problem, adjoint and self adjoint operators, self adjoint differential equations, Eigen value and Eigen functions, Sturm-Liouville (S-L) boundary value problems, regular and singular S-L problems, properties of regular S-L problems.
Series Solutions: Power series, ordinary and singular points, Existence of power series solutions, power series solution, types of singular points, Frobenius theorem,

RECOMMENDED BOOKS:

1. D. G. Zill, M. R. Cullin, 2009. Differential Equations With Boundary Value Problems. 7th Edition. Brooks/Cole.
2. T. M. Apostol, 2014. Calculus (Volume 2: Multi-Variable Calculus and Linear Algebra, with Applications to Differential Equations and Probability). 2nd Edition. John Wiley & Sons.
3. W. E. Boyce, R. C. Diprima, 2001. Elementary Differential Equations and Boundary Value Problems. 7th Edition. John Wiley & Sons. Inc.
4. W. T. Ang, Y. S. Park, 2008. Ordinary Differential Equations: Methods and Applications. Universal Publishers. Boca Raton.

SEMESTER V

Course Title: **Topology**
Course Code: **MTH-501**
Credit Hours: **3(3-0)**

AIMS AND OBJECTIVES:

The aim of this course is to introduce the students to metric spaces and topological spaces. After completion of this course, they would be familiar with separation axioms, compactness and completeness. They would be able to determine whether a function defined on a metric or topological space is continuous or not and what homeomorphisms are.

THEORY:

Review of metric spaces. Topological spaces: Examples; open and closed subsets, neighborhoods. Examples. Limit points and accumulation points. Interior, closure, dense subsets.Constructing new topological spaces: Cartesian products, induced topology and quotient topology.Continuous maps, open and closed maps, homeomorphisms.Examples: R, RxR, S^1, S^2, torus, cylinder. Cauchy sequences,complete metric spaces. Separation axioms. Compact spaces.Properties. Power of Compactness. Image of a compact set through a continuous map. Compactness and completeness of metric spaces.Connected spaces, connected components. Properties. Image of a connected set through a continuous map. Path-connectedness.

RECOMMENDED BOOKS:

1. G. F. Simmons. 2004. Introduction to Topology and Modern Analysis. Edition 9th. McGraw- Hill.
2. J. Kelly. 2005. General Topology. Edition Ist. Springer.
3. J. G. Hocking, G. S. Young. 2012.Topology. Edition 5th. Dover Publications.
4. J. R. Munkres. 2000.Topology-A First Course, Edition 2nd. Prentice-Hall
5. S. Lipschutz .2004. General Topology. Edition Ist. McGraw-Hill.

Course Title: **Differential Geometry**
Course Code: **MTH-503**
Credit Hours: **3(3-0)**

AIMS AND OBJECTIVES:

After having completed this course, the students would be expected to understand classical concepts in the local theory of curves and surfaces including normal, principal,mean, curvature, and geodesics. They will also learn about tensors of different ranks.

THEORY:

Theory of Space Curves: Introduction, index notation and summation convention. Space curves, arc length, tangent, normal and binormal.Osculating, normal and rectifying planes.Curvature and torsion.The Frenet-Serret theorem.Natural equation of a curve. Involutes and evolutes, helices. Fundamental existence theorem of space curves.
Theory of Surfaces: Coordinate transformation. Tangent plane and surface normal.The first fundamental form and the metric tensor.The second fundamental form. Principal, Gaussian, mean, geodesic and normal curvatures. Gauss and Weingarten equations.Gauss and Codazzi equations.
Tensor Analysis: Einstein summation convention. Tensors of different ranks.Contravariant, covariant and mixed tensors. Addition,
subtraction, inner and outer products of tensors. Contraction theorem,
quotient law. The line element and metric tensor.Christoffel symbols.

RECOMMENDED BOOKS:

1. A. N. Pressley. 2010. Elementry Differential Geometry. Edition 2nd, Springer.
2. A. W. Joshi. Matrices and Tensors in Physics. Edition Latest.Wiley Eastern Limited.
1. 3 . D. Somasundaram. 2005. Differential Geometry, Narosa Publishing House, New Delhi
3. E. Kreyszig. 2002.Differential Geometry, Edition Ist. Dover.
4. M. M. Lipschutz.Schaum’s Outline of Differential Geometry. Latest Edition. McGraw Hill.

Course Title: **Real Analysis I**
Course Code: **MTH-505**
Credit Hours: **3(3-0)**

AIMS AND OBJECTIVES:

This is the first course in analysis. It develops the fundamental ideas of analysis and is aimed at developing the students' ability in reading and writing mathematical proofs.Another objective is to provide sound understanding of the axiomatic
foundations of the real number system, in particular the notions of completeness and compactness.

THEORY:

Algebraic and ordered properties of Real Numbers, Absolute values,Inequalities (Cauchy's, Minkoski's, Bernoulli's) Properties and concepts of supremum and infimum, Ordered sets, Fields, Field of Real, The extended real number system, Euclidean spaces, Sequences, Subsequences, Cauchy sequence,Series of Numbers and their convergence. The Comparison, Root, Ratio and Integral tests.Absolute and Conditional convergence of infinite series.Limits and Continuity.Properties of continuous functions.Types of discontinuities. Differentiable functions.Mean-value theorems, Continuity of derivatives. Partial Derivatives and Differentiability. Derivative and differentials of Composite functions. The Directional Derivative, the Laplacian in polar cylindrical and Spherical coordinates.

RECOMMENDED BOOKS:

1. R .G. Bartle, D. R. Sherbert. 2000. Introduction to Real Analysis. Edition 5^{th}. John Wiley New York.
2. T. M. Apostol. Mathematical Analysis. Latest Edition. Addison-Wesley Publishing Company.
3. W. Kaplan. 2002. Advance Calculus. Edition 5^{th}. Published by Pearson Education.
4. W.Rudin. 2013. Principles of Mathematics Analysis. Edition 3^{rd}. McGraw-Hill. New York.

Course Title **Algebra I**
Course Code **MTH-507**
Credit Hours **3(3-0)**

AIMS AND OBJECTIVES:

This course introduces basic concepts of groups and their homomorphisms. The main objective of this course is to prepare students for courses which require a good back ground in group theory like Rings and Modules, Linear Algebra, Group Representation, Galois Theory etc.

THEORY:

Review of Groups. Complexes and coset decomposition of groups, normalize centralizer. The center of a group. Equivalence relation in a group, Conjugacy classes, double cosets. normal subgroups, quotient group.
Group homomorphisms: Homomorphisms, isomorphism and automorphism. Kernel and image of homomorphism. Isomorphism theorems. commutator subgroups of a group. permutation groups. The cyclic decomposition of permutation group. Cayley's theorem. Sylow Theorems: Cauchy's theorem for Abelian and non-Abelian group, Sylow theorems.

RECOMMENDED BOOKS:

1. D. S. Dummit, R. M. Foote. 2004. Abstract Algebra, Edition 3rd. Addison-Wesley Publishing Company.

2. J. S. Rose. 2012. A Course on Group Theory. Revised edition. Dover Publications.

3. J. B. Fraleigh. 2002. A First Course in Abstract Algebra, Edition 7th. Addison-Wesley

4. Publishing company.

5. P. M. Cohn . 2000. Algebra. Edition 2nd. John Wiley and Sons. London.

Course Title **Vector and Tensor Analysis**
Course Code **MTH-509**
Credit Hours **3(3-0)**

AIMS AND OBJECTIVES:

The aim of this course is to introduce the vectors and tensor analysis which is useful for advance courses.

THEORY:

3-D vectors, summation convention, kronecker delta, Levi-Civita symbol, vectors as quantities transforming under rotations with $\in_{ijk}$ notation, scalar- and vector- triple products, scalar- and vector-point functions, differentiation and integration of vectors, line integrals, path independence, surface integrals, volume integrals, gradient, divergence and curl with physical significance and applications, vector identities, Green's theorem in a plane, divergence theorem, Stokes's theorem, coordinate systems and their bases, the spherical-polar- and the cylindrical-coordinate meshes, tensors of first, second and higher orders, algebra of tensors, contraction of tensor, quotient theorem, symmetric and skew-symmetric tensors, invariance property, application of tensors in modeling anisotropic systems, study of physical tensors (moment of inertia, index of refraction, etc.), diagonalization of inertia tensor as aligning coordinate frame with natural symmetries of the system

RECOMMENDED BOOKS:

1. D. E. Bourne, P. C. Kendall, Vector Analysis and Cartesian Tensors. Edition Latest. Thomas Nelson.
2. G. D. Smith. 2000. Vector Analysis. Edition Latest. Oxford University Press.
3. N. A. Shah, 2005. Vector and Tensor Analysis. Edition Latest. A-One Publishers. Lahore
4. K. A. Stroud, 2003. Advanced Engineering Mathematics. Fourth Edition. Palgrave Macmillan

Course Title **Complex Analysis I**
Course Code **MTH-511**
Credit Hours **3(3-0)**

AIMS AND OBJECTIVES:

This is an introductory course in complex analysis, giving the basics of the theory along with applications, with an emphasis on applications of complex analysis and especially conformal mappings. Students should have a background in real analysis (as in the course Real Analysis- I), including the ability to write a simple proof in an analysis context.

THEORY:

The Concept of Analytic Functions: Complex numbers, complex planes, complex functions, Analytic functions, entire functions, Harmonic functions, Elementary functions: complex exponential, logarithmic and hyperbolic functions. Infinite Series: Power series, derived series, radius of convergence, Taylor series and Laurent series. Conformal Representation: Transformation, conformal transformation, linear transformation, Möbius transformations. Complex Integration: Complex integrals, Cauchy-Goursat theorem, Cauchy's integral formula and their consequences, Liouville's theorem, Morera's theorem, Derivative of an analytic function.

RECOMMENDED BOOKS:

1. D. G. Zill and P. D. Shanahan. 2003. Complex Analysis. Jones and Bartlett Publishers.
2. H. S. Kasana 2005. Complex Variables: Theory and Applications. Prentice Hall.
3. J. W. Brown and R. V. Churchill. 2004. Complex Variables and Applications, 7th edition. McGraw Hill Company.
4. M. R. Spiegel 1974. Complex Variables. McGraw Hill Book Company.
5. Louis L. Pennisi. 1976. Elements of Complex Variables. Holt, Linehart and Winston.

SEMESTER VI

Course Title: **Partial Differential Equations**
Course Code: **MTH-502**
Credit Hours: **3(3-0)**

AIMS AND OBJECTIVES:

Partial Differential Equations (PDEs) are at the heart of applied mathematics and many other scientific disciplines. The course aims at developing understanding about fundamental concepts of PDEs theory, identification and classification of their different types, how they arise in applications, and analytical methods for solving them. Special emphasis would be on wave, heat and Laplace equations.

THEORY:

Pre-Requisite: Ordinary Differential Equations Introduction, Review of ordinary differential equation in more than one variables, Linear partial differential equations (PDEs) of the first order, Cauchy's problem for quasilinear first order PDEs. PDEs of Second Order: PDEs of second order in two independent variables with variable coefficients, Linear transformation from one equation to another equation, Normal form, Cauchy's problem for second order PDEs in two independent variables. Adjoint Equation: Adjoint operator, Self adjoint equation and operator Linear PDEs in n independent variables, Lagrange's identity, Green's theorem for self adjoint operator. Boundary Value Problems: Laplace equation, Dirichlet problem for a circle, Poisson's integral for a circle, Solution of Laplace equation in Cartesian, cylindrical and spherical coordinates, The wave equation in one dimension, The wave equation in higher dimensions, The heat equation, Axially symmetric solutions

RECOMMENDED BOOKS:

1. I. N. Sneddon, Elements of Partial Differential Equations (Dover Publishing, Inc., 2006)
2. R. Dennemyer, Introduction to Partial Differential Equations and Boundary Value Problems (McGraw Hill Book Company, 1968)
3. M. Humi and W. B. Miller, Boundary Value Problem and Partial Differential Equations(PWS-Kent Publishing Company, Boston, 1991)
4. C. R. Chester, Techniques in Partial Differential Equations (McGraw Hill Book Company, 1971)
5. R. Haberman, Elementary Applied Partial Differential Equations, 2nd edition (Prentice Hall Inc., New Jersey, 1987)
6. E. Zauderer, Partial Differential Equations of Applied Mathematics (Wiley-Interscience, Englewood Cliff, New York, 2006

Course Title: **Classical Mechanics**
Course Code: **MTH-504**
Credit Hours: **3(3-0)**

AIMS AND OBJECTIVES:

To provide solid understanding of classical mechanics and enable the students to use this understanding while studying courses on quantum mechanics, statistical mechanics, electromagnetism, fluid dynamics, space-flight dynamics, astrodynamics and continuum mechanics.

THEORY:

Kinematics. Kinetics: Work, power, kinetic energy, conservative force fields. Conservation of energy, impulse, torque, Conservation of linear and angular momentum. Non-conservative forces. Simple Harmonic Motion: The simple harmonic oscillator, period, frequency. Resonance and energy. The damped harmonic oscillator, over damped, critically damped and under damped Motion, forces and vibrations.
Central Forces and Planetary Motion: Central force fields, equations of motion, potential energy, orbits Kepler’s law of planetary motion. Apsides and apsidal angles for nearly circular orbits. Motion in an inverse square field.
Planer Motion of Rigid Bodies: Introduction to rigid and elastic bodies, degree of freedom, translations, rotations, instantaneous axis and center of rotation, motion of center of mass. Euler’s theorem and Chasles’ theorem. Rotation of a rigid body about a fixed axis, moments and products of inertia. Parallel and perpendicular axis theorem.
Motion of Rigid Bodies in Three Dimensions: General motion of rigid bodies in space. The momental ellipsoid and equimomental systems. Angular momentum vector and rotational kinetic energy.Principal axes and principal moments of inertia. Determination of principal axes by diagonalizing the inertia matrix.Euler Equations of Motion of a Rigid Body: Force free motion. Free rotation of a rigid body with an axis of symmetry. Free rotation of a rigid body with three different principal moments.The Eulerian angles, angular velocity and kinetic energy in terms of Euler angles. Motion of a spinning top and gyroscopes-steady precession, sleeping top.

RECOMMENDED BOOKS:

1. C. F. Chorlton. 2004, Text Book of Dynamics. Edition 2nd. CBS Publishers.
2. E. DiBenedetto. 2011. Classical Mechanics: Theory and Mathematical Modeling. Edition Latest. Birkhauser Boston.
3. G. R. Fowles, G. L. Cassiday. 2005. Analytical Mechanics. Edition 5th.Thomson Brooks/Cole, USA.
4. John R. Taylor. 2005. Classical Mechanics. Edition Latest. University of Colorado.
5. M. R. Spiegel. 2004. Theoretical Mechanics. Edition 3rd. Addison-Wesley Publishing Company.

Course Title: **Complex Analysis II**
Course Code: **MTH-506**
Credit Hours: **3(3-0)**

AIMS AND OBJECTIVES:

The course unit aims to introduce the ideas of complex analysis with particular emphasis on Cauchy's theorem and the calculus of residues. Students should have a background in complex analysis (as in the course Complex Analysis- I), including the ability to write a simple proof in an analysis context.

THEORY:
Singularity and Poles: Review of Laurent series, zeros, singularities,Poles and residues. Contour Integration: Cauchy's residue theorem, applications of Cauchy's residue theorem. Expansion of Functions and Analytic Continuation: Mittag-Leffler theorem, Weierstrass's factorization theorem, analytic continuation. Elliptic Functions: Periodic functions, Elliptic functions and its properties, Weierstrass function $\varphi(z)$, differential equation satisfied by $\varphi(z)$, integral formula for $\varphi(z)$, addition theorem for $\varphi(z)$, duplication formula for $\varphi(z)$, Elliptic functions in terms of Weierstrass function with the same periods, Quasi periodic functions: The zeta and sigma functions of Weierstrass, Jacobian elliptic functions and its properties.

RECOMMENDED BOOKS:

1. H. S. Kasana. 2005. Complex Variables: Theory and Applications. Prentice Hall.
2. M. R. Spiegel. 1974. Complex Variables. McGraw Hill Book Company.
3. Louis L. Pennisi. 1976. Elements of Complex Variables. Holt, Linehart and Winston.
4. W. Kaplan 1966. Introduction to Analytic Functions. Addison-Wesley.
5. E. D. Rainville. 1965. Special Functions. The Macmillan Company, New York.
6. E. T. Whittaker and G. N. Watson. 1958. A Course of Modern Analysis. Cambridge University Press.

Course Title: **Real Analysis II**
Course Code: **MTH-508**
Credit Hours: **3(3-0)**

AIMS AND OBJECTIVES:

A continuation of Real Analysis I, this course will continue to cover the fundamentals of real analysis,concentrating on the Riemann-Stieltjes integrals, Functions of Bounded Variation, Improper Integrals, and convergence of series.

THEORY:

The Riemann - Stieltjes (R-S) Integrals.Properties of R-S integrals. Functions of bounded variations. Point wise and uniform convergence of sequences and series of functions, Weierstrass M-Test, Uniform convergence and continuity. Uniform Convergence and differentiation, Uniform Convergence and integration. Convergence of improper integrals.Beta and Gamma functions and their properties. Implicit functions, Jacobians, Functional dependence. Taylor’s theorem for a function of two variables.Maxmima and minima of functions of two and three variables.Method of Lagrange Mulitipliers.

RECOMMENDED BOOK:

1. R .G. Bartle, D.R.Sherbert. 2000. Introduction to Real Analysis.Edition 5th, John Wiley New York.
2. T. M. Apostol. Mathematical Analysis. Latest Edition. Addison-Wesley Publishing Company.
3. W. Kaplan. 2002. Advance Calculus .Edition 5th. Pearson Education.
4. W. Rudin. 2013. Principles of Mathematics Analysis. Edition 3rd, McGraw-Hill New York.

Course Title: **Functional Analysis**
Course Code: **MTH-510**
Credit Hours: **3(3-0)**

AIMS AND OBJECTIVES:

This course extends methods oflinear algebra and analysis to spaces of functions, in which theinteraction between algebra and analysis allows powerful methods tobe developed. The course will be mathematically sophisticated and willuse ideasboth from linear algebra and analysis.

THEORY:

Metric Space: Review of metric spaces, Convergence in metric spaces, Complete metric spaces, Dense sets and separable spaces, No-where dense sets, Baire category theorem. Normed Spaces: Normed linear spaces, Banach spaces, Equivalent norms, Linear operator, Finite dimensional normed spaces, Continuous and bounded linear operators, Dual spaces. Inner Product Spaces: Definition and examples, Orthonormal sets and bases, Annihilators, projections, Linear functionals on Hilbert spaces. Reflexivity of Hilbert spaces.

RECOMMENDED BOOKS:

1. A. V. Balakrishnan. 2000. Applied Functional Analysis. Edition 2nd. Springer-Verlag, Berlin.

2. E. Kreyszig. 2004. Introduction to Functional Analysis with Applications. Latest Edition. John Wiley and Sons.

3. J. B. Conway. 2000. A Course in Functional Analysis. Edition 2nd. Springer-Verlag, Berlin.

4. K. Yosida. Functional Analysis. Edition 5th. Springer-Verlag. Berlin.

Course Title: **Algebra II**
Course Code: **MTH-512**
Credit Hours: **3(3-0)**

AIMS AND OBJECTIVES:

This is a course in advanced abstract algebra, which builds on the concepts learnt in Algebra I. The objectives of the course are to introduce students to the basic ideas and methods of modern algebra and enable them to understand the idea of a ring and an integral domain, and be aware of examples of these structures in mathematics; appreciate and be able to prove the basic results of ring theory; appreciate the significance of unique factorization in rings and integral domains.

THEORY:

Rings: Definition, examples. Quadratic integer rings. Examples of non-commutative rings.The Hamilton quaternions. Polynomial rings. Matrix rings. Units, zero-divisors.Nilpotent, idempotent.Subrings, ideals.Maximal and prime ideals Left, right and two-sided ideals; Operations with ideals. The ideal generated by sets. Quotient rings. Ring homomorphism. The isomorphism theorems, applications. Finitely generated ideals. Rings of fractions.Integral Domain: The Chinese remainder theorem. Divisibility in integral domains, Greatest common divisor, least common multiple. Euclidean domains. The Euclidean algorithm.Principal ideal domains.Prime and irreducible elements in an integral domain.Gauss lemma, irreducibility criteria for polynomials.Unique factorization domains. Finite fields. Polynomials in several variables. Symmetric polynomials. The fundamental theorem of symmetric polynomials.

RECOMMENDED BOOKS:

1. D.S. Dummit, R.M. Foote 2004. Abstract Algebra. Edition 3rd. Addison-Wesley Publishing Company.
2. J. B. Fraleigh. 2002. A First Course in Abstract Algebra. Edition Latest. Addison Wesley Publishing Company.
3. P. M. Cohn. 2000. Algebra, Edition 2nd. John Wiley and Sons. London.
4. P. B. Bhattacharya, S. K. Jain, S.R.Nagpaul.1994. Basic Abstract Algebra, Edition 2nd. Cambridge University Press.

SEMESTER VII

Course Title: **Numerical Analysis I**
Course Code: **MTH-601**
Credit Hours: **3(3-0)**

AIMS AND OBJECTIVES:

This course is designed to teach the students about numerical methods and their theoretical bases. The course aims at inculcating in the students the skill to apply various techniques in numerical analysis, understand and do calculations about errors that can occur in numerical methods and understand and be able to use the basics of matrix analysis.

THEORY:

Number Systems and Errors, Interpolation by Polynomials: Existence and uniqueness of the interpolating polynomial. Lagrangian interpolation, the divided difference table. Error of the interpolating polynomial; interpolation with equally spaced data, Newton's forward and backward difference formulas, Bessel's interpolation formula. Solution of non-linear Equations: Bisection method, iterative methods, secant and regula falsi methods; fixed point iteration, convergence criterion for a fixed point iteration, Newton-Raphson method,order of convergence of Newton-Raphson and secant methods. System of Linear Equations: Gauss elimination methods, triangular factorization, Crout method. Iterative methods: Jacobi method, Gauss-Seidel method, SOR method, convergence of iterative methods. Numerical Differentiation: Numerical differentiation formulae based on interpolation polynomials, error estimates. Numerical Integration: Newton-Cotes formulae; trapezoidal rule, Simpson's formulas, composite rules, Romberg improvement, Richardson extrapolation. Error estimation of integration formulas, Gaussian quadrature.

RECOMMENDED BOOKS:

1. A. Komech, A. Komech. 2009. Principles of Partial Differential Equations, Springer-New York.
2. C. F. Gerlad, P.O. Wheatley. 2005. Applied Numerical Analysis. Pearson Education. Singapore.
3. J. H. Mathews, Numerical Methods for Mathematics, Latest Edition. Prentice Hall International,
4. L. Debnath. 2005. Nonlinear Partial Differential Equations for Scientists and Engineers, Birkhauser-Boston.
5. R. L. Burden, J. D. Faires: Numerical Analysis, Latest Edition. PWS Pub. Co.
6. W. E. Boyce, R. C. DiPrima. 2001. Elementary Differential Equations and Boundary Value Problems, John Wiley & sons, Inc.

Course Title: **Number Theory**
Course Code: **MTH-603**
Credit Hours: **3(3-0)**

AIMS AND OBJECTIVES:

The focus of the course is on study of the fundamental properties of integers and develops ability to prove basic theorems. The specific objectives include study of division algorithm, prime numbers and their distributions, Diophantine equations, and the theory of congruences.

THEORY:

Preliminaries: Well-ordering principle of finite induction. Divisibility theory: The division algorithms. Basis representation theorem. Prime and composite numbers. Canonial decomposition. The greatest common divisor.The Euclidean algorithm. The Fundamental theorem of arithmetic. Latest common multiple. Linear Diophantine equations: congruences. Linear congruences. System of linear congruences. The Chinese remainder theorem. Divisibility tests. Solving polynomial congruences. Fermat's and Euler's theorems. Wilson's theorem. Arithmetic Functions: Euler's phi-function. The function of J and Sigma.The Mobius function.The sieve of Eratosthenes. Perfect numbers. Fermat and Mersenne primes.
Primitive Roots and indices: The order of intger mod n. Primitive roots for primes. Composite numbers having primitive roots. Quadratic residues: Legendre symbols and its properties. The quadratic reciprocity law.

RECOMMENDED BOOKS:

1. A. Adler, J. E. Coury. 2002. The Theory of Numbers. Jones and Bartlett Publishers.
2. D. M. Burton. 2007. Elementary Number Theory. McGraw-Hill.
3. I. Niven, H. S. Zuckerman, H. L. Montgomery. 2014. An Introduction to The Theory of Numbers. John Wiley and Sons.
4. K. H. Rosen. 2005. Elementary Number Theory and Its Applications. Edition 5^{th}. Pearson/Addison Wesley.
5. W. J. Leveque. 2015. Topics in Number Theory. Edition 7^{th}. Addison-Wesley. Vols.I and II.

Course Title: **Mathematical Statistics I**
Course Code: **MTH-605**
Credit Hours: **3(3-0)**

AIMS AND OBJECTIVES:

The principal aim of this course is to provide students with a solid grounding in probability theory and mathematical statistics.

THEORY:

Probability Distributions: The postulates of probability, Some elementary theorems, Addition and multiplication rules, Baye's rule and future Baye's theorem. Random variables and probability functions, Discrete Probability Distributions: Uniform, Bernoulli and Binomial distribution, Hypergeometric and geometric distribution, Negative binomial and Poisson distribution. Continuous Probability Distributions: Uniform and exponential distribution, Gamma and beta distributions, Normal distribution Mathematical Expectations: Moments and moment generating functions, Moments of binomial, hypergeometric, Poisson, gamma, beta and normal distributions.

RECOMMENDED BOOKS:

1. J. E. Freund, Mathematical Statistics, (Prentice Hall Inc., 1992)
2. Hogg and Craig, Introduction to Mathematical Statistics, (Collier Macmillan, 1958)
3. Mood, Greyill and Boes, Introduction to the Theory of Statistics, (McGraw Hill)
4. R. E. Walpole, Introduction to Statistics, 3rd edition, (Macmillan Publishing Company London, 1982)
5. M. R. Spiegel and L. J. Stephens, Statistics, (McGraw Hill Book Company, 1984)

Course Title: **Advanced Group Theory**
Course Code: **MTH-607**
Credit Hours: **3(3-0)**

AIMS AND OBJECTIVES:

The aim of this course is to study advance topics of group theory.

THEORY:

Direct products and normal products of groups, Holomorphic of a group, Finitely generated abelian groups, Group action on a set, orbits and transitive actions, Stabilizers , The orbit stabilizer theorem, Characteristic and fully invariant subgroups, symmetric and alternating groups, generators of symmetric and alternating groups, Simple groups, simplicity of An, $n \geq 5$, series in groups. Zassenhau's Lemma, normal series and their refinements, composition series, principal or chief series.

RECOMMENDED BOOKS:

1. N. Carter. 2009.Visual Group Theory. American Association of America Inc.
2. P.M. Cohn. 2000. Classic Algebra. London. John Wiley & Sons Inc.
3. D.S. Dummit, R.M. Foote.2004. Abstract Algebra.Edition 3rd.John Wiley & Sons, .
4. J. Gallian. 2013. Contemporary Abstract Algebra. Edition 8th.Brooks/Cole Cengage Learning.

Course Title: **Methods of Mathematical Physics**
Course Code: **MTH-609**
Credit Hours: **3(3-0)**

AIMS AND OBJECTIVES:

The main objective of this course is to provide the students with a range of mathematical methods that are essential to the solution of advanced problems encountered in the fields of applied physics and engineering. In addition this course is intended to prepare the students with mathematical tools and techniques that are required in advanced courses offered in the applied physics and engineering programs.

THEORY:

Fourier Methods: The Fourier transforms. Fourier analysis of the generalized functions. The Laplace transforms. Hankel transforms for the solution of PDEs and their application to boundary value problems.
Green's Functions and Transform Methods: Expansion for Green's functions. Transform methods. Closed form Green's functions.
Perturbation Techniques: Perturbation methods for algebraic equations. Perturbation methods for differential equations.
Variational Methods: Euler- Langrange equations. Integrand involving one, two, three and n variables. Special cases of Euler- Langrange's equations. Necessary conditions for existence of an extremum of a functional. Constrained maxima and minima.

RECOMMENDED BOOKS:

1. A. D. Snider. 2007. Partial Differential Equations. Sources and Solutions. Prentice Hall Inc.
2. D. L. Powers. 2005. Boundary Value Problems and Partial Differential Equations. Edition 5^{th}. Academic Press.
3. J. W. Brown, R. V. Churchil. 2006. Fourier Series and Boundary Value Problems. McGraw-Hill.
4. W. E.Boyce. 2005. Elementary Differential Equations. Edition 8th. John Wiley and Sons.

Course Title: **Quantum Mechanics I**
Course Code: **MTH-611**
Credit Hours: **3(3-0)**

AIMS AND OBJECTIVES:

The aim of the course is to provide mathematics students with a thorough introduction to nonrelativistic quantum mechanics, with emphasis on the mathematical structure of the theory.

THEORY:

Inadequacy of Classical Mechanics: Black body radiation, Photoelectric effect, Compton effect, Bohr's theory of atomic structure, Wave-particle duality, the de- Broglie postulate.
The Uncertainty Principle: Uncertainty of position and momentum, statement and proof of the uncertainty principle, Energy time uncertainty. Eigenvalues and eigen functions, Operators and eigen functions, Linear Operators, Operator formalism in Quantum Mechanics, Orthonormal systems, Hermitian operators and their properties, Simultaneous eigen functions. Parity operators. Postulates of quantum mechanics, the Schrödinger wave equation.
Motion in one Dimension: Step potential, potential barrier, Potential well, and Harmonic oscillator.

RECOMMENDED BOOKS:

1. E. Merzdacker. 2005. Quantum Mechanics. Edition 5^{th}. John Wiley and Sons Inc. New York.
2. H. Muirhead. 2002. The Physics of Elementary Particles. Pergamon Press.
3. J.G. Taylor. 2010. Quantum Mechanics George Allen and Unwin. .
4. R. M. Eisberg. 2005. Fundamental of Modern Mechanics. John Wiley and Sons Inc.
5. T. L.Powell, B. Crasemann. 2002. Quantum Mechanics. Addison-Wesley.

Course Title: **Fluid Mechanics I**
Course Code: **MTH-613**
Credit Hours: **3(3-0)**

AIMS AND OBJECTIVES:

The aim of the course is to introduce some of the most current research subjects in the field of fluid dynamics.

THEORY:

Real fluids and ideal fluids, Velocity of a fluid at a point, Streamlines and path lines, Steady ad unsteady flows, Velocity potential, Vorticity vector, Local and particle rates of change, Equation of continuity. Acceleration of a fluid, Conditions at a rigid boundary, General Analysis of fluid motion Euler's equations of motion, Bernoulli's equations steady motion under conservative body forces, Some potential theorems, impulsive motion. Sources, Sinks and doublets, Images in rigid infinite plane and solid spheres, Axi-symmetric flows, Stokes's stream function.
Stream function, Complex potential for two-dimensional, Irrational, Incompressible flow, Complex velocity spotential for uniform stream. Line sources and line sinks, Line doublets image systems, Miline-Thomson circle theorem, Blasius's Theorem.

RECOMMENDED BOOKS:

1. G. Currie. 2012. Fundamental Mechanics and Fluids. CRC Press.
2. H. Schlichting . 2000. Boundary Layer Theory. Springer.
3. J. H. Spurk, N. Aksel. 2008. Fluid Mechanics. Edition 2nd.Springer.
4. R. K. Bansal. 2005. A Textbook of Fluid Mechanics. Laxmi Publications (P) LTD, New Delhi.

Course Title: **Advanced Topology**
Course Code: **MTH-615**
Credit Hours: **3(3-0)**

AIMS AND OBJECTIVES:

The aim of this course is to introduce advance topics in topology.

THEORY:

Compactness in metric spaces, Limit point, Compactness, Sequential compactness and their various characterizations, Equivalence of different notions of compactness. Connectedness, various characterizations of connectedness, Connectedness and T()spaces, Local connectedness, Path-connectedness, Components. Homotopic maps, Homotopic paths, Loop spaces, Fundamental groups, Covering spaces, the lifting theorem, Fundamental groups of the circle () etc.Chain complex, Notion of homology.

RECOMMENDED BOOKS:

1. J. Hocking. G.Young. 2001. Topology. Dover Publications.
2. J. Kelly. 2005. General Topology. Springer .
3. J. R. Munkres. 2003.Topology - A First Course. Prentice-Hall.
4. S. Lipschutz. 2004. General Topology. McGraw-Hill.

Course Title: **Algebraic Topology**
Course Code: **MTH-617**
Credit Hours: **3(3-0)**

AIMS AND OBJECTIVES:

The aim of the unit is to give an introduction to algebraic topology with an emphasis on cell complexes, fundamental groups and homology.

THEORY:

Homotopy theory, Homotopy theory of path and maps, Fundamental group of circle, Covering spaces, Lifting criterion, Loop spaces and higher homotopy group. Affin spaces, Singular theory, Chain complexes, Homotopy invariance of homology, Relation between n, and H,relative homology The exact homology sequence.
Relative homology, The exact homology sequences, Excion theorem and application to spheres, Mayer Victoris sequences, Jordan-Brouwer separation theorem, Spherical complexes, Betti number and Euler characteristic, Cell Complexes and adjunction spaces.

RECOMMENDED BOOKS:

1. A. H. Wallace. 2004. Algebraic Topology. Homology and Cohomology. W.A. Benjamin Inc. New York.
2. A. Hatcher. 2002.Algebraic Topology. Cambridge University Press.
3. C. A. Kosniowski. 2003. First Course in Algebraic Topology. C.U.P.
4. F. H. Croom. 2005. Basic Concept of Algebraic Theory. Spinger-Verlag, New York,
5. M.J.Greenberg, J. R.Harper. 2007. Algebraic Topology. A First Course. The Bonjan Cunning Pub. Co.

Course Title: **Continuous Group**
Course Code: **MTH-619**
Credit Hours: **3(3-0)**

AIMS AND OBJECTIVES:

The aim of this course is to give introduction on continuous groups which is useful to learn theoretical physics related subjects.

THEORY:

Continuous Groups; Gl(n,r), Gl(n,c), So(p,q), Sp(2n); generalities on Continuous Groups; Groups of isometrics; Introduction to Lie groups with special emphasis on matrix Lie groups; Relationship of isometrics and Lie group; Theorem of Cartan; Correspondence of continuous groups with Lie algebras; Classification of groups of low dimensions; Homogeneous spaces and orbit types; Curvature of invariant metrics on Lie groups and homogeneous spaces.

RECOMMENDED BOOKS:

1. G. E. Bredon. 2006. Introduction to Compact Transformation Groups. Academic Press.
2. H. Taqdir. 2007. Introduction to Topological Groups. W.B.Saunder's-Company.
3. Jr. M.Willard. 2008. Symmetry Groups and Their Application. Academic Press-New York and London. Latest Edition.
4. L. P. Eisenhart. 2003. Continuous Groups of Transformations. Priceton U. P.

Course Title: **Rings and Modules**
Course Code: **MTH-621**
Credit Hours: **3(3-0)**

AIMS AND OBJECTIVES:

The aim of this course is to realize the importance of rings and modules as central objects in algebra and to study some applications.

THEORY:

Basic concepts of Ring Theory, Some Special Classis of Rings, Product, Matrix and Polynomial Rings, Subrings, Ring Homomorphism, Ideal and Quotient Rings, The Field of Quotients of an Integral Domain, Euclidean Rings, Polynomial Rings, Basic concepts of Module Theory, Submodules, Quotient Modules, Direct Sums, Homomorphism, Finitely generated Modules, Torsion Modules, Free Modules.

RECOMMENDED BOOKS:

1. M. F. Atiyah and I. G. Macdonald, 1969, Introduction to Commutative Algebra. Addison-Wesley Publishing Company, Inc.
2. O. Zariski and P. Samuel.1975-6, Commutative Algebra, Vols I and II. Springer
3. D. S. Dummit, R. M. Foote. 2004. Abstract Algebra; 3rd Edition. John Wiley & Sons.
4. R. Gilmer. 1972. Multiplicative Ideal Theory. Marcel Dekker, New York.

Course Title: **Special Theory of Relativity**
Course Code: **MTH-623**
Credit Hours: **3(3-0)**

AIMS AND OBJECTIVES:

The aim of this course is to introduce the concept of special relativity and its application to Physical Sciences.

THEORY:

Historical background and fundamental concepts of Special Theory of Relativity. Lorentz transformations (for motion along axis). Length contraction. Time dilation and simultaneity. Velocity addition formulae. 3-dimensional Lorentz transformations. Introduction to 4-vector formalism. Lorentz transformations in the 4 vector formalism. The Lorentz and Poincare groups. Introduction to classical Mechanics. Minkowski space time and null cone. 4-velocity, 4 acceleration 4- momentum and 4-force. Application of Special Relativity to Doppler shift and Compton Effect. Particle scattering. Binding energy, Particle production and decay. Electromagnetism in Relativity. Electric current. Maxwell's equations and electromagnetic waves. The 4-vector formulation of Maxwell's equations. Special Relativity with small acceleration.

RECOMMENDED BOOKS:

1. A. Qadir, 1989. Relativity: An Introduction to the Special Theory. World Scientific Press.
2. J. D. Jackson. 1977. Classical Relativity. Springer-Verlag.
3. J. G. Taylor. 1965. Special Relativity. Oxford University Press.
4. R. D' Inverno. 1992. Introduction Einstein's Relativity. Oxford University Press.

Course Title: **Operations Research**
Course Code: **MTH-625**
Credit Hours: **3(3-0)**

AIMS AND OBJECTIVES:

This course deals with the optimization techniques that allocate the available resources in an optimal manner.

THEORY:

Linear Programming: Mathematical modeling. Formulation and graphical solution. Analytical solution. Simplex method. Two- phase and M-technique for Linear programs.
Duality. Duality simplex method. Sensitivity Analysis.
Transportation Problems: Definition. Various methods including North –West Corner method. Least –cost method and Vogel's approximation. The Assignment model. Application to Networks. Shortest- Route Algorithm for acyclic and cyclic networks. Maximal- flow problems.
Integer Programming: Definition and formulation- Cutting-Plane Algorithm and Branch-and Bound method,Application. The mixed Algorithm, Zero-one polynomial programming.

RECOMMENDED BOOKS:

1. C. M. Harvey, 1979, Operation Research, North Holland, New Delhi.
2. F. S Hiller, G. J. Liebraman, 1974. Operational Research. CBS Publisher and Distributors. New Delhi.
3. H. A. Taha. 1987. An Introduction to Operations Research. Macmillan Publishing Company Inc. New York.
4. S. Kalavathy, Operations Research. Vikas Publishing House Ltd.
5. S. A. Bhatti, 1996, Operations Research: An Introduction, Shaharyar Publishers, Lahore.

Course Title **Software Packages**
Course Code **MTH-627**
Credit Hours **3(1-2)**

AIMS AND OBJECTIVES:

This subject covers the foundations of programming applications and analyze the requirements of an entry-level programming task,

THEORY & PRACTICAL

Microsoft Office: Working with Documents, Formatting a Document. Customizing a Document, Entering and Editing Data, Formatting a Worksheet, Entering pictures and graphs, Using Formulas and Functions, Creating a Presentation, Working with Slides.
MATLAB BASICS: Introduction to Matlab, Arithmetic Operations, Display Formats, Elementary Math Built-in Functions ,Variable Names, Predefined Variables , Commands for Managing Variables, General Commands, Polynomials , System of Linear Equations.
Math Type: Working with File, Entering the Mathematical Symbols, Using Math Type as Equation Editor, Inserting Math Type file in the Ms Office File, Using Formulas and Functions, Creating a Presentation, Working with Slides.
Latex: Working with .tex file, Formatting a file. Customizing a file, Entering and Editing Data, Using Formulas and Functions, Creating a Presentation, Working with Slides. Entering pictures and graphs. Working with Beamer for slides and presentations.

RECOMMENDED BOOKS:

1. B. R. Hunt, R. L. Lipsman, J. M. Rosenberg, 2001. A Guide to MATLAB for Beginners and Experienced Users. 1st Edition, Cambridge University Press
2. L. Beach, 2001. Math Type Mathematical Equation Editor. Edition 5th. Design Science, Inc. U.S.A.
3. M. Matthews, C. Matthews, 2007. Microsoft Office 2007. Quick Steps. 1st Edition. McGraw-Hill Professional Publishing.
4. R. V. Dukkipati, 2010. MATLAB An Introduction With Applications. New Age International Publishers

<u>SEMESTER VIII</u>

Course Title: **Mathematical Statistics II**
Course Code: **MTH-602**
Credit Hours: **3(3-0)**

AIMS AND OBJECTIVES:

The aim of the course is to present a solid calculus-based background in statistical theory together with its applications to solving practical real-world problems.

THEORY:

Functions of Random Variables: Distribution function technique, Transformation technique: One variable, several variables, Moment-generating function technique. Sampling Distributions: The distribution of the mean, The distribution of the mean: Finite populations, The Chi-Square distribution., The *t* distribution, The *F* distribution. Regression and Correlation**:** Linear regression, The methods of least squares, Normal regression analysis, Normal correlation analysis, Multiple linear regression, Multiple linear regression (matrix notation).

RECOMMENDED BOOKS:

1. J. E. Freund, Mathematical Statistics, (Prentice-Hall Inc., 1992).
2. Hogg and Craig, Introduction to Mathematical Statistics, (Collier Macmillan, 1958).
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3. Mood, Greyill and Boes, Introduction to the Theory of Statistics, (McGraw Hill).
4. R. E. Walpole, *Introduction to Statistics*, 3rd edition, (Macmillan Publishing Company
London, 1982)
5. M. R. Spiegel, L. J. Stephens, *Statistics*, (McGraw Hill Book Company, 1984)

Course Title: **Advanced Set Theory**
Course Code: **MTH-604**
Credit Hours: **3(3-0)**

AIMS AND OBJECTIVES:

The aim of the course is to present advance topics of set theory.

THEORY:

Equivalent sets and examples, Countable sets, examples of countable sets, uncountable sets, examples of uncountable sets, cardinal number as equivalence classes, example of cardinal numbers, Cantor's theorem, Partially ordered sets, chains, lattices, Partial ordering on cardinal numbers, Cantor-Bernstein theorem and applications, Addition, multiplication and exponentiation of cardinals, Zorn's lemma and applications, axiom of choice, equivalence of axiom of choice and Zorn's lemma, well ordered sets and related concepts, ordinal numbers, addition and multiplication of ordinal numbers.

RECOMMENDED BOOKS:

1. S. Shen, N. K. Vereshchagin, A. Shen. *Basic Set Theory*. American Mathematical Soc.; 2002.
2. I. Kaplansky, *Set theory and metric spaces*. Vol. 298. American Mathematical Soc., 2001.
3. A. N. Kolmogorov ,& S. V. Fomin, (2012). *Introductory Real Analysis*. Courier Corporation.
4. P. R. Halmos, *Naïve Set Theory,* New York, Van Nonstrand.
5. Hrbacek, Karel, and Thomas Jech. *Introduction to Set Theory, Revised and Expanded*. Crc Press, 1999.

Course Title: **Numerical Analysis II**
Course Code: **MTH-606**
Credit Hours: **3(3-0)**

AIMS AND OBJECTIVES:

Numerical methods for the solution of some of the main problems of the scientific computing are introduced (nonlinear sytems, data approximation, numerical differentiation and integration, numerical solution of ODE); their implementation and analysis are given by using interactive environments for the computing and the scientific visualization.

THEORY:

Osculating polynomials, Differentiation and integration in multidimension. Ordinary differential equations: Predictor methods, Modified Eulers method, Truncation error and stability, The Taylor series method, Runge-Kutta methods. Differential equations of higher order: System of differential equations; Runge-Kutta methods, shooting methods, finite difference methods. Partial differential equations: Elliptic hyperbolic and parabolic equations; Explicit and implicit finite difference methods, stability, convergence and consistency analysis, The method of characteristic. Eigen value problems; Estimation of Eigen values and corresponding error bounds, Gerschgorin's theorem and its applications Schur's theorem, Power method, Shift of origin, Deflation method for the subdominant Eigen values.

RECOMMENDED BOOKS:

1. A. Komech, A. Komech. 2009. Principles of Partial Differential Equations, Springer-New York.
2. C. F. Gerlad, P.O. Wheatley. 2005. Applied Numerical Analysis. Pearson Education. Singapore.
3. J. H. Mathews, Numerical Methods for Mathematics, Latest Edition. Prentice Hall International,
4. L. Debnath. 2005. Nonlinear Partial Differential Equations for Scientists and Engineers, Birkhauser-Boston.
5. R. L. Burden, J. D. Faires: Numerical Analysis, Latest Edition. PWS Pub. Co.
6. W. E. Boyce, R. C. DiPrima. 2001. Elementary Differential Equations and Boundary Value Problems, John Wiley & sons, Inc.

Course Title: **Theory of Modules**
Course Code: **MTH-608**
Credit Hours: **3(3-0)**

AIMS AND OBJECTIVES:

The main objective of this course is introduce the basic theory of modules which is useful in advance level algebra courses.

THEORY:

Definition and examples, Sub modules, Homeomorphisms and quotient modules. Direct sums of modules. Finitely generated modules, Torsion Modules, Free modules. Basis, Rank and endomorphism of free modules. Matrices over Rings and their connections with the basis of free modules. A Module. A Module as the direct sum of a free and a torsion module. Exact sequences and elementary notions of homological algebra. Noetherian and modules, Radicals, Semi simple rings and modules.

RECOMMENDED BOOKS:

1. T. S. Blyth. 2004. Module Theory. Oxford University Press.
2. D. S. Dummit, R. M. Foote. 2004. Abstract Algebra.Edition 3rd. John Wiley & Sons.
3. B. Hartley, T.O.Hawkes. 2006. Rings, Modules and Linear Algebra, Chapmanand Hall.
4. G. Kemper. 2010. A Course in Commutative Algebra. Springer.

Course Title: **Algebraic Number Theory**
Course Code: **MTH-610**
Credit Hours: **3(3-0)**

AIMS AND OBJECTIVES:

The aims of this unit are to enable students to gain an understanding and appreciation of algebraic number theory and familiarity with the basic objects of study, namely number fields and their rings of integers. In particular, it should enable them to become comfortable working with the basic algebraic concepts involved, to appreciate the failure of unique factorisation in general, and to see applications of the theory to Diophantine equations.

THEORY:

Review of polynomials, irreducible polynomials, Algebraic numbers and integers, Units and Primes in R[v] ideals. Arithmetic of ideals congruencies, the norm of an ideal. Prime ideals, Units of algebraic number field.
Application to Rational Number Theory: Equivalence and class number, Cyclotomic field Kp, Fermat's equation, Kummer's theorem, The equation: x2 + 2=y3, pure cubic fields, Distribution of primes and Riemann's zeta function.

RECOMMENDED BOOKS:

1. A. Adler, J. E. Coury, The Theory of Numbers, Jones and Bartlett Publishers.
2. D. M. Burton. 2007. Elementary Number Theory, McGraw-Hill.
3. I. Niven, H. S. Zuckerman, H. L. Montgomery. An Introduction to the Theory of Numbers. John Wiley & Sons. Inc.
4. K. H. Rosen. 2005. Elementary Number Theory and its Applications. Addison-Wesley. 5^{th} Edition.
5. I. N. Stewart, D. O. Tall, Algebraic Number Theory. 2nd Edition. Chapman and Hall/CRC Press. 1987.
6. W. J. LeVeque. 2002. Topics in Number Theory. Volumes I and II.

Course Title: **Category Theory**
Course Code: **MTH-612**
Credit Hours: **3(3-0)**

AIMS AND OBJECTIVES:

The aim of this course unit is to introduce the basic ideas of Category theory.

THEORY:

Basic concepts of category, Definition of category, examples, epimorphism, monomorphism, retractions, Initial, Terminal, and null objects, Category of graphs, Limits in categories, Equalizers, Pull backs, Inverse images and intersections, Constructions with kernel pairs, Functions and adjoint Functions, Functions, Bifunctions, Natural transformations, Diagrams, Limits, Colimits, Universal problems and adjoint functions.
Subjects, Quotient objects and factorization, (E,M) Categories, (Epi external mono) and (external epi mono) Categories, (Generating external mono) factorization. Pointed categories: Normal and exact categories, Additive categories, Abelian categories, Definition of automation and examples, Category of automata, Epimorphism, Monomorphism, initial, terminal and null objects in Aut. Congruences and factor automata, Automata with constant input and output.

RECOMMENDED BOOKS:

1. J. V. Oosten. 2007. Basic Category Theory. University of Otrecht.
2. M. A. Arbib, E. G. Manes, 1977, Arrows, structure and functions, Academic press New York.
3. P. Freyd, 1964, Abelian Categories: An Introduction to the Theory of Funtors, Harper and Row.
4. T. Leinster. 2014. Basic Category Theory. Cambridge University Press.

Course Title: **Galois Theory**
Course Code: **MTH-614**
Credit Hours: **3(3-0)**

AIMS AND OBJECTIVES:

To present an introduction to Galois theory in the context of arbitrary field extensions and apply it to a number of historically important mathematical problems.

THEORY:

Introduction to Extension Fields, Algebraic extensions, Finite fields, The basic isomorphism of algebraic field theory, Automorphism and fields, The Isomorphism Extension Theorem, Splitting fields, Separable extensions - Galois Theory, Illustrations of Galois Theory.

RECOMMENDED BOOKS:

1. D. A. Cox. 2012. Galois Theory. 2nd Edition. John Wiley & Sons, Inc.
2. D. S. Dummit, R. M. Foote. 2004. Abstract Algebra.Edition 3rd.John Wiley & Sons.
3. I. Kaplansky. Fields and Rings. Latest Edition. Chicago: University of Chicago Press.
4. I. Stewart. 2004. Galois Theory. 3rd Edition. Chapman & Hall/CRC.

Course Title: **Probability Theory**
Course Code: **MTH-616**
Credit Hours: **3(3-0)**

AIMS AND OBJECTIVES:

A prime objective of the course is to introduce the students to the fundamentals of probability theory and present techniques and basic results of the theory and illustrate these concepts with applications. This course will also present the basic principles of random variables and random processes needed in 24applications.

THEORY:

Finite probability spaces: Basic concept, probability and related frequency, combination of events, examples, Independence, Random variables, Expected value. Standard deviation and Chebyshev's inequality. Independence of random variables. Multiplicativity of the expected value. Additivity of the variance, Discrete probability distribution. Probability as a continuous set function:sigma-algebras, examples. Continuous random variables, Expectation and variance. Normal random variables and continuous probability distribution. Applications: de Moivre-Laplace limit theorem, weak and strong lawof large numbers. The central limit theorem, Markov chains and continuous Markov process.

RECOMMENDED BOOKS:

1. M. Capinski, E. Kopp,Measure, Integral and Probability,Springer-Verlag, 1998.
2. R. M. Dudley,Real Analysis and Probability, CambridgeUniver-sity Press, 2004.
3. S. I. Resnick,A Probability Path, Birkhauser, 1999.
4. S. Ross,A first Course in Probability Theory, 5th ed., PrenticeHall, 1998.
5. Robert B. Ash,Basic Probability Theory, Dover. B, 20

Course Title: **Theory of Elasticity**
Course Code: **MTH-618**
Credit Hours: **3(3-0)**

AIMS AND OBJECTIVES:

The objective of the course is to introduce the theory of elasticity and to analyze some real problems and to formulate the conditions of theory of elasticity applications.

THEORY:

Cartesian tensors, Analysis of stress and strain, Generalized Hooke's law; crystalline structure, Point groups of crystals, Reduction in the number of elastic moduli due to crystal symmetry; Equations of equilibrium; Boundary conditions, ompatibility equations; Plane stress and plane strain problems; Two dimensional problems in rectangular and polar co-ordinates; torsion of rods and beams.

RECOMMENDED BOOKS:

1. A. P. Boresi And K. P. Chong, 2000, Elasticity iri Engineering Mechanics, 2nd Edition, John Wiley & Sons.
2. A. C. Ugural, S. K. Fenster, . Advanced Strength and Applied Elasticity, Latest Edition. Elsevier Science Publishing Co., Inc..
3. A. S. Saada, Elasticity: Theory and Applications. Latest Edition. Krieger Publishing, Malabar, Florida,
4. S. P. Timoshenko And J. N. Goodier, Theory of Elasticity, McGraw Hill Book Company. Latest Edition.

Course Title: **Electromagnetism**
Course Code: **MTH-620**
Credit Hours: **3(3-0)**

AIMS AND OBJECTIVES:

The aim of this course is to provide the students with the fundamental principles of electrical energy (electro- magnetism).

THEORY:

Electrostatics and the solution of electrostatics problems in vacuum and in media, Electrostatic energy, Electro currents, The magnetic field of steady currents. Magnetic properties of matter. Magnetic energy, Electromagnetic Introduction, Maxwell's equations, Boundary Value Potential Problems in two dimensions, Electromagnetic Waves, Radiation, Motion of electric charges.

RECOMMENDED BOOKS:

1. D. Corson, P. Lerrain. Latest Edition. Introduction to Electromagnetic Fields and Waves. Freeman.
2. J. R. Reitz, F. J. Milford. Latest Edition. Foundation of Electromagnetic Theory. Addison-Wesley
3. K. H. Panofsky,M.Philips. Latest Edition. Classical Electricity and Magnetism. Addison-Wesley.
4. V. C. A. Ferraro. Latest Edition. Electromagnetic Theory. The Athlone Press.

Course Title: **Quantum Mechanics II**
Course Code: **MTH-622**
Credit Hours: **3(3-0)**

AIMS AND OBJECTIVES:

The aim of the course is to provide mathematics students with a thorough introduction to nonrelativistic quantum mechanics, with emphasis on the mathematical structure of the theory.

THEORY:

Motion in three dimensions, angular momentum, commutation relations between components of angular momentum, and their representation in spherical polar coordinates, simultaneous Eigen functions of L_z and L^2, Spherically symmetric potential and the hydrogen atom.
Scattering Theory: The scattering cross-section, scattering amplitude, scattering equation, Born approximation, partial wave analysis.
Perturbation Theory: Time independent perturbation of non-degenerate and degenerate cases. Time-dependent perturbations.
Identical Particle: Symmetric and anti-symmetric Eigen function, The Pauli exclusion principle.

RECOMMENDED BOOKS:

1. E. Merzdacker. Latest Edition. Quantum Mechanics. Edition 2^{nd}. John Wiley and Sons.
2. J. G. Taylor. Latest Edition. Quantum Mechanics. George Allen and Unwin.
3. R. Dicke, J .P. Witke. Latest Edition. Quantum Mechanics. Addison Wesley.
4. R. M. Eisberg. Latest Edition. Fundamental of Modern Mechanics.John Willey and Sons H.Muirhead. The Physics of Elementary Particles. Pergamon Press.
5. T. L. Powell, B.Crasemann . Latest Edition. Quantum Mechanics. Addison Wesley.

Course Title: **Theory of Optimization**
Course Code: **MTH-624**
Credit Hours: **3(3-0)**

AIMS AND OBJECTIVES:

The aim of this course is to obtain a rigorous mathematical background to optimization techniques used in other related fields.

THEORY:

Introduction to optimization. Relative and absolute extreme. Convex. Concave and unimodal functions. Constants. Mathematical programming problems. Optimization of one, two and several variables functions and necessary and sufficient conditions for their optima. Direct substitution method and Lagrange multiplier method, necessary and sufficient conditions for an equality-constrained optimum with bounded independent variables. Inequality constraints and Lagrange multipliers. Kuhn- Tucker Theorem. Multidimensional optimization by Gradient method. Convex and concave programming, Calculus of variation and Euler Language equations, Functions depending on several independent variables. Variational problems in parametric form. Generalized mathematical formulation of dynamics programming. Non-Linear continuous models, Dynamics programming and Variational calculus. Control theory.

RECOMMENDED BOOKS:

1. B. S. Gotfried, J.Weisman. Latest Edition. Introduction to Optimization Theory. Prentice-Inc.New Jersy.
2. D. A. Wismer, R Chattergy. Latest Edition. Introduction to Nonlinear Optimization. North - Holland, New York.
3. L. Elsgolts. Latest Edition . Differential Equations and the Calculus of Variations. New Edition. University Press of the Pacific.
4. M. D. Intriligator. Latest Edition.Mathematical Optimization and Economic Theory. Society Forindustrial and Applied Mathematics.

Course Title: **Measure Theory**
Course Code: **MTH-626**
Credit Hours: **3(3-0)**

AIMS AND OBJECTIVES:

To gain understanding of the abstract measure theory and definition and main properties of the integral. To construct Lebesgue's measure on the real line and in *n*-dimensional Euclidean space. To explain the basic advanced directions of the theory.

THEORY:

Review of definitions of set theory and properties of sets, Relations and functions, Relationship between equivalence relations on a set A and partitions of A, Different types of functions. Choice functions, Axiom of choice, Equivalent sets, Countable sets. Definition and its properties, Review of elementary concepts of Topology, G,sets. Borel sets, Cantor set, Continuous functions, Review of elementary real analysis, Ring, ó - ring of sets and their relationship, Algebra, ó - algebra of sets and relationship between them and ring, ó - ring. Existence of smallest ó – algebra containing a given collection of subsets of a set, General definitions of outer measure and measure of a set and their properties.Lebesgue outer measure. Definition and its properties Lebesgue measurable set, Its Caratheodar's definition and properties, Approximation of measurable sets by open / Gand closed /sets, Lebesgue measure, Definition and its properties, Lebesgue measure of Cantor set, Existence of Lebesgue non-measureable set, Measurable function, Definition, algebra of measurable functions and various other properties of measurable functions, Measurability of step. Characteristic, Dinchlet's and simple functions etc.

RECOMMENDED BOOKS:

1. R. G. Bartle. 1995.The Elements of Integration and Lebesgue Measure. International Edition. Wiley Interscience.
2. H. Bauer. 2001.Measure and Integration Theory. Berlin. de Gruyter.
3. H. S. Bear. 2001. A Primer of Lebesgue Integration. Edition 2^{nd}. San Diego. Academic Press.
4. V. I. Bogachev. 2007. Measure Theory. Volume 1. Berlin.Springer.

Course Title: **Combinatorics**
Course Code: **MTH-628**
Credit Hours: **3(3-0)**

AIMS AND OBJECTIVES:

The aim of this class is to introduce the basic combinatorial tools of computer science, to train students in mathematical thinking and reasoning that is pertinent to computer science, and to present that reasoning in rigorous written text.

THEORY:

Basic counting principles, Permutations, Combinations, The injective and bijective principles, Arrangements and selections with repetitions, Graphs in Combinatorics, The Binomial theorem, combinatorial identities. Properties of binomial coefficients, Multinomial coefficients, The multinomial theorem, The Pigeonhole principle, Examples, Ramsay numbers, The principle of inclusion and exclusion, Generalization, Integer solutions, Surjective mapping, Stirling numbers of the second kind, The Sieve of Eratostheries, Euler φ-function, The Probleme des Manages, Ordinary Generating Functions, Modeling problems. Partition of integers, Exponential generating functions, Linear homogeneous recurrence relations, Algebraic solutions of linear recurrence relations and constant functions, The method of generating functions, A non-linear recurrence relation and Catalpa numbers.

RECOMMENDED BOOKS:

1. A. Tucker. Applied Combinatorics. Latest Edition. John Wiley & Sons. New York,
2. C. C. Chen, K. M. Koh, 1992. Principles and Techniques in Combinatorics. World Scientific Pub. Co. Pte. Ltd. Singapore.
3. C. L. Liu. 1968. Introduction to Combinatorial Mathematics. McGraw-Hill. New York.
4. J. H.V. Ling, R. M. Wilson. 2001. A Course on Combinatorics, 2nd Edition, Cambridge University Press, Cambridge.
5. V. K. Balakrishnan. 1995. Theory and Problems of Combunatorics. Schaum’s Outline Series. McGraw-Hill International Edition. Singapore.

Course Title: **Fluid Mechanics-II**
Course Code: **MTH-634**
Credit Hours: **3(3-0)**

AIMS AND OBJECTIVES:

The aim of the course is to introduce some of the most current research subjects in the field of fluid dynamics.

THEORY:

Vortex motion, Line Vortex, Vortex row Image System, Kelvin's minimum energy theorem, Uniqueness theorem, Fluid streaming past a circular cylinder, Irrational motion produced by a vortex filament. The Helmholtz vorticity equation, Karman's vortex-street. Constitutive equations; Navier- Stoke's equations; Exact solution of Navier-Stoke's equations; Steady unidirectional flow; Poiseuille flow; Couette flow; Unsteady undirectional flow, Sudden motion of a plane boundary in a fluid at rest; Flow due to an oscillatory boundary; Equations of motion relative to a rotatingsystem; Ekman flow; Dynamical similarity of turbulent motion.

RECOMMENDED BOOKS:

1. H. Schlichting. 2000. Boundary Layer Theory. Edition 8th. Springer.
2. I. G. Currie. 2012. Fundamental Mechanics and Fluids. Edition 4th. CRC Press.
3. J. H. Aksel, N. Spurk. 2008. Fluid Mechanics. Edition 2nd.Springer.
4. R. K. Bansal. 2005. A Textbook of Fluid Mechanics. Edition 9th. Laxmi Publications LTD, New Delhi. H

Course Title: **Integral Equations**
Course Code: **MTH-636**
Credit Hours: **3(3-0)**

AIMS AND OBJECTIVES:

Many physical problems that are usually solved by differential equation methods can be solved more effectively by integral equation methods. This course will help students gain insight into the application of advanced mathematics and guide them through derivation of appropriate integral equations governing the behavior of several standard physical problems.

THEORY:

Linear Integral Equations of the 1^{st} kind, Linear Integral Equations of the 2^{nd} kind, Relationship between differential equation and Volterra Integral Equation. Neumann series. FredholmIntegral Equations of the 2^{nd} kind with separable Kernels. Eigenvalues and eigenvectors. Iterated functions. Quadrature methods. Least square methods. Homogenous Integral Equations of the 2^{nd} kind. Fredholm Integral Equations of the 1^{st} kind. Fredholm Integral Equations of the 1^{st} kind. FredholmIntegral Equations of the 2^{nd} kind. Abel's Integral Equations.Hilbert Schmidt theory of Integral Equations with symmetric Kernels, Regularization and filtering techniques.

RECOMMENDED BOOKS:

1. A.M.Wazwaz. A First Course in Integral Equations. World Scientific Pub.
2. C.T.H.Baker. Integral Equations. Clarendon Press.
3. F.Smithies. Integral Equations. Cambridge University Press.
4. W. V. Lovitt. 2005. Linear Integral Equations. Dover Publications.

Course Title: **Graph Theory**
Course Code: **MTH-638**
Credit Hours: **3(3-0)**

AIMS AND OBJECTIVES:

The aim of this course is to introduce basic graph theory and applications.

THEORY:

Graphs: Graphs Models, Some special classes of graphs, Connected graphs, Multigraphs, Digraphs Degrees: The Degree of a vertex, Degree Sequence, Graphs and MatricesRegular and Irregular graphs, Isomorphic Graphs: Graphs and Groups,Trees: Bridges, Trees, The minimum spanning tree, Connectivity: Cut-Vertices, Blocks, Menger Theorem, Eulerian Graphs, Hamiltonian graphs, Planar graphs, Digraphs: Strong digraphs, Tournaments

RECOMMENDED BOOKS:

1. B. Bollobas. 2002. Modern Graph theory. Springer Verlag , Newyork.
2. B. Bollobas, 1979, Graph theory. Springer Verlag , Newyork.
3. J. L. Gross, J. Yellen. 2005, Graph theory and Its Applications. Chapman and Hall.
4. R. J. Wilson, Introduction to Graph Theory. Latest Edition. Pearson Education Ltd.

Govt. College Women University Faisalabad
Department of Mathematics

Scheme of Studies M.Sc. Mathematics Four Years Degree Program 2019

SemesterI

Course Code	Title of the Course	Credit Hours	
Major Course			
MTH-551	Topology	3(3-0)	61
MTH-553	Differential Geometry	3(3-0)	62
MTH-555	Real Analysis I	3(3-0)	63
MTH-557	Algebra I	3(3-0)	64
MTH-559	Vector and Tensor Analysis	3(3-0)	65
MTH-561	Complex Analysis I	3(3-0)	66
Total		**18(18-0)**	

Semester II

Course Code	Title of the Course	Credit Hours	
Major Course			
MTH-552	Partial Differential Equations	3(3-0)	67
MTH-554	Classical Mechanics	3(3-0)	68
MTH-556	Complex Analysis II	3(3-0)	69
MTH-558	Real Analysis II	3(3-0)	70
MTH-560	Functional Analysis	3(3-0)	71
MTH-562	Algebra II	3(3-0)	72
Total		**18(18-0)**	

Semester III

Course Code	Title of the Course	Credit Hours	
Major Course			
MTH-651	Numerical Analysis I	3(3-0)	73
MTH-653	Number Theory	3(3-0)	74
MTH-655	Mathematical Statistics I	3(3-0)	75
MTH-679	Seminar	1(0-1)	
Minor Course			
ICT-323	Introduction to Programming	3(2-1)	
Elective Courses (2 courses out of following)			
MTH-657	Advanced Group Theory	3(3-0)	76

MTH-659	Methods of Mathematical Physics	3(3-0)	77
MTH-661	Quantum Mechanics I	3(3-0)	78
MTH-663	Fluid Mechanics I	3(3-0)	79
MTH-665	Advanced Topology	3(3-0)	80
MTH-667	Algebraic Topology	3(3-0)	81
MTH-669	Continuous Groups	3(3-0)	82
MTH-671	Rings and Modules	3(3-0)	83
MTH-673	Special Theory of Relativity	3(3-0)	84
MTH-625	Operations Research	3(3-0)	85
MTH-627	Software Packages	3(2-1)	86
Total		19(17-2)	

Semester IV

Course Code	**Title of the Course**	**Credit Hours**	
Major Course			
MTH-652	Mathematical Statistics II	3(3-0)	87
MTH-654	Advanced Set Theory	3(3-0)	88
MTH-656	Numerical Analysis II	3(3-0)	89
MTH-680	Special Problem	1(0-1)	
Elective Courses (3 Courses or 1 Course and (Project/ Thesis/ Internship)) from the following			
MTH-658	Theory of Modules	3(3-0)	90
MTH-660	Algebraic Number Theory	3(3-0)	91
MTH-662	Category Theory	3(3-0)	92
MTH-664	Galois Theory	3(3-0)	93
MTH-666	Probability Theory	3(3-0)	94
MTH-668	Theory of Elasticity	3(3-0)	95
MTH-670	Electromagnetism	3(3-0)	96
MTH-672	Quantum Mechanics II	3(3-0)	97
MTH-674	Theory of Optimization	3(3-0)	98
MTH-676	Measure Theory	3(3-0)	99
MTH-678	Combinatorics	3(3-0)	100
MTH-684	Fluid Mechanics II	3(3-0)	101
MTH-686	Integral Equations	3(3-0)	102
MTH-688	Graph Theory	3(3-0)	103
MTH-681	Project	6(0-6)	
MTH-682	Internship	6(0-6)	
MTH-683	Thesis	6(0-6)	
		19(18-1)	

Program	Award	Duration	Semester	Credit Hours
Master of Sciences	M.Sc. Mathematics	2Years	4 Semesters	74

SEMESTER I

Course Title: **Topology**
Course Code: **MTH-551**
Credit Hours: **3(3-0)**

AIMS AND OBJECTIVES:

The aim of this course is to introduce the students to metric spaces and topological spaces. After completion of this course, they would be familiar with separation axioms, compactness and completeness. They would be able to determine whether a function defined on a metric or topological space is continuous or not and what homeomorphisms are.

THEORY:

Review of metric spaces. Topological spaces: Examples; open and closed subsets, neighborhoods. Examples. Limit points and accumulation points. Interior, closure, dense subsets.Constructing new topological spaces: Cartesian products, induced topology and quotient topology.Continuous maps, open and closed maps, homeomorphisms.Examples: R, RxR, S^1, S^2, torus, cylinder. Cauchy sequences,complete metric spaces. Separation axioms. Compact spaces.Properties. Power of Compactness. Image of a compact set through a continuous map. Compactness and completeness of metric spaces.Connected spaces, connected components. Properties. Image of a connected set through a continuous map. Path-connectedness.

RECOMMENDED BOOKS:

6. G. F. Simmons. 2004. Introduction to Topology and Modern Analysis. Edition 9th. McGraw- Hill.
7. J. Kelly. 2005. General Topology. Edition Ist. Springer.
8. J. G. Hocking, G. S. Young. 2012.Topology. Edition 5th. Dover Publications.
9. J. R. Munkres. 2000.Topology-A First Course, Edition 2nd. Prentice-Hall
10. S. Lipschutz .2004. General Topology. Edition Ist. McGraw-Hill.

Course Title: **Differential Geometry**
Course Code: **MTH-553**
Credit Hours: **3(3-0)**

AIMS AND OBJECTIVES:

After having completed this course, the students would be expected to understand classical concepts in the local theory of curves and surfaces including normal, principal,mean, curvature, and geodesics. They will also learn about tensors of different ranks.

THEORY:

Theory of Space Curves: Introduction, index notation and summation convention. Space curves, arc length, tangent, normal and binormal.Osculating, normal and rectifying planes.Curvature and torsion.The Frenet-Serret theorem.Natural equation of a curve. Involutes and evolutes, helices. Fundamental existence theorem of space curves.
Theory of Surfaces: Coordinate transformation. Tangent plane and surface normal.The first fundamental form and the metric tensor.The second fundamental form. Principal, Gaussian, mean, geodesic and normal curvatures. Gauss and Weingarten equations.Gauss and Codazzi equations.
Tensor Analysis: Einstein summation convention. Tensors of different ranks.Contravariant, covariant and mixed tensors. Addition,
subtraction, inner and outer products of tensors. Contraction theorem,
quotient law. The line element and metric tensor.Christoffel symbols.

RECOMMENDED BOOKS:

5. A. N. Pressley. 2010. Elementry Differential Geometry. Edition 2nd, Springer.
6. A. W. Joshi. Matrices and Tensors in Physics. Edition Latest.Wiley Eastern Limited.
2. 3 . D. Somasundaram. 2005. Differential Geometry, Narosa Publishing House, New Delhi
7. E. Kreyszig. 2002.Differential Geometry, Edition Ist. Dover.
8. M. M. Lipschutz.Schaum’s Outline of Differential Geometry. Latest Edition. McGraw Hill.

Course Title: **Real Analysis I**
Course Code: **MTH-555**
Credit Hours: **3(3-0)**

AIMS AND OBJECTIVES:

This is the first course in analysis. It develops the fundamental ideas of analysis and is aimed at developing the students' ability in reading and writing mathematical proofs.Another objective is to provide sound understanding of the axiomatic
foundations of the real number system, in particular the notions of completeness and compactness.

THEORY:

Algebraic and ordered properties of Real Numbers, Absolute values,Inequalities (Cauchy's, Minkoski's, Bernoulli's) Properties and concepts of supremum and infimum, Ordered sets, Fields, Field of Real, The extended real number system, Euclidean spaces, Sequences, Subsequences, Cauchy sequence,Series of Numbers and their convergence. The Comparison, Root, Ratio and Integral tests.Absolute and Conditional convergence of infinite series.Limits and Continuity.Properties of continuous functions.Types of discontinuities. Differentiable functions.Mean-value theorems, Continuity of derivatives. Partial Derivatives and Differentiability. Derivative and differentials of Composite functions. The Directional Derivative, the Laplacian in polar cylindrical and Spherical coordinates.

RECOMMENDED BOOKS:

5. R .G. Bartle, D. R. Sherbert. 2000. Introduction to Real Analysis. Edition 5th. John Wiley New York.
6. T. M. Apostol. Mathematical Analysis. Latest Edition. Addison-Wesley Publishing Company.
7. W. Kaplan. 2002. Advance Calculus. Edition 5th. Published by Pearson Education.
8. W.Rudin. 2013. Principles of Mathematics Analysis. Edition 3rd. McGraw-Hill. New York.

Course Title **AlgebraI**
Course Code **MTH-557**
Credit Hours **3(3-0)**

AIMS AND OBJECTIVES:

This course introduces basic concepts of groups and their homomorphisms. The main objective of this course is to prepare students for courses which require a good back ground in group theory like Rings and Modules, Linear Algebra, Group Representation, Galois Theory etc.

THEORY:

Review of Groups. Complexes and coset decomposition of groups, normalize centralizer. The center of a group. Equivalence relation in a group, Conjugacy classes, double cosets. normal subgroups, quotient group.
Group homomorphisms: Homomorphisms, isomorphism and automorphism. Kernel and image of homomorphism. Isomorphism theorems. commutator subgroups of a group. permutation groups. The cyclic decomposition of permutation group. Cayley’s theorem. Sylow Theorems: Cauchy’s theorem for Abelian and non-Abelian group, Sylow theorems.

RECOMMENDED BOOKS:

6. D. S. Dummit, R. M. Foote. 2004. Abstract Algebra, Edition 3rd. Addison-Wesley Publishing Company.

7. J. S. Rose. 2012. A Course on Group Theory. Revised edition. Dover Publications.

8. J. B. Fraleigh. 2002. A First Course in Abstract Algebra, Edition 7th. Addison-Wesley

9. Publishing company.

10. P. M. Cohn . 2000. Algebra. Edition 2nd. John Wiley and Sons. London.

Course Title **Vector and Tensor Analysis**
Course Code **MTH-559**
Credit Hours **3(3-0)**

AIMS AND OBJECTIVES:

The aim of this course is to introduce the vectors and tensor analysis which is useful for advance courses.

THEORY:

3-D vectors, summation convention, kronecker delta, Levi-Civita symbol, vectors as quantities transforming under rotations with $\in_{ijk}$ notation, scalar- and vector- triple products, scalar- and vector-point functions, differentiation and integration of vectors, line integrals, path independence, surface integrals, volume integrals, gradient, divergence and curl with physical significance and applications, vector identities, Green's theorem in a plane, divergence theorem, Stokes's theorem, coordinate systems and their bases, the spherical-polar- and the cylindrical-coordinate meshes, tensors of first, second and higher orders, algebra of tensors, contraction of tensor, quotient theorem, symmetric and skew-symmetric tensors, invariance property, application of tensors in modeling anisotropic systems, study of physical tensors (moment of inertia, index of refraction, etc.), diagonalization of inertia tensor as aligning coordinate frame with natural symmetries of the system

RECOMMENDED BOOKS:

5. D. E. Bourne, P. C. Kendall, Vector Analysis and Cartesian Tensors. Edition Latest. Thomas Nelson.
6. G. D. Smith. 2000. Vector Analysis. Edition Latest. Oxford University Press.
7. N. A. Shah, 2005. Vector and Tensor Analysis. Edition Latest. A-One Publishers. Lahore
8. K. A. Stroud, 2003. Advanced Engineering Mathematics. Fourth Edition. Palgrave Macmillan

Course Title **Complex Analysis I**
Course Code **MTH-561**
Credit Hours **3(3-0)**

AIMS AND OBJECTIVES:

This is an introductory course in complex analysis, giving the basics of the theory along with applications, with an emphasis on applications of complex analysis and especially conformal mappings. Students should have a background in real analysis (as in the course Real Analysis- I), including the ability to write a simple proof in an analysis context.

THEORY:

The Concept of Analytic Functions: Complex numbers, complex planes, complex functions, Analytic functions, entire functions, Harmonic functions, Elementary functions: complex exponential, logarithmic and hyperbolic functions. Infinite Series: Power series, derived series, radius of convergence, Taylor series and Laurent series. Conformal Representation: Transformation, conformal transformation, linear transformation, Möbius transformations. Complex Integration: Complex integrals, Cauchy-Goursat theorem, Cauchy's integral formula and their consequences, Liouville's theorem, Morera's theorem, Derivative of an analytic function.

RECOMMENDED BOOKS:

6. D. G. Zill and P. D. Shanahan. 2003. Complex Analysis. Jones and Bartlett Publishers.
7. H. S. Kasana 2005. Complex Variables: Theory and Applications. Prentice Hall.
8. J. W. Brown and R. V. Churchill. 2004. Complex Variables and Applications, 7th edition. McGraw Hill Company.
9. M. R. Spiegel 1974. Complex Variables. McGraw Hill Book Company.
10. Louis L. Pennisi. 1976. Elements of Complex Variables. Holt, Linehart and Winston.

SEMESTER II

Course Title: **Partial Differential Equations**
Course Code: **MTH-552**
Credit Hours: **3(3-0)**

AIMS AND OBJECTIVES:

Partial Differential Equations (PDEs) are at the heart of applied mathematics and many other scientific disciplines. The course aims at developing understanding about fundamental concepts of PDEs theory, identification and classification of their different types, how they arise in applications, and analytical methods for solving them. Special emphasis would be on wave, heat and Laplace equations.

THEORY:
Pre-Requisite: Ordinary Differential Equations Introduction, Review of ordinary differential equation in more than one variables, Linear partial differential equations (PDEs) of the first order, Cauchy's problem for quasilinear first order PDEs. PDEs of Second Order: PDEs of second order in two independent variables with variable coefficients, Linear transformation from one equation to another equation, Normal form, Cauchy's problem for second order PDEs in two independent variables. Adjoint Equation: Adjoint operator, Self adjoint equation and operator Linear PDEs in n independent variables, Lagrange's identity, Green's theorem for self adjoint operator. Boundary Value Problems: Laplace equation, Dirichlet problem for a circle, Poisson's integral for a circle, Solution of Laplace equation in Cartesian, cylindrical and spherical coordinates, The wave equation in one dimension, The wave equation in higher dimensions, The heat equation, Axially symmetric solutions

RECOMMENDED BOOKS:

7. I. N. Sneddon, Elements of Partial Differential Equations (Dover Publishing, Inc., 2006)
8. R. Dennemyer, Introduction to Partial Differential Equations and Boundary Value Problems (McGraw Hill Book Company, 1968)
9. M. Humi and W. B. Miller, Boundary Value Problem and Partial Differential Equations(PWS-Kent Publishing Company, Boston, 1991)
10. C. R. Chester, Techniques in Partial Differential Equations (McGraw Hill Book Company, 1971)
11. R. Haberman, Elementary Applied Partial Differential Equations, 2nd edition (Prentice Hall Inc., New Jersey, 1987)
12. E. Zauderer, Partial Differential Equations of Applied Mathematics (Wiley-Interscience, Englewood Cliff, New York, 2006

Course Title: **Classical Mechanics**
Course Code: **MTH-554**
Credit Hours: **3(3-0)**

AIMS AND OBJECTIVES:

To provide solid understanding of classical mechanics and enable the students to use this understanding while studying courses on quantum mechanics, statistical mechanics, electromagnetism, fluid dynamics, space-flight dynamics, astrodynamics and continuum mechanics.

THEORY:

Kinematics. Kinetics: Work, power, kinetic energy, conservative force fields. Conservation of energy, impulse, torque, Conservation of linear and angular momentum. Non-conservative forces. Simple Harmonic Motion: The simple harmonic oscillator, period, frequency. Resonance and energy. The damped harmonic oscillator, over damped, critically damped and under damped Motion, forces and vibrations.

Central Forces and Planetary Motion: Central force fields, equations of motion, potential energy, orbits Kepler's law of planetary motion. Apsides and apsidal angles for nearly circular orbits. Motion in an inverse square field.

Planer Motion of Rigid Bodies: Introduction to rigid and elastic bodies, degree of freedom, translations, rotations, instantaneous axis and center of rotation, motion of center of mass. Euler's theorem and Chasles' theorem. Rotation of a rigid body about a fixed axis, moments and products of inertia. Parallel and perpendicular axis theorem.

Motion of Rigid Bodies in Three Dimensions: General motion of rigid bodies in space. The momental ellipsoid and equimomental systems. Angular momentum vector and rotational kinetic energy.Principal axes and principal moments of inertia. Determination of principal axes by diagonalizing the inertia matrix.Euler Equations of Motion of a Rigid Body: Force free motion. Free rotation of a rigid body with an axis of symmetry. Free rotation of a rigid body with three different principal moments.The Eulerian angles, angular velocity and kinetic energy in terms of Euler angles. Motion of a spinning top and gyroscopes-steady precession, sleeping top.

RECOMMENDED BOOKS:

6. C. F. Chorlton. 2004, Text Book of Dynamics. Edition 2nd. CBS Publishers.
7. E. DiBenedetto. 2011. Classical Mechanics: Theory and Mathematical Modeling. Edition Latest. Birkhauser Boston.
8. G. R. Fowles, G. L. Cassiday. 2005. Analytical Mechanics. Edition 5th.Thomson Brooks/Cole, USA.
9. John R. Taylor. 2005. Classical Mechanics. Edition Latest. University of Colorado.
10. M. R. Spiegel. 2004. Theoretical Mechanics. Edition 3rd. Addison-Wesley Publishing Company.

Course Title: **Complex Analysis II**
Course Code: **MTH-556**
Credit Hours: **3(3-0)**

AIMS AND OBJECTIVES:

The course unit aims to introduce the ideas of complex analysis with particular emphasis on Cauchy's theorem and the calculus of residues. Students should have a background in complex analysis (as in the course Complex Analysis- I), including the ability to write a simple proof in an analysis context.

THEORY:

Singularity and Poles: Review of Laurent series, zeros, singularities,Poles and residues. Contour Integration: Cauchy's residue theorem, applications of Cauchy's residue theorem. Expansion of Functions and Analytic Continuation: Mittag-Leffler theorem, Weierstrass's factorization theorem, analytic continuation. Elliptic Functions: Periodic functions, Elliptic functions and its properties, Weierstrass function $\varphi(z)$, differential equation satisfied by $\varphi(z)$, integral formula for $\varphi(z)$, addition theorem for $\varphi(z)$, duplication formula for $\varphi(z)$, Elliptic functions in terms of Weierstrass function with the same periods, Quasi periodic functions: The zeta and sigma functions of Weierstrass, Jacobian elliptic functions and its properties.

RECOMMENDED BOOKS:

7. H. S. Kasana. 2005. Complex Variables: Theory and Applications. Prentice Hall.
8. M. R. Spiegel. 1974. Complex Variables. McGraw Hill Book Company.
9. Louis L. Pennisi. 1976. Elements of Complex Variables. Holt, Linehart and Winston.
10. W. Kaplan 1966. Introduction to Analytic Functions. Addison-Wesley.
11. E. D. Rainville. 1965. Special Functions. The Macmillan Company, New York.
12. E. T. Whittaker and G. N. Watson. 1958. A Course of Modern Analysis. Cambridge University Press.

Course Title: **Real Analysis II**
Course Code: **MTH-558**
Credit Hours: **3(3-0)**

AIMS AND OBJECTIVES:

A continuation of Real Analysis I, this course will continue to cover the fundamentals of real analysis,concentrating on the Riemann-Stieltjes integrals, Functions of Bounded Variation, Improper Integrals, and convergence of series.

THEORY:

The Riemann - Stieltjes (R-S) Integrals.Properties of R-S integrals. Functions of bounded variations. Point wise and uniform convergence of sequences and series of functions, Weierstrass M-Test, Uniform convergence and continuity. Uniform Convergence and differentiation, Uniform Convergence and integration. Convergence of improper integrals.Beta and Gamma functions and their properties. Implicit functions, Jacobians, Functional dependence. Taylor's theorem for a function of two variables.Maxmima and minima of functions of two and three variables.Method of Lagrange Mulitipliers.

RECOMMENDED BOOK:

5. R .G. Bartle, D.R.Sherbert. 2000. Introduction to Real Analysis.Edition 5th, John Wiley New York.
6. T. M. Apostol. Mathematical Analysis. Latest Edition. Addison-Wesley Publishing Company.
7. W. Kaplan. 2002. Advance Calculus .Edition 5th. Pearson Education.
8. W. Rudin. 2013. Principles of Mathematics Analysis. Edition 3rd, McGraw-Hill New York.

Course Title: **Functional Analysis**
Course Code: **MTH-560**
Credit Hours: **3(3-0)**

AIMS AND OBJECTIVES:

This course extends methods oflinear algebra and analysis to spaces of functions, in which theinteraction between algebra and analysis allows powerful methods tobe developed. The course will be mathematically sophisticated and willuse ideasboth from linear algebra and analysis.

THEORY:

Metric Space: Review of metric spaces, Convergence in metric spaces, Complete metric spaces, Dense sets and separable spaces, No-where dense sets, Baire category theorem. Normed Spaces: Normed linear spaces, Banach spaces, Equivalent norms, Linear operator, Finite dimensional normed spaces, Continuous and bounded linear operators, Dual spaces. Inner Product Spaces: Definition and examples, Orthonormal sets and bases, Annihilators, projections, Linear functionals on Hilbert spaces. Reflexivity of Hilbert spaces.

RECOMMENDED BOOKS:

1. A. V. Balakrishnan. 2000. Applied Functional Analysis. Edition 2nd. Springer-Verlag, Berlin.

2. E. Kreyszig. 2004. Introduction to Functional Analysis with Applications. Latest Edition. John Wiley and Sons.

3. J. B. Conway. 2000. A Course in Functional Analysis. Edition 2nd. Springer-Verlag, Berlin.

4. K. Yosida. Functional Analysis. Edition 5th. Springer-Verlag. Berlin.

Course Title: **Algebra II**
Course Code: **MTH-562**
Credit Hours: **3(3-0)**

AIMS AND OBJECTIVES:

This is a course in advanced abstract algebra, which builds on the concepts learnt in Algebra I. The objectives of the course are to introduce students to the basic ideas and methods of modern algebra and enable them to understand the idea of a ring and an integral domain, and be aware of examples of these structures in mathematics; appreciate and be able to prove the basic results of ring theory; appreciate the significance of unique factorization in rings and integral domains.

THEORY:

Rings: Definition, examples. Quadratic integer rings. Examples of non-commutative rings.The Hamilton quaternions. Polynomial rings. Matrix rings. Units, zero-divisors.Nilpotent, idempotent.Subrings, ideals.Maximal and prime ideals Left, right and two-sided ideals; Operations with ideals. The ideal generated by sets. Quotient rings. Ring homomorphism. The isomorphism theorems, applications. Finitely generated ideals. Rings of fractions.Integral Domain: The Chinese remainder theorem. Divisibility in integral domains, Greatest common divisor, least common multiple. Euclidean domains. The Euclidean algorithm.Principal ideal domains.Prime and irreducible elements in an integral domain.Gauss lemma, irreducibility criteria for polynomials.Unique factorization domains. Finite fields. Polynomials in several variables. Symmetric polynomials. The fundamental theorem of symmetric polynomials.

RECOMMENDED BOOKS:

7. D.S. Dummit, R.M. Foote 2004. Abstract Algebra. Edition 3rd. Addison-Wesley Publishing Company.
8. J. B. Fraleigh. 2002. A First Course in Abstract Algebra. Edition Latest. Addison Wesley Publishing Company.
9. P. M. Cohn. 2000. Algebra, Edition 2nd. John Wiley and Sons. London.
10. P. B. Bhattacharya, S. K. Jain, S.R.Nagpaul.1994. Basic Abstract Algebra, Edition 2nd. Cambridge University Press.

SEMESTER III

Course Title: **Numerical Analysis I**
Course Code: **MTH-651**
Credit Hours: **3(3-0)**

AIMS AND OBJECTIVES:

This course is designed to teach the students about numerical methods and their theoretical bases. The course aims at inculcating in the students the skill to apply various techniques in numerical analysis, understand and do calculations about errors that can occur in numerical methods and understand and be able to use the basics of matrix analysis.

THEORY:

Number Systems and Errors, Interpolation by Polynomials: Existence and uniqueness of the interpolating polynomial. Lagrangian interpolation, the divided difference table. Error of the interpolating polynomial; interpolation with equally spaced data, Newton's forward and backward difference formulas, Bessel's interpolation formula. Solution of non-linear Equations: Bisection method, iterative methods, secant and regula falsi methods; fixed point iteration, convergence criterion for a fixed point iteration, Newton-Raphson method,order of convergence of Newton-Raphson and secant methods. System of Linear Equations: Gauss elimination methods, triangular factorization, Crout method. Iterative methods: Jacobi method, Gauss-Seidel method, SOR method, convergence of iterative methods. Numerical Differentiation: Numerical differentiation formulae based on interpolation polynomials, error estimates. Numerical Integration: Newton-Cotes formulae; trapezoidal rule, Simpson's formulas, composite rules, Romberg improvement, Richardson extrapolation. Error estimation of integration formulas, Gaussian quadrature.

RECOMMENDED BOOKS:

5. A. Komech, A. Komech. 2009. Principles of Partial Differential Equations, Springer-New York.
6. C. F. Gerlad, P.O. Wheatley. 2005. Applied Numerical Analysis. Pearson Education. Singapore.
7. J. H. Mathews, Numerical Methods for Mathematics, Latest Edition. Prentice Hall International,
8. L. Debnath. 2005. Nonlinear Partial Differential Equations for Scientists and Engineers, Birkhauser-Boston.
11. R. L. Burden, J. D. Faires: Numerical Analysis, Latest Edition. PWS Pub. Co.
12. W. E. Boyce, R. C. DiPrima. 2001. Elementary Differential Equations and Boundary Value Problems, John Wiley & sons, Inc.

Course Title: **Number Theory**
Course Code: **MTH-653**
Credit Hours: **3(3-0)**

AIMS AND OBJECTIVES:

The focus of the course is on study of the fundamental properties of integers and develops ability to prove basic theorems. The specific objectives include study of division algorithm, prime numbers and their distributions, Diophantine equations, and the theory of congruences.

THEORY:

Preliminaries: Well-ordering principle of finite induction. Divisibility theory: The division algorithms. Basis representation theorem. Prime and composite numbers. Canonial decomposition. The greatest common divisor.The Euclidean algorithm. The Fundamental theorem of arithmetic. Latest common multiple. Linear Diophantine equations: congruences. Linear congruences. System of linear congruences. The Chinese remainder theorem. Divisibility tests. Solving polynomial congruences. Fermat's and Euler's theorems. Wilson's theorem. Arithmetic Functions: Euler's phi-function. The function of J and Sigma.The Mobius function.The sieve of Eratosthenes. Perfect numbers. Fermat and Mersenne primes. Primitive Roots and indices: The order of intger mod n. Primitive roots for primes. Composite numbers having primitive roots. Quadratic residues: Legendre symbols and its properties. The quadratic reciprocity law.

RECOMMENDED BOOKS:

6. A. Adler, J. E. Coury. 2002. The Theory of Numbers. Jones and Bartlett Publishers.
7. D. M. Burton. 2007. Elementary Number Theory. McGraw-Hill.
8. I. Niven, H. S. Zuckerman, H. L. Montgomery. 2014. An Introduction to The Theory of Numbers. John Wiley and Sons.
9. K. H. Rosen. 2005. Elementary Number Theory and Its Applications. Edition 5th. Pearson/Addison Wesley.
10. W. J. Leveque. 2015. Topics in Number Theory. Edition 7th. Addison-Wesley. Vols.I and II.

Course Title: **Mathematical Statistics I**
Course Code: **MTH-655**
Credit Hours: **3(3-0)**

AIMS AND OBJECTIVES:

The principal aim of this course is to provide students with a solid grounding in probability theory and mathematical statistics.

THEORY:

Probability Distributions: The postulates of probability, Some elementary theorems, Addition and multiplication rules, Baye's rule and future Baye's theorem. Random variables and probability functions, Discrete Probability Distributions: Uniform, Bernoulli and Binomial distribution, Hypergeometric and geometric distribution, Negative binomial and Poisson distribution. Continuous Probability Distributions: Uniform and exponential distribution, Gamma and beta distributions, Normal distribution Mathematical Expectations: Moments and moment generating functions, Moments of binomial, hypergeometric, Poisson, gamma, beta and normal distributions.

RECOMMENDED BOOKS:

6. J. E. Freund, Mathematical Statistics, (Prentice Hall Inc., 1992)
7. Hogg and Craig, Introduction to Mathematical Statistics, (Collier Macmillan, 1958)
8. Mood, Greyill and Boes, Introduction to the Theory of Statistics, (McGraw Hill)
9. R. E. Walpole, Introduction to Statistics, 3rd edition, (Macmillan Publishing Company London, 1982)
10. M. R. Spiegel and L. J. Stephens, Statistics, (McGraw Hill Book Company, 1984)

Course Title: **Advanced Group Theory**
Course Code: **MTH-657**
Credit Hours: **3(3-0)**

AIMS AND OBJECTIVES:

The aim of this course is to study advance topics of group theory.

THEORY:

Direct products and normal products of groups, Holomorphic of a group, Finitely generated abelian groups, Group action on a set, orbits and transitive actions, Stabilizers , The orbit stabilizer theorem, Characteristic and fully invariant subgroups, symmetric and alternating groups, generators of symmetric and alternating groups, Simple groups, simplicity of An, n≥5, series in groups. Zassenhau's Lemma, normal series and their refinements, composition series, principal or chief series.

RECOMMENDED BOOKS:

5. N. Carter. 2009.Visual Group Theory. American Association of America Inc.
6. P.M. Cohn. 2000. Classic Algebra. London. John Wiley & Sons Inc.
7. D.S. Dummit, R.M. Foote.2004. Abstract Algebra.Edition 3rd.John Wiley & Sons, .
8. J. Gallian. 2013. Contemporary Abstract Algebra. Edition 8th.Brooks/Cole Cengage Learning.

Course Title: **Methods of Mathematical Physics**
Course Code: **MTH-659**
Credit Hours: **3(3-0)**

AIMS AND OBJECTIVES:

The main objective of this course is to provide the students with a range of mathematical methods that are essential to the solution of advanced problems encountered in the fields of applied physics and engineering. In addition this course is intended to prepare the students with mathematical tools and techniques that are required in advanced courses offered in the applied physics and engineering programs.

THEORY:

Fourier Methods: The Fourier transforms. Fourier analysis of the generalized functions. The Laplace transforms. Hankel transforms for the solution of PDEs and their application to boundary value problems.
Green's Functions and Transform Methods: Expansion for Green's functions. Transform methods. Closed form Green's functions.
Perturbation Techniques: Perturbation methods for algebraic equations. Perturbation methods for differential equations.
Variational Methods: Euler- Langrange equations. Integrand involving one, two, three and n variables. Special cases of Euler- Langrange's equations. Necessary conditions for existence of an extremum of a functional. Constrained maxima and minima.

RECOMMENDED BOOKS:

5. A. D. Snider. 2007. Partial Differential Equations. Sources and Solutions. Prentice Hall Inc.
6. D. L. Powers. 2005. Boundary Value Problems and Partial Differential Equations. Edition 5^{th}. Academic Press.
7. J. W. Brown, R. V. Churchil. 2006. Fourier Series and Boundary Value Problems. McGraw-Hill.
8. W. E.Boyce. 2005. Elementary Differential Equations. Edition 8th. John Wiley and Sons.

Course Title: **Quantum Mechanics I**
Course Code: **MTH-661**
Credit Hours: **3(3-0)**

AIMS AND OBJECTIVES:

The aim of the course is to provide mathematics students with a thorough introduction to nonrelativistic quantum mechanics, with emphasis on the mathematical structure of the theory.

THEORY:

Inadequacy of Classical Mechanics: Black body radiation, Photoelectric effect, Compton effect, Bohr's theory of atomic structure, Wave-particle duality, the de- Broglie postulate.
The Uncertainty Principle: Uncertainty of position and momentum, statement and proof of the uncertainty principle, Energy time uncertainty. Eigenvalues and eigen functions, Operators and eigen functions, Linear Operators, Operator formalism in Quantum Mechanics, Orthonormal systems, Hermitian operators and their properties, Simultaneous eigen functions. Parity operators. Postulates of quantum mechanics, the Schrödinger wave equation. Motion in one Dimension: Step potential, potential barrier, Potential well, and Harmonic oscillator.

RECOMMENDED BOOKS:

6. E. Merzdacker. 2005. Quantum Mechanics. Edition 5^{th}. John Wiley and Sons Inc. New York.
7. H. Muirhead. 2002. The Physics of Elementary Particles. Pergamon Press.
8. J.G. Taylor. 2010. Quantum Mechanics George Allen and Unwin. .
9. R. M. Eisberg. 2005. Fundamental of Modern Mechanics. John Wiley and Sons Inc.
10. T. L.Powell, B. Crasemann. 2002. Quantum Mechanics. Addison-Wesley.

Course Title: **Fluid Mechanics I**
Course Code: **MTH-663**
Credit Hours: **3(3-0)**

AIMS AND OBJECTIVES:

The aim of the course is to introduce some of the most current research subjects in the field of fluid dynamics.

THEORY:

Real fluids and ideal fluids, Velocity of a fluid at a point, Streamlines and path lines, Steady ad unsteady flows, Velocity potential, Vorticity vector, Local and particle rates of change, Equation of continuity. Acceleration of a fluid, Conditions at a rigid boundary, General Analysis of fluid motion Euler's equations of motion, Bernoulli's equations steady motion under conservative body forces, Some potential theorems, impulsive motion. Sources, Sinks and doublets, Images in rigid infinite plane and solid spheres, Axi-symmetric flows, Stokes's stream function.
Stream function, Complex potential for two-dimensional, Irrational, Incompressible flow, Complex velocity spotential for uniform stream. Line sources and line sinks, Line doublets image systems, Miline-Thomson circle theorem, Blasius's Theorem.

RECOMMENDED BOOKS:

5. G. Currie. 2012. Fundamental Mechanics and Fluids. CRC Press.
6. H. Schlichting . 2000. Boundary Layer Theory. Springer.
7. J. H. Spurk, N. Aksel. 2008. Fluid Mechanics. Edition 2nd.Springer.
8. R. K. Bansal. 2005. A Textbook of Fluid Mechanics. Laxmi Publications (P) LTD, New Delhi.

Course Title: **Advanced Topology**
Course Code: **MTH-665**
Credit Hours: **3(3-0)**

AIMS AND OBJECTIVES:

The aim of this course is to introduce advance topics in topology.

THEORY:

Compactness in metric spaces, Limit point, Compactness, Sequential compactness and their various characterizations, Equivalence of different notions of compactness. Connectedness, various characterizations of connectedness, Connectedness and T()spaces, Local connectedness, Path-connectedness, Components. Homotopic maps, Homotopic paths, Loop spaces, Fundamental groups, Covering spaces, the lifting theorem, Fundamental groups of the circle () etc.Chain complex, Notion of homology.

RECOMMENDED BOOKS:

5. J. Hocking. G.Young. 2001. Topology. Dover Publications.
6. J. Kelly. 2005. General Topology. Springer .
7. J. R. Munkres. 2003.Topology - A First Course. Prentice-Hall.
8. S. Lipschutz. 2004. General Topology. McGraw-Hill.

Course Title: **Algebraic Topology**
Course Code: **MTH-667**
Credit Hours: **3(3-0)**

AIMS AND OBJECTIVES:

The aim of the unit is to give an introduction to algebraic topology with an emphasis on cell complexes, fundamental groups and homology.

THEORY:

Homotopy theory, Homotopy theory of path and maps, Fundamental group of circle, Covering spaces, Lifting criterion, Loop spaces and higher homotopy group. Affin spaces, Singular theory, Chain complexes, Homotopy invariance of homology, Relation between n, and H,relative homology The exact homology sequence.
Relative homology, The exact homology sequences, Excion theorem and application to spheres, Mayer Victoris sequences, Jordan-Brouwer separation theorem, Spherical complexes, Betti number and Euler characteristic, Cell Complexes and adjunction spaces.

RECOMMENDED BOOKS:

6. A. H. Wallace. 2004. Algebraic Topology. Homology and Cohomology. W.A. Benjamin Inc. New York.
7. A. Hatcher. 2002.Algebraic Topology. Cambridge University Press.
8. C. A. Kosniowski. 2003. First Course in Algebraic Topology. C.U.P.
9. F. H. Croom. 2005. Basic Concept of Algebraic Theory. Spinger-Verlag, New York,
10. M.J.Greenberg, J. R.Harper. 2007. Algebraic Topology. A First Course. The Bonjan Cunning Pub. Co.

Course Title: **Continuous Group**
Course Code: **MTH-669**
Credit Hours: **3(3-0)**

AIMS AND OBJECTIVES:

The aim of this course is to give introduction on continuous groups which is useful to learn theoretical physics related subjects.

THEORY:

Continuous Groups; Gl(n,r), Gl(n,c), So(p,q), Sp(2n); generalities on Continuous Groups; Groups of isometrics; Introduction to Lie groups with special emphasis on matrix Lie groups; Relationship of isometrics and Lie group; Theorem of Cartan; Correspondence of continuous groups with Lie algebras; Classification of groups of low dimensions; Homogeneous spaces and orbit types; Curvature of invariant metrics on Lie groups and homogeneous spaces.

RECOMMENDED BOOKS:

5. G. E. Bredon. 2006. Introduction to Compact Transformation Groups. Academic Press.
6. H. Taqdir. 2007. Introduction to Topological Groups. W.B.Saunder's-Company.
7. Jr. M.Willard. 2008. Symmetry Groups and Their Application. Academic Press-New York and London. Latest Edition.
8. L. P. Eisenhart. 2003. Continuous Groups of Transformations. Priceton U. P.

Course Title: **Rings and Modules**
Course Code: **MTH-671**
Credit Hours: **3(3-0)**

AIMS AND OBJECTIVES:

The aim of this course is to realize the importance of rings and modules as central objects in algebra and to study some applications.

THEORY:

Basic concepts of Ring Theory, Some Special Classis of Rings, Product, Matrix and Polynomial Rings, Subrings, Ring Homomorphism, Ideal and Quotient Rings, The Field of Quotients of an Integral Domain, Euclidean Rings, Polynomial Rings, Basic concepts of Module Theory, Submodules, Quotient Modules, Direct Sums, Homomorphism, Finitely generated Modules, Torsion Modules, Free Modules.

RECOMMENDED BOOKS:

5. M. F. Atiyah and I. G. Macdonald, 1969, Introduction to Commutative Algebra. Addison-Wesley Publishing Company, Inc.
6. O. Zariski and P. Samuel.1975-6, Commutative Algebra, Vols I and II. Springer
7. D. S. Dummit, R. M. Foote. 2004. Abstract Algebra; 3rd Edition. John Wiley & Sons.
8. R. Gilmer. 1972. Multiplicative Ideal Theory. Marcel Dekker, New York.

Course Title: **Special Theory of Relativity**
Course Code: **MTH-673**
Credit Hours: **3(3-0)**

AIMS AND OBJECTIVES:

The aim of this course is to introduce the concept of special relativity and its application to Physical Sciences.

THEORY:

Historical background and fundamental concepts of Special Theory of Relativity. Lorentz transformations (for motion along axis). Length contraction. Time dilation and simultaneity. Velocity addition formulae. 3-dimensional Lorentz transformations. Introduction to 4-vector formalism. Lorentz transformations in the 4 vector formalism. The Lorentz and Poincare groups. Introduction to classical Mechanics. Minkowski space time and null cone. 4-velocity, 4 acceleration 4- momentum and 4-force. Application of Special Relativity to Doppler shift and Compton Effect. Particle scattering. Binding energy, Particle production and decay. Electromagnetism in Relativity. Electric current. Maxwell's equations and electromagnetic waves. The 4-vector formulation of Maxwell's equations. Special Relativity with small acceleration.

RECOMMENDED BOOKS:

5. A. Qadir, 1989. Relativity: An Introduction to the Special Theory. World Scientific Press.
6. J. D. Jackson. 1977. Classical Relativity. Springer-Verlag.
7. J. G. Taylor. 1965. Special Relativity. Oxford University Press.
8. R. D' Inverno. 1992. Introduction Einstein's Relativity. Oxford University Press.

Course Title: **Operations Research**
Course Code: **MTH-675**
Credit Hours: **3(3-0)**

AIMS AND OBJECTIVES:

This course deals with the optimization techniques that allocate the available resources in an optimal manner.

THEORY:

Linear Programming: Mathematical modeling. Formulation and graphical solution. Analytical solution. Simplex method. Two- phase and M-technique for Linear programs.
Duality. Duality simplex method. Sensitivity Analysis.
Transportation Problems: Definition. Various methods including North –West Corner method. Least –cost method and Vogel's approximation. The Assignment model. Application to Networks. Shortest- Route Algorithm for acyclic and cyclic networks. Maximal- flow problems.
Integer Programming: Definition and formulation- Cutting-Plane Algorithm and Branch-and Bound method,Application. The mixed Algorithm, Zero-one polynomial programming.

RECOMMENDED BOOKS:

6. C. M. Harvey, 1979, Operation Research, North Holland, New Delhi.
7. F. S Hiller, G. J. Liebraman, 1974. Operational Research. CBS Publisher and Distributors. New Delhi.
8. H. A. Taha. 1987. An Introduction to Operations Research. Macmillan Publishing Company Inc. New York.
9. S. Kalavathy, Operations Research. Vikas Publishing House Ltd.
10. S. A. Bhatti, 1996, Operations Research: An Introduction, Shaharyar Publishers, Lahore.

Course Title **Software Packages**
Course Code **MTH-677**
Credit Hours **3(1-2)**

AIMS AND OBJECTIVES:

This subject covers the foundations of programming applications and analyze the requirements of an entry-level programming task,

THEORY & PRACTICAL

Microsoft Office: Working with Documents, Formatting a Document. Customizing a Document, Entering and Editing Data, Formatting a Worksheet, Entering pictures and graphs, Using Formulas and Functions, Creating a Presentation, Working with Slides.
MATLAB BASICS: Introduction to Matlab, Arithmetic Operations, Display Formats, Elementary Math Built-in Functions ,Variable Names, Predefined Variables , Commands for Managing Variables, General Commands, Polynomials , System of Linear Equations.
Math Type: Working with File, Entering the Mathematical Symbols, Using Math Type as Equation Editor, Inserting Math Type file in the Ms Office File, Using Formulas and Functions, Creating a Presentation, Working with Slides.
Latex: Working with .tex file, Formatting a file. Customizing a file, Entering and Editing Data, Using Formulas and Functions, Creating a Presentation, Working with Slides. Entering pictures and graphs. Working with Beamer for slides and presentations.

RECOMMENDED BOOKS:

11. B. R. Hunt, R. L. Lipsman, J. M. Rosenberg, 2001. A Guide to MATLAB for Beginners and Experienced Users. 1st Edition, Cambridge University Press
12. L. Beach, 2001. Math Type Mathematical Equation Editor. Edition 5th. Design Science, Inc. U.S.A.
13. M. Matthews, C. Matthews, 2007. Microsoft Office 2007. Quick Steps. 1st Edition. McGraw-Hill Professional Publishing.
14. R. V. Dukkipati, 2010. MATLAB An Introduction With Applications. New Age International Publishers

SEMESTER IV

Course Title: **Mathematical Statistics II**
Course Code: **MTH-652**
Credit Hours: **3(3-0)**

AIMS AND OBJECTIVES:

The aim of the course is to present a solid calculus based background in statistical theory together with its applications to solving practical real world problems.

THEORY:

Functions of Random Variables: Distribution function technique, Transformation technique: One variable, several variables, Moment-generating function technique. Sampling Distributions: The distribution of the mean, The distribution of the mean: Finite populations, The Chi-Square distribution., The *t* distribution, The *F* distribution. Regression and Correlation**:** Linear regression, The methods of least squares, Normal regression analysis, Normal correlation analysis, Multiple linear regression, Multiple linear regression (matrix notation).

RECOMMENDED BOOKS:

1. J. E. Freund, Mathematical Statistics, (Prentice-Hall Inc., 1992).
2. Hogg and Craig, Introduction to Mathematical Statistics, (Collier Macmillan, 1958).
47
3. Mood, Greyill and Boes, Introduction to the Theory of Statistics, (McGraw Hill).
4. R. E. Walpole, *Introduction to Statistics*, 3rd edition, (Macmillan Publishing Company
London, 1982)
5. M. R. Spiegel, L. J. Stephens, *Statistics*, (McGraw Hill Book Company, 1984)

Course Title: **Advanced Set Theory**
Course Code: **MTH-654**
Credit Hours: **3(3-0)**

AIMS AND OBJECTIVES:

The aim of the course is to present advance topics of set theory.

THEORY:

Equivalent sets and examples, Countable sets, examples of countable sets, uncountable sets, examples of uncountable sets, cardinal number as equivalence classes, example of cardinal numbers, Cantor's theorem, Partially ordered sets, chains, lattices, Partial ordering on cardinal numbers, Cantor-Bernstein theorem and applications, Addition, multiplication and exponentiation of cardinals, Zorn's lemma and applications, axiom of choice, equivalence of axiom of choice and Zorn's lemma, well ordered sets and related concepts, ordinal numbers, addition and multiplication of ordinal numbers.

RECOMMENDED BOOKS:

1. S. Shen, N. K. Vereshchagin, A. Shen. *Basic Set Theory*. American Mathematical Soc.; 2002.
2. I. Kaplansky, *Set theory and metric spaces*. Vol. 298. American Mathematical Soc.,
    a. 2001.
3. A. N. Kolmogorov ,& S. V. Fomin, (2012). *Introductory Real Analysis*. Courier
    a. Corporation.
4. P. R. Halmos, *Naïve Set Theory,* New York, Van Nonstrand.
5. Hrbacek, Karel, and Thomas Jech. *Introduction to Set Theory, Revised and*
    a. *Expanded*. Crc Press, 1999.

Course Title: **Numerical Analysis II**
Course Code: **MTH-656**
Credit Hours: **3(3-0)**

AIMS AND OBJECTIVES:

Numerical methods for the solution of some of the main problems of the scientific computing are introduced (nonlinear sytems, data approximation, numerical differentiation and integration, numerical solution of ODE); their implementation and analysis are given by using interactive environments for the computing and the scientific visualization.

THEORY:

Osculating polynomials, Differentiation and integration in multidimension. Ordinary differential equations: Predictor methods, Modified Eulers method, Truncation error and stability, The Taylor series method, Runge-Kutta methods. Differential equations of higher order: System of differential equations; Runge-Kutta methods, shooting methods, finite difference methods. Partial differential equations: Elliptic hyperbolic and parabolic equations; Explicit and implicit finite difference methods, stability, convergence and consistency analysis, The method of characteristic. Eigen value problems; Estimation of Eigen values and corresponding error bounds, Gerschgorin's theorem and its applications Schur's theorem, Power method, Shift of origin, Deflation method for the subdominant Eigen values.

RECOMMENDED BOOKS:

1. A. Komech, A. Komech. 2009. Principles of Partial Differential Equations, Springer-New York.
2. C. F. Gerlad, P.O. Wheatley. 2005. Applied Numerical Analysis. Pearson Education. Singapore.
3. J. H. Mathews, Numerical Methods for Mathematics, Latest Edition. Prentice Hall International,
4. L. Debnath. 2005. Nonlinear Partial Differential Equations for Scientists and Engineers, Birkhauser-Boston.
5. R. L. Burden, J. D. Faires: Numerical Analysis, Latest Edition. PWS Pub. Co.
6. W. E. Boyce, R. C. DiPrima. 2001. Elementary Differential Equations and Boundary Value Problems, John Wiley & sons, Inc.

Course Title: **Theory of Modules**
Course Code: **MTH-658**
Credit Hours: **3(3-0)**

AIMS AND OBJECTIVES:

The main objective of this course is introduce the basic theory of modules which is useful in advance level algebra courses.

THEORY:

Definition and examples, Sub modules, Homeomorphisms and quotient modules. Direct sums of modules. Finitely generated modules, Torsion Modules, Free modules. Basis, Rank and endomorphism of free modules. Matrices over Rings and their connections with the basis of free modules. A Module. A Module as the direct sum of a free and a torsion module. Exact sequences and elementary notions of homological algebra. Noetherian and modules, Radicals, Semi simple rings and modules.

RECOMMENDED BOOKS:

5. T. S. Blyth. 2004. Module Theory. Oxford University Press.
6. D. S. Dummit, R. M. Foote. 2004. Abstract Algebra.Edition 3rd. John Wiley & Sons.
7. B. Hartley, T.O.Hawkes. 2006. Rings, Modules and Linear Algebra, Chapmanand Hall.
8. G. Kemper. 2010. A Course in Commutative Algebra. Springer.

Course Title: **Algebraic Number Theory**
Course Code: **MTH-660**
Credit Hours: **3(3-0)**

AIMS AND OBJECTIVES:

The aims of this unit are to enable students to gain an understanding and appreciation of algebraic number theory and familiarity with the basic objects of study, namely number fields and their rings of integers. In particular, it should enable them to become comfortable working with the basic algebraic concepts involved, to appreciate the failure of unique factorisation in general, and to see applications of the theory to Diophantine equations.

THEORY:

Review of polynomials, irreducible polynomials, Algebraic numbers and integers, Units and Primes in R[v] ideals. Arithmetic of ideals congruencies, the norm of an ideal. Prime ideals, Units of algebraic number field.
Application to Rational Number Theory: Equivalence and class number, Cyclotomic field Kp, Fermat's equation, Kummer's theorem, The equation: x2 + 2=y3, pure cubic fields, Distribution of primes and Riemann's zeta function.

RECOMMENDED BOOKS:

7. A. Adler, J. E. Coury, The Theory of Numbers, Jones and Bartlett Publishers.
8. D. M. Burton. 2007. Elementary Number Theory, McGraw-Hill.
9. I. Niven, H. S. Zuckerman, H. L. Montgomery. An Introduction to the Theory of Numbers. John Wiley & Sons. Inc.
10. K. H. Rosen. 2005. Elementary Number Theory and its Applications. Addison-Wesley. 5th Edition.
11. I. N. Stewart, D. O. Tall, Algebraic Number Theory. 2nd Edition. Chapman and Hall/CRC Press. 1987.
12. W. J. LeVeque. 2002. Topics in Number Theory. Volumes I and II.

Course Title: **Category Theory**
Course Code: **MTH-662**
Credit Hours: **3(3-0)**

AIMS AND OBJECTIVES:

The aim of this course unit is to introduce the basic ideas of Category theory.

THEORY:

Basic concepts of category, Definition of category, examples, epimorphism, monomorphism, retractions, Initial, Terminal, and null objects, Category of graphs, Limits in categories, Equalizers, Pull backs, Inverse images and intersections, Constructions with kernel pairs, Functions and adjoint Functions, Functions, Bifunctions, Natural transformations, Diagrams, Limits, Colimits, Universal problems and adjoint functions.
Subjects, Quotient objects and factorization, (E,M) Categories, (Epi external mono) and (external epi mono) Categories, (Generating external mono) factorization. Pointed categories: Normal and exact categories, Additive categories, Abelian categories, Definition of automation and examples, Category of automata, Epimorphism, Monomorphism, initial, terminal and null objects in Aut. Congruences and factor automata, Automata with constant input and output.

RECOMMENDED BOOKS:

5. J. V. Oosten. 2007. Basic Category Theory. University of Otrecht.
6. M. A. Arbib, E. G. Manes, 1977, Arrows, structure and functions, Academic press New York.
7. P. Freyd, 1964, Abelian Categories: An Introduction to the Theory of Funtors, Harper and Row.
8. T. Leinster. 2014. Basic Category Theory. Cambridge University Press.

Course Title: **Galois Theory**
Course Code: **MTH-664**
Credit Hours: **3(3-0)**

AIMS AND OBJECTIVES:

To present an introduction to Galois theory in the context of arbitrary field extensions and apply it to a number of historically important mathematical problems.

THEORY:

Introduction to Extension Fields, Algebraic extensions, Finite fields, The basic isomorphism of algebraic field theory, Automorphism and fields, The Isomorphism Extension Theorem, Splitting fields, Separable extensions - Galois Theory, Illustrations of Galois Theory.

RECOMMENDED BOOKS:

5. D. A. Cox. 2012. Galois Theory. 2nd Edition. John Wiley & Sons, Inc.
6. D. S. Dummit, R. M. Foote. 2004. Abstract Algebra.Edition 3rd.John Wiley & Sons.
7. I. Kaplansky. Fields and Rings. Latest Edition. Chicago: University of Chicago Press.
8. I. Stewart. 2004. Galois Theory. 3rd Edition. Chapman & Hall/CRC.

Course Title: **Probability Theory**
Course Code: **MTH-666**
Credit Hours: **3(3-0)**

AIMS AND OBJECTIVES:

A prime objective of the course is to introduce the students to the fundamentals of probability theory and present techniques and basic results of the theory and illustrate these concepts with applications. This course will also present the basic principles of random variables and random processes needed in 24applications.

THEORY:

Finite probability spaces: Basic concept, probability and related frequency, combination of events, examples, Independence, Random variables, Expected value. Standard deviation and Chebyshev's inequality. Independence of random variables. Multiplicativity of the expected value. Additivity of the variance, Discrete probability distribution. Probability as a continuous set function:sigma-algebras, examples. Continuous random variables, Expectation and variance. Normal random variables and continuous probability distribution. Applications: de Moivre-Laplace limit theorem, weak and strong lawof large numbers. The central limit theorem, Markov chains and continuous Markov process.

RECOMMENDED BOOKS:

6. M. Capinski, E. Kopp,Measure, Integral and Probability,Springer-Verlag, 1998.
7. R. M. Dudley,Real Analysis and Probability, CambridgeUniver-sity Press, 2004.
8. S. I. Resnick,A Probability Path, Birkhauser, 1999.
9. S. Ross,A first Course in Probability Theory, 5th ed., PrenticeHall, 1998.
10. Robert B. Ash,Basic Probability Theory, Dover. B, 20

Course Title: **Theory of Elasticity**
Course Code: **MTH-668**
Credit Hours: **3(3-0)**

AIMS AND OBJECTIVES:

The objective of the course is to introduce the theory of elasticity and to analyze some real problems and to formulate the conditions of theory of elasticity applications.

THEORY:

Cartesian tensors, Analysis of stress and strain, Generalized Hooke's law; crystalline structure, Point groups of crystals, Reduction in the number of elastic moduli due to crystal symmetry; Equations of equilibrium; Boundary conditions, ompatibility equations; Plane stress and plane strain problems; Two dimensional problems in rectangular and polar co-ordinates; torsion of rods and beams.

RECOMMENDED BOOKS:

5. A. P. Boresi And K. P. Chong, 2000, Elasticity iri Engineering Mechanics, 2nd Edition, John Wiley & Sons.
6. A. C. Ugural, S. K. Fenster, . Advanced Strength and Applied Elasticity, Latest Edition. Elsevier Science Publishing Co., Inc..
7. A. S. Saada, Elasticity: Theory and Applications. Latest Edition. Krieger Publishing, Malabar, Florida,
8. S. P. Timoshenko And J. N. Goodier, Theory of Elasticity, McGraw Hill Book Company. Latest Edition.

Course Title: **Electromagnetism**
Course Code: **MTH-670**
Credit Hours: **3(3-0)**

AIMS AND OBJECTIVES:

The aim of this course is to provide the students with the fundamental principles of electrical energy (electro- magnetism).

THEORY:

Electrostatics and the solution of electrostatics problems in vacuum and in media, Electrostatic energy, Electro currents, The magnetic field of steady currents. Magnetic properties of matter. Magnetic energy, Electromagnetic Introduction, Maxwell's equations, Boundary Value Potential Problems in two dimensions, Electromagnetic Waves, Radiation, Motion of electric charges.

RECOMMENDED BOOKS:

5. D. Corson, P. Lerrain. Latest Edition. Introduction to Electromagnetic Fields and Waves. Freeman.
6. J. R. Reitz, F. J. Milford. Latest Edition. Foundation of Electromagnetic Theory. Addison-Wesley
7. K. H. Panofsky,M.Philips. Latest Edition. Classical Electricity and Magnetism. Addison-Wesley.
8. V. C. A. Ferraro. Latest Edition. Electromagnetic Theory. The Athlone Press.

Course Title: **Quantum Mechanics II**
Course Code: **MTH-672**
Credit Hours: **3(3-0)**

AIMS AND OBJECTIVES:

The aim of the course is to provide mathematics students with a thorough introduction to nonrelativistic quantum mechanics, with emphasis on the mathematical structure of the theory.

THEORY:

Motion in three dimensions, angular momentum, commutation relations between components of angular momentum, and their representation in spherical polar coordinates, simultaneous Eigen functions of L_z and L^2, Spherically symmetric potential and the hydrogen atom.
Scattering Theory: The scattering cross-section, scattering amplitude, scattering equation, Born approximation, partial wave analysis.
Perturbation Theory: Time independent perturbation of non-degenerate and degenerate cases. Time-dependent perturbations.
Identical Particle: Symmetric and anti-symmetric Eigen function, The Pauli exclusion principle.

RECOMMENDED BOOKS:

6. E. Merzdacker. Latest Edition. Quantum Mechanics. Edition 2^{nd}. John Wiley and Sons.
7. J. G. Taylor. Latest Edition. Quantum Mechanics. George Allen and Unwin.
8. R. Dicke, J .P. Witke. Latest Edition. Quantum Mechanics. Addison Wesley.
9. R. M. Eisberg. Latest Edition. Fundamental of Modern Mechanics.John Willey and Sons H.Muirhead. The Physics of Elementary Particles. Pergamon Press.
10. T. L. Powell, B.Crasemann . Latest Edition. Quantum Mechanics. Addison Wesley.

Course Title: **Theory of Optimization**
Course Code: **MTH-674**
Credit Hours: **3(3-0)**

AIMS AND OBJECTIVES:

The aim of this course is to obtain a rigorous mathematical background to optimization techniques used in other related fields.

THEORY:

Introduction to optimization. Relative and absolute extreme. Convex. Concave and unimodal functions. Constants. Mathematical programming problems. Optimization of one, two and several variables functions and necessary and sufficient conditions for their optima. Direct substitution method and Lagrange multiplier method, necessary and sufficient conditions for an equality-constrained optimum with bounded independent variables. Inequality constraints and Lagrange multipliers. Kuhn- Tucker Theorem. Multidimensional optimization by Gradient method. Convex and concave programming, Calculus of variation and Euler Language equations, Functions depending on several independent variables. Variational problems in parametric form. Generalized mathematical formulation of dynamics programming. Non-Linear continuous models, Dynamics programming and Variational calculus. Control theory.

RECOMMENDED BOOKS:

5. B. S. Gotfried, J.Weisman. Latest Edition. Introduction to Optimization Theory. Prentice-Inc.New Jersy.
6. D. A. Wismer, R Chattergy. Latest Edition. Introduction to Nonlinear Optimization. North - Holland, New York.
7. L. Elsgolts. Latest Edition . Differential Equations and the Calculus of Variations. New Edition. University Press of the Pacific.
8. M. D. Intriligator. Latest Edition.Mathematical Optimization and Economic Theory. Society Forindustrial and Applied Mathematics.

Course Title: **Measure Theory**
Course Code: **MTH-676**
Credit Hours: **3(3-0)**

AIMS AND OBJECTIVES:

To gain understanding of the abstract measure theory and definition and main properties of the integral. To construct Lebesgue's measure on the real line and in *n*-dimensional Euclidean space. To explain the basic advanced directions of the theory.

THEORY:

Review of definitions of set theory and properties of sets, Relations and functions, Relationship between equivalence relations on a set A and partitions of A, Different types of functions. Choice functions, Axiom of choice, Equivalent sets, Countable sets. Definition and its properties, Review of elementary concepts of Topology, G,sets. Borel sets, Cantor set, Continuous functions, Review of elementary real analysis, Ring, ó - ring of sets and their relationship, Algebra, ó - algebra of sets and relationship between them and ring, ó - ring. Existence of smallest ó – algebra containing a given collection of subsets of a set, General definitions of outer measure and measure of a set and their properties.Lebesgue outer measure. Definition and its properties Lebesgue measurable set, Its Caratheodar's definition and properties, Approximation of measurable sets by open / Gand closed /sets, Lebesgue measure, Definition and its properties, Lebesgue measure of Cantor set, Existence of Lebesgue non-measureable set, Measurable function, Definition, algebra of measurable functions and various other properties of measurable functions, Measurability of step. Characteristic, Dinchlet's and simple functions etc.

RECOMMENDED BOOKS:

5. R. G. Bartle. 1995.The Elements of Integration and Lebesgue Measure. International Edition. Wiley Interscience.
6. H. Bauer. 2001.Measure and Integration Theory. Berlin. de Gruyter.
7. H. S. Bear. 2001. A Primer of Lebesgue Integration. Edition 2nd. San Diego. Academic Press.
8. V. I. Bogachev. 2007. Measure Theory. Volume 1. Berlin.Springer.

Course Title: **Combinatorics**
Course Code: **MTH-678**
Credit Hours: **3(3-0)**

AIMS AND OBJECTIVES:

The aim of this class is to introduce the basic combinatorial tools of computer science, to train students in mathematical thinking and reasoning that is pertinent to computer science, and to present that reasoning in rigorous written text.

THEORY:

Basic counting principles, Permutations, Combinations, The injective and bijective principles, Arrangements and selections with repetitions, Graphs in Combinatorics, The Binomial theorem, combinatorial identities. Properties of binomial coefficients, Multinomial coefficients, The multinomial theorem, The Pigeonhole principle, Examples, Ramsay numbers, The principle of inclusion and exclusion, Generalization, Integer solutions, Surjective mapping, Stirling numbers of the second kind, The Sieve of Eratostheries, Euler φ-function, The Probleme des Manages, Ordinary Generating Functions, Modeling problems. Partition of integers, Exponential generating functions, Linear homogeneous recurrence relations, Algebraic solutions of linear recurrence relations and constant functions, The method of generating functions, A non-linear recurrence relation and Catalpa numbers.

RECOMMENDED BOOKS:

6. A. Tucker. Applied Combinatorics. Latest Edition. John Wiley & Sons. New York,
7. C. C. Chen, K. M. Koh, 1992. Principles and Techniques in Combinatorics. World Scientific Pub. Co. Pte. Ltd. Singapore.
8. C. L. Liu. 1968. Introduction to Combinatorial Mathematics. McGraw-Hill. New York.
9. J. H.V. Ling, R. M. Wilson. 2001. A Course on Combinatorics, 2nd Edition, Cambridge University Press, Cambridge.
10. V. K. Balakrishnan. 1995. Theory and Problems of Combunatorics. Schaum’s Outline Series. McGraw-Hill International Edition. Singapore.

Course Title: **Fluid Mechanics-II**
Course Code: **MTH-684**
Credit Hours: **3(3-0)**

AIMS AND OBJECTIVES:

The aim of the course is to introduce some of the most current research subjects in the field of fluid dynamics.

THEORY:

Vortex motion, Line Vortex, Vortex row Image System, Kelvin's minimum energy theorem, Uniqueness theorem, Fluid streaming past a circular cylinder, Irrational motion produced by a vortex filament. The Helmholtz vorticity equation, Karman's vortex-street. Constitutive equations; Navier- Stoke's equations; Exact solution of Navier-Stoke's equations; Steady unidirectional flow; Poiseuille flow; Couette flow; Unsteady undirectional flow, Sudden motion of a plane boundary in a fluid at rest; Flow due to an oscillatory boundary; Equations of motion relative to a rotatingsystem; Ekman flow; Dynamical similarity of turbulent motion.

RECOMMENDED BOOKS:

5. H. Schlichting. 2000. Boundary Layer Theory. Edition 8th. Springer.
6. I. G. Currie. 2012. Fundamental Mechanics and Fluids. Edition 4th. CRC Press.
7. J. H. Aksel, N. Spurk. 2008. Fluid Mechanics. Edition 2nd.Springer.
8. R. K. Bansal. 2005. A Textbook of Fluid Mechanics. Edition 9th. Laxmi Publications LTD, New Delhi. H

Course Title: **Integral Equations**
Course Code: **MTH-686**
Credit Hours: **3(3-0)**

AIMS AND OBJECTIVES:

Many physical problems that are usually solved by differential equation methods can be solved more effectively by integral equation methods. This course will help students gain insight into the application of advanced mathematics and guide them through derivation of appropriate integral equations governing the behavior of several standard physical problems.

THEORY:

Linear Integral Equations of the 1^{st} kind, Linear Integral Equations of the 2^{nd} kind, Relationship between differential equation and Volterra Integral Equation. Neumann series. FredholmIntegral Equations of the 2^{nd} kind with separable Kernels. Eigenvalues and eigenvectors. Iterated functions. Quadrature methods. Least square methods. Homogenous Integral Equations of the 2^{nd} kind. Fredholm Integral Equations of the 1^{st} kind. Fredholm Integral Equations of the 1^{st} kind. FredholmIntegral Equations of the 2^{nd} kind. Abel's Integral Equations.Hilbert Schmidt theory of Integral Equations with symmetric Kernels, Regularization and filtering techniques.

RECOMMENDED BOOKS:

5. A.M.Wazwaz. A First Course in Integral Equations. World Scientific Pub.
6. C.T.H.Baker. Integral Equations. Clarendon Press.
7. F.Smithies. Integral Equations. Cambridge University Press.
8. W. V. Lovitt. 2005. Linear Integral Equations. Dover Publications.

Course Title: **Graph Theory**
Course Code: **MTH-688**
Credit Hours: **3(3-0)**

AIMS AND OBJECTIVES:

The aim of this course is to introduce basic graph theory and applications.

THEORY:

Graphs: Graphs Models, Some special classes of graphs, Connected graphs, Multigraphs, Digraphs Degrees: The Degree of a vertex, Degree Sequence, Graphs and MatricesRegular and Irregular graphs, Isomorphic Graphs: Graphs and Groups,Trees: Bridges, Trees, The minimum spanning tree, Connectivity: Cut-Vertices, Blocks, Menger Theorem, Eulerian Graphs, Hamiltonian graphs, Planar graphs, Digraphs: Strong digraphs, Tournaments

RECOMMENDED BOOKS:

5. B. Bollobas. 2002. Modern Graph theory. Springer Verlag , Newyork.
6. B. Bollobas, 1979, Graph theory. Springer Verlag , Newyork.
7. J. L. Gross, J. Yellen. 2005, Graph theory and Its Applications. Chapman and Hall.
8. R. J. Wilson, Introduction to Graph Theory. Latest Edition. Pearson Education Ltd.

Govt. College Women University Faisalabad

Department of Mathematics

Scheme of Studies M. Phil. Mathematics Program
2019

DURATION OF THE PROGRAM AND SEMESTER–WISE COURSE BREAKDOWN

- 4-6 semesters for regular
- 6-8 semesters for employee

M. Phil. Mathematics Two Year Program

- Year 1 (Two Semester) Course Work
- Year 2 (Two Semester) Research Work

Govt. College Women University Faisalabad

Department of Mathematics

Scheme of Studies MS/M. Phil. Mathematics Program

DURATION OF THE PROGRAM AND SEMESTER–WISE COURSE BREAKDOWN

- 4-6 semesters for regular
- 6-8 semesters for employee

M. Phil. Mathematics Two Year Program

- Year 1 (Two Semester) Course Work
- Year 2 (Two Semester) Research Work

Course Code		Credit Hours
Semester-I		
MTH-	Core	3
MTH-	Core	3
MTH-	Core	3
MTH-	Core	3
Total		**12**
Semester-II		
MTH-	Optional	3
MTH-	Optional	3
MTH-	Optional	3
MTH-	Optional	3
Total		**12**

Semester-III & IV		
MTH-729	Seminar	1(0-1)
MTH-730	Special Problem	1(0-1)
MTH-731	Thesis	6(0-6)
Total		**8**

Total Credit Hours	32

List of Courses

MTH-722	Convex Analysis	3(3-0)	129
MTH-723	*Inequalities Involving Convex Functions	3(3-0)	130
MTH-724	Perturbation Methods	3(3-0)	131
MTH-725	*Theory of Interpolation Spaces	3(3-0)	132
MTH-726	Variational Inequalities and its Applications	3(3-0)	133
MTH-727	*Integral Equations	3(3-0)	134
MTH-728	Theory of Majorization	3(3-0)	135
MTH-732	Homological Algebra	3(3-0)	136
MTH-733	*Advanced Number Theory	3(3-0)	137
MTH-734	Field Extensions & Galois Theory	3(3-0)	138
MTH-735	*Linear Groups & Group Representations	3(3-0)	139
MTH-736	Operator Theory	3(3-0)	140
MTH-737	Fuzzy Algebra	3(3-0)	141

*Core courses for M. Phil. program; the students will have to take four core courses as and when offered by the department.

- Overall minimum 24 teaching credit hours for M. Phil. program are mandatory. However, the research supervisor of students may recommend additional courses.
- The department will offer the courses keeping in view the availability of teachers and nature of research to be conducted from the following list.

Course Title: **Commutative Algebra**
Course Code: **MTH-701**
Credit Hours: **3(3-0)**

AIMS AND OBJECTIVES:

This course will give the student a solid grounding in commutative algebra which is used in computational algebra.

THEORY:

Rings and ideals, quotient rings, prime, maximal, radical, Nil-radicals, Jacobson radicals, domains, UFDs, and related theorems. Modules, types of modules. Regular sequences, some functors applied on exact sequences and their behavior. Chain conditions, spectrum and Max-spectrum of rings Nakayama Lemma and system of generators. Rings and modules of fractions and behavior of classes of ideals in ring of fractions. Noetherianess and Artinianess of rings, Hilbert Basis Theorem. Primary decomposition, Filtration of ideals and modules, associated graded rings. Krull-dimensions. Krull intersection theorem. Hilbert function. System of parameters and injective dimension and add equivalent definitions of Krull-dimension. Free resolutions associated to modules. Depth of modules, Cohen-Macaulay Rings. Regular local rings

RECOMMENDED BOOKS:

1. D. S . Dummit , R . M . Foote . 2004. Abstract Algebra.3rdEdition. John Wiley & Sons.
2. E . Kunz . 2012. Introduction to Commutative Algebra and Algebraic Geometry. 1st Edition . Birkhauser.
3. G . Kemper . 2010. A Course in Commutative Algebra. 1st Edition.Springer.
4. R . Y. Sharp. 2000. Steps in Commutative Algebra. 2nd Edition . Cambridge University Press.

Course Title: **Theoretical Physics (Plasma Physics)**
Course Code: **MTH-702**
Credit Hours: **3(3-0)**

AIMS AND OBJECTIVES:

The aim of this course is to give students a solid grounding in fundamental plasma physics. The course is designed to appeal to graduate students in astrophysics and physics.

THEORY:

Occurrence of plasmas in nature, definition of plasma, concept of temperature , Debye shielding, plasmas parameters, criteria for plasmas, and applications

Single particle motion: Uniform and non-uniform electrostatic **E** and magnetic **B** fields, time -varying **E** and **B** fields and their description for plasmas

Waves in plasmas**:** Introduction to plasma oscillations, electron plasma waves, ion waves, plasma approximation, electrostatic electron oscillations perpendicular to **B**, the lower hybrid Frequency, the upper hybrid frequency, electromagnetic waves with $\mathbf{B_0=0}$, electromagnetic waves perpendicular to $\mathbf{B_0}$ cut-offs and resonances, electromagnetic waves parallel to B_0, Alfeven waves, magneto sonic waves,

Introduction to controlled fusion, fusion reactions (P^p CNO Cycles controlled nuclear fusion, D^D D Reactor fusion related to the future.

Equilibrium and stability: Stream instability, the gravitational instability.

RECOMMENDED BOOKS:

1. A. Piel. 2010. Plasma Physics. An Introduction to Labortory. Space and Fusion Plasmas. 1st Edition. Springer.
2. J. A. Bittoncourt. 2004. Fundamentals of Plasma Physics. 3rd Edition. Springer Verlag
3. P. M . Bellan. 2008. Fundamentals of Plasma Physics. 1st Edition. Cambridge University Press.
4. W. M. Stacey. 2005. Fusion Plasma Physics.1st Edition. Wiley-VCH.

Course Title: **Advanced Functional Analysis**
Course Code: **MTH-703**
Credit Hours: **3(3-0)**

AIMS AND OBJECTIVES:

The course combines ideals and methods from different areas of mathematics. It is designed especially for students who want to choose operator algebras as their speciality, but the content of the course also be useful to students interested in other branches of analysis.

THEORY:

Topological vector spaces, separation properties, linear mappings, meterizations, boundedness and continuity, semi norms and local convexity, quotient spaces, fundamental theorem of functional analysis, Zorn's lemma, Hahn-Banach theorem, Banach-Steinhaus theorem, open mapping theorem, closed graph theorem, convexity, Weal topologies, vector valued integration, homomorphism functions, duality, adjoints compact operators, bounded operators on the Hilbert Spaces, bounded linear operators, the spectral theory, Positive operators and square roots, The group of invertible operators, B^* algebras, a characterization of B^* algebras.

RECOMMENDED BOOKS:

1. E . Kreyzig,. 2001. Introductory Functional Analysis with Applications. 1st Edition John Wiley.
2. H. Brezis. 2011. Functional Analysis. Sobolev Spaces and Partial Differential Equations. 1st Edition Springer.
3. W . Ruden . 2001. Functional Analysis.1st Edition. McGraw-Hill.
4. Y . Eidelman,. V. Milman. 2004. Functional Analysis An Introduction. 1st Edition Americal Mathematical Society.

Course Title: **Representation Theory of Symmetric Groups**
Course Code: **MTH-704**
Credit Hours: **3(3-0)**

AIMS AND OBJECTIVES:

The representation theory of symmetric groups is a special case of representation theory of finite groups. One main aim is to construct and to parameterize the simple modules of the symmetric groups over an arbitrary field.

THEORY:

Matrix representation of groups, examples for cyclic groups, symmetric groups, permutation groups, permutation and regular representations, equivalence of representations, irreducible representations, reducible and completely reducible representations, Mashke's theorem, groups characters, permutation and regular character, examples, condition of irreducibility and equivalence in terms of characters, number of irreducible characters equal to number of classes of conjugate elements, character tables, Schur's lemma and relations, orthogonality relations, construction of representations, direct product of representations, induced representations and characters, lifting of representations

RECOMMENDED BOOKS:

1. A. Kleshchev. 2005. Linear and Projective Representations of Symmetric Groups. 1st Edition Cambridge University Press.
2. B. E .Sagan. 2001. The Symmetric Group Representations. Combinatorial Algorithms and Symmetric Functions. 2nd Edition. Springer.
3. G. D. James, M. Liebeck. 2001. Representation of characters and groups.1st Edition Cambridge University Press.
4. G. D . James. 2009. Representation Theory of Symmetric Groups.1st Edition Cambridge University Press.

Course Title: **Advanced Numerical Analysis**
Course Code: **MTH-705**
Credit Hours: **3(3-0)**

AIMS AND OBJECTIVES:

This course is designed to teach the students about numerical methods and their theoretical bases. The course aims at inculcating in the students the skill to apply various techniques in numerical analysis , understand and do calculations about error that can occur in numerical methods.

THEORY:

Numerical solutions of nonlinear equations: bisection, regula falsi, Newton-Raphson, fixed point methods, some higher order methods for the solution of non linear equations and their convergences, solution of system of linear equations: Gauss elimination method, Jacobi and Gauss-Seidel methods and their convergences, relaxation, SOR, SUR, eigenvalues and eigenfunctions, system of nonlinear equations, interpolations, Lagrange interpolating polynomials, Hermite polynomial, cubic spline, numerical integration, solution of differential equations: Euler's method, Runge-Kutta method, Adam Bashforth method, system of differential equations, Milne methods(Algorithms with computer programming)

RECOMMENDED BOOKS:

1. C. F. Gerald. 2003. Applied Numerical Analysis. 1st Edition. Pearson.
2. P. Linz, R .W. Exploring. 2003. Numerical Methods. 1st Edition. Jones and Bartlett Publishers. Barb House. Barb news London W6 7PA. UK.
3. R. L . Burden, D. J . Faires. 2015. Numerical Analysis . 10th Edition. Brooks/Cole.
4. W. Gautschi. 2012. Numerical Analysis. 2nd Edition . Springer.

Course Title: **Fixed Point Theory**
Course Code: **MTH-706**
Credit Hours: **3(3-0)**

AIMS AND OBJECTIVES:

To learn fixed point theory as an interesting application of metric spaces, to understand the applications of this theory to numerical analysis, ordinary differential equations and integral equations and linear algebra.

THEORY:

What is fixed point theory? The Banach contraction principle, geometry of Banach spaces, elements of non-expensive mapping theory, minimal invariant sets, uniformly Lipschitzian, periodic, rotative maps etc, compact sets in Banach spaces, Schuder's theorem, equivalence of Brouwer's and Shuder's theorems, some applications, some more fixed point methods

RECOMMENDED BOOKS:

1. J. Dugundji. A. Granas. 2003. Fixed Point Theory. 1st Edition. Springer.
2. K.. Goebel . 2002. Concise Course on Fixed Point Theorems. 1st Edition. Yokohama Publishers Japan.
3. K. A. M. Khamsi. 2001. An Introduction to Metric Spaces and Fixed Point Theory. 1st Edition. John Wiley & Sons. Inc.
4. M. P. R. Agarwal, M. O'Regan. 2004. Fixed Point Theory and Applications. 1st Edition. Cambridge University Press.

Course Title: **Advanced Partial Differential Equations**
Course Code: **MTH-707**
Credit Hours: **3(3-0)**

AIMS AND OBJECTIVES:

The course aims at developing understanding about fundamental concepts of PDEs theory, identification and classification of their different types, how they arise in applications, and analytical methods for solving them. Special emphasis would be on wave, heat and Laplace equations.

THEORY:

Cauchy's problem for linear second order equations in n-independent variables, Cauchy Kowalewski theorem, characteristics surfaces, adjoint operations, bi-characteristics, spherical and cylindrical waves, heat equation, wave equation, Laplace equation, maximum-minimum principle, integral transform.

RECOMMENDED BOOKS:

1. C. R. Chester. 2000. Techniques in Partial Differential Equations. 1st Edition. McGraw-Hill .
2. J. D. Logan . 2015. Applied Partial Differential Equations. 3rd Edition. Springer.
3. L. Debnath , T. Mynit-U. 2006. Linear Partial Differential Equations for Scientists and Engineers. 4th Edition. Birkhaser.
4. L. C . Evans. 2010. Partial Differential Equations. 2nd Edition American. Mathematical Society.

Course Title: **Lie algebra**
Course Code: **MTH-708**
Credit Hours: **3(3-0)**

AIMS AND OBJECTIVES:

This is an introductory graduate course in Lie algebras. The course will start with basic concepts in Lie algebras such as subalgebras, ideals, homomorphisms, and derivations. Then we will discuss various properties of solvable, nilpotent, and semi-simple Lie algebras. At the end of the course, students will have a basic understanding of Lie algebras that will allow them to continue their study of this important area of Mathematics if they so desire.

THEORY:

Definition and examples of Lie algebras, ideals and quotients, simple solvable and nilpotent Lie algebras, radical of Lie algebra, semi-simple Lie algebra, Engel's forms criterion for semi-simplicity, product of Lie algebras, classification of Lie algebras up to dimension 4, application of Lie algebras

RECOMMENDED BOOKS:

1. B. C. Hall. 2003. Lie Groups. Lie Algebrasand Representations An Elementary Introduction. 1st Edition. Springer-Verlag.
2. K. Edmann, W .Mark. 2006. Introduction to Lie Algebras. 1st Edition. Springer.
3. R. Gilmore. 2012. Lie Groups. Lie Algebras and Some of their Applications. 1st Edition. Dover Publication.
4. W. Rossmann. 2002. Lie Groups An Introduction Trough Linear Groups. 1st Edition. Oxford University Press Inc.

Course Title: **Numerical Solution of Ordinary Differential Equations**
Course Code: **MTH-709**
Credit Hours: **3(3-0)**

AIMS AND OBJECTIVES:

To introduce and give an understanding of numerical methods for the solution of ordinary differential equations, their derivation, analysis and applicability.

THEORY:

Theory and implementation of numerical methods for initial and boundary value problems in ordinary differential equations, one-step, linear multi-step, Runge-Kutta and extrapolation methods; convergence, stability, error estimates and practical implementation, study and analysis of shooting, finite difference and projection methods for boundary value problems for ordinary differential equations.

RECOMMENDED BOOKS:

1. A . Iserles. 2011. A First Course in Numerical Analysis of Differential Equations. 2nd Edition Cambridge University Press.
2. D . F. Griffiths, D. J. Higham. 2010. Numerical Methods for Ordinary Differential Equations Initial Value Problem. 1st Edition. Springer.
3. J. C . Butcher . 2010. Numerical Methods for Ordinary Differential Equations. 2nd Edition. John Wiley & Sons Ltd.
4. K . Atkinson. E. W. Han , D. E .Stewart .2009. Numerical Solution of Ordinary Differential Equations. 1st Edition. John Wiley & Sons.

Course Title: **Numerical Solutions of Partial Differential Equations**
Course Code: **MTH-710**
Credit Hours: **3(3-0)**

AIMS AND OBJECTIVES:

This course will introduce fundamental methods for approximating the solution of PDEs that are widely used in a various fields of science and engineering. These include both discretization methods that reduce infinite-dimensional PDEs to finite-dimensional systems of equations that may be solved on a computer, and also solution methods that efficiently solve the discretized equations.

THEORY:

Classification of PDEs into elliptic, parabolic and hyperbolic types, initial and boundary conditions, finite difference approximation methods (explicit and implicit), matrix and Von-Neumann methods for stability analysis for different schemes, convergence, method of characteristics for quasi-linear equations, finite element methods, Rayleigh-Ritz and Galerkin methods.

RECOMMENDED BOOKS:

1. G. D. Smith. 2001. Numerical solution of partial differential equations. 3rd Edition. Oxford University Press.
2. G. Sewell. 2005. The Numerical Solution of Ordinary and Partial Differential Equations. 2nd Edition. John Wiley & Sons. Inc.
3. K. W. Morton, D. F. Mayers. 2005. Numerical Solution of Partial Differential Equations. 2nd Edition. Cambridge University Press.
4. L. Lapidus, D. F. Pinder. 2011. Numerical Solution of Partial Differential Equations in Science and Engineering. 1st Edition. John Wiley & Sons. Inc.

Course Title: **Geometric Function Theory**
Course Code: **MTH-711**
Credit Hours: **3(3-0)**

AIMS AND OBJECTIVES:

The aim of this course is to acquire the distortion theorems, special classes of univalent functions, Lowner's theory, generalization of the area theorem, Gunsky inequalities.

THEORY:

Area theorem, growth, distortion theorems, coefficient estimates for univalent functions, special classes of univalent functions, Lowner's theory and its applications, Bieberbach conjecture, de Branges theorem, generalization of the area theorem, Grunsky inequalities, exponentiation of the Grunsky inequalities, logarithmic coefficients, subordination and sharpened form of Schwarz lemma

RECOMMENDED BOOKS:

1. D. Shoikhet. 2001. Semigroups in Geometrical Function Theory. 1st Edition. Kluwer Academic Publishers.
2. I. Graham, G. Kohr. 2003. Geometric Function Theory in One and Higher Dimensions. 1st Edition. Marcel Dekker. New York.
3. L. V. Ahlfors. 2010. Conformal Invariants. Topics in Geometric Function Theory. 1st Edition. AMS Chelsea Publishing.
4. S. G. Krantz. 2007. Geometric Function Theory Explorations in Complex Analysis. 1st Edition. Springer.

Course Title: **Advanced Graph Theory**
Course Code: **MTH-712**
Credit Hours: **3(3-0)**

AIMS AND OBJECTIVES:

After completion, the students will be able to use combination of theoretical knowledge and independent mathematical thinking in creative investigation of questions in graph theory.

THEORY:

Basics of Graphs: Graphs Models, Connected graphs, Multigraphs, Digraphs, Degrees, Regular and Irregular graphs, Isomorphic Graphs: Graphs and Groups, Trees: Bridges, Trees, The minimum spanning tree, Connectivity: Cut-Vertices, Blocks,
Eulerian Graphs, Hamiltonian graphs, Digraphs: Strong digraphs, Tournaments, Mathching: Marriage and Menger's Theorem, Planar Graphs, Coloring: The four color problem. Flows: Flows in networks. Labeling

RECOMMENDED BOOKS:

1. B. Bollobas. 2002. Modern Graph theory.1st Edition. Springer Verlag. New York.
2. J. L. Gross, J. Yellen. 2005. Graph Theory and I ts Applications.1st Edition. Chapman and Hall.
3. R. Balakrishnan, K. Ranganathan. 2012. A Textbook of Graph Theory. 2nd Edition. Springer.
4. R. Diestel. 2012. Graph Theory. 4th Electronic Edition. Springer.

Course Title: **Advanced Group Theory**
Course Code: **MTH-713**
Credit Hours: **3(3-0)**

AIMS AND OBJECTIVES:

This is advance course on group theory. The learning out come of this subject are to learn Sylow P-theorems, Fundamental theorem of finitely generated groups, free groups and solvable groups.

THEORY:

Review: Dihedral groups, Quaternion group, Quotient groups, P-groups, Isomorphism theorems, Automorphisms

Direct products and normal products of groups, Holomorphic of a group, Finitely generated abelian groups, Group action on a set, orbits and transitive actions, Stabilizers , The orbit stabilizer theorem, Characteristic and fully invariant subgroups, symmetric and alternating groups, generators of symmetric and alternating groups, Simple groups, simplicity of An, $n \geq 5$, series in groups. Zassenhau's Lemma, normal series and their refinements, composition series, principal or chief series, Nilpotent and Solvable groups

RECOMMENDED BOOKS:

1. D. S. Dummit, R. M. Foote, 2004. Abstract Algebra. 3rd Edition. John Wiley & Son.
2. J. Gallian, 2013. Contemporary Abstract Algebra. 8th Edition. Brooks/Cole Cengage Learning.
3. N. Carter, 2009. Visual Group Theory. American Association of America Inc.
4. P. M. Cohn, 2000. Classic Algebra. 1stEdition. London . John Wiley & Sons Inc.

Course Title: **Approximation Theory**
Course Code: **MTH-714**
Credit Hours: **3(3-0)**

AIMS AND OBJECTIVES:

To systematic study of the different approximation methods, numerical evaluation of the approximations and the error involved.

THEORY:

Introduction and revision of function norms, Weierstrass theorem for polynomial approximation, Chebyshev polynomials, best Euclidean (L_2) polynomial approximation, rational approximation, Padé approximants, Weierstrass approximation theorem, interpolation, interpolation by polynomials, Neville's algorithm, Newton's interpolation formula, the error in the polynomial interpolation, Hermite interpolation, the Hermite cubic form, least square approximation, Lagrange interpolations, interpolation by rational functions, trigonometric interpolation, interpolation based surfaces, tensor product based patches, interpolation based patches: Lagrange interpolation, Hermite interpolation, fast Fourier transform, the Z – transform

RECOMMENDED BOOKS:

1. E. W. Cheney, W. Light, 2009. A Course in Approximation Theory. 1st Edition. American Mathematical Society.

2. H. N. Mhaskar, D. V. Pai, 2000. Fundamentals of Approximation Theory. 1st Edition, Narosa Publishing House New Delhi.

3. J. H. Mathews, K. K. Fink, 2004. Numerical Methods Using MATLAB. 3rd Edition. Pearson Education, Inc., Publishing as Prentice Hall.

4. L. N. Trefethen, 2013. Approximation Theory and Approximation Practice. 1st Edition. Oxford University. Oxford.

Course Title: **Theory of Semi-groups**
Course Code: **MTH-715**
Credit Hours: **3(3-0)**

AIMS AND OBJECTIVES:

The aim of the course is to familiarize students with the elementary notions of semigroup theory. Abstract ideas will be illustrated by applying them to semigroups such as $\mathcal{T}_{X,}$ $M_n(\mathbb{R})$ and the bicyclic semigroup B. The will move on to study Green's relations and how these may be used to develop structure theorems for semigroups.

THEORY:

Semi-groups, monoids, ideals, homomorphisms and congruences, the essential difference between semi-groups and previously studied algebraic structure, Green's relations, regular D-Classes, Green's theorem that any II-Class containing an idempotent is a subgroup, completely 0-simple semi-groups, Rees' theorem, regular and inverse semi-groups

RECOMMENDED BOOKS:

1. A. Nagy, 2001. Special Classes of Semigroups. 1st Edition. Kluwer Academic Publishers.
2. J. N. Mordeson, D. S. Malik, N. Kuroki, 2003. Fuzzy Semigroups. 1st Edition. Springer.
3. T. W. Hungerford, 2012. Abstract Algebra. An Introduction, Brooks/Cole 1st Edition. Cengage Learning.
4. U. Kaljulaid, 2006. Semigroups and Automata. 1stEdition. Selecta IOS Press.

Course Title: **Advanced Fluid Dynamics**
Course Code: **MTH-716**
Credit Hours: **3(3-0)**

AIMS AND OBJECTIVES:

The aim of the course is to introduce some of the most current research subjects in the field of fluid dynamics and to present them for research in this area.

THEORY:

Exact solutions of the Navier Stokes equations, approximate solutions for low Reynolds numbers, approximate solutions for high Reynolds numbers, incompressible boundary layer theory, laminar and turbulent boundary layer theory, flow separation, compressible laminar and turbulent boundary layers

RECOMMENDED BOOKS:

1. G. Currie, 2012. Fundamental Mechanics and Fluids. 1st Edition. CRC Press.
2. H. Schlichting, 2000. Boundary Layer Theory. 1st Edition. Springer.
3. J. H. Spurk, N. Aksel, 2008. Fluid Mechanics. 2nd Edition. Springer.
4. R. K. Bansal, 2005. A Textbook of Fluid Mechanics. 1st Edition. Laxmi Publications (P) LTD. New Delhi.

Course Title: **Acoustics**
Course Code: **MTH-717**
Credit Hours: **3(3-0)**

AIMS AND OBJECTIVES:

To introduce the participants to fundamental acoustic concepts and to give the necessary background for more specialized courses in acoustic.

THEORY:

Fundamental of vibrations, Energy of vibration, Damped and free oscillations Transient response of an oscillator vibrations of springs, membranes and plates, forced vibrations. Normal modes, acoustic waves equation and its solution, equation of state, Cout-Euler equations, linearized wave equation, speed of sound in fluid, energy density, acoustic intensity, specific acoustic impedance, spherical waves, transmission, transmission from one fluid to another (Normal incidence) reflection at a surface of solid (Normal and oblique incidence). Absorption and attenuation of sound waves in fluids, pipes cavities waves guides; under water acoustics.

RECOMMENDED BOOKS:

1. L. E. Kinsler, A. R. Frey, A. B. Coppens, J. V. Sanders, 2000. Fundamentals of Acoustics. 4^{th} Edition. John Wiley & Son.
2. L. L. Beranek, T. J. Mellow, 2012. Acoustics: Sound Fields and Transducers. 1^{st} Edition. Elsevier Inc..
3. M. P. Morse, 2005. Vibration and Sound. 1^{st} Edition. McGraw Hill Book Company.
4. U. Inguard, 2008. Acoustics. 1^{st} Edition . Infinity Science Press LLC.

Course Title: **Computational Algebra**
Course Code: **MTH-718**
Credit Hours: **3(3-0)**

AIMS AND OBJECTIVES:

To study monomial ideals and related concepts using computer algebra systems so that students can do research in this field.

THEORY:

Monomial ideals: Operations on ideals. Module Theory: Graded modules. Operations on submodules. Direct Sum and direct product. Finitely generated modules. Primary decomposition and associated prime ideals. Integral Closure of monomial ideals. Simplicial Complex. Grobner bases: Dickson's Lemma. Hilbert basis theorem. Division algorithm. Buchberger's criterion. Edge ideals. Dimension Theory: Hilbert function and Hilbert Series. Graded free resolution. The Koszul Complex. Depth. Cohen-Macaulay modules. Introduction to Singular.

RECOMMENDED BOOKS:

1. E. Miller, B. Strumfels. 2006. Combinatorial Commutative Algebra. 1st Edition. Springer.
2. G. M. Gruel, G. Pfister, H. Schonemann, 2001. A Computer Algebra System for Polynomial Computations. 1st Edition. Centre for Computer Algebra, University of Kaiserslautern.
3. J. Herzog, T. Hibi, 2010. Monomial Ideals. 1st Edition. Springer.
4. R. H. Villaraeal, 2000. Monomial Algebras. 1st Edition. Marcel Dekker Inc. New York.

Course Title: **Integral Transforms**
Course Code: **MTH-719**
Credit Hours: **3(3-0)**

AIMS AND OBJECTIVES:

The aim of the course is to describe the ideas of Fourier and Laplace Transforms and indicate their applications in fields such as differential equations.

THEORY:

Introduction. their appearance in ODEs and PDEs. the Laplace transforms the Fourier transform. the Hankel transform. the Mellin transform. their properties like linearity. scaling. differential formulas and their applications to solutions of boundary and initial value problems.

RECOMMENDED BOOKS:

1. B. Davies. 2002. Integral Transforms and Their Applications. 3rd Edition. Springer-Verlag.
2. J. W. Miles. 2008. Integral Transforms in Applied Mathematics. 1st Edition. Cambridge University Press.
3. L. Debnath, D. Bhatta. 2014. Integral Transforms and Their Applications. 3nd Edition. Chapman & Hall/CRC.
4. M. Y. Antimirov, A. A. Kolyshkin, R. Vaillancourt. 2007. Applied Integral Transforms. 1st Edition. American Mathematical Society.

Course Title: **Heat Transfer**

Course Code: **MTH-720**

Credit Hours: **3(3-0)**

AIMS AND OBJECTIVES:

The aim of the course is to describe the ideas Heat Transfer and indicate their applications in fields such as Fluid Mechanics and Viscous Fluid.

THEORY:

The importance of heat transfer. the fundamental laws of conductions. the fundamental laws of convection. the fundamental laws of radiation. material properties of importance in heat transfer. steady state heat conduction in one dimension. the critical thickness of pipe insulation. heat conduction in two or more independent variables. numerical methods for heat conduction. the fundamental principles of viscous. steady state conduction in rectangular plates. transient conduction in the infinite slab. fluid motion and boundary layer motion. examples of analytic solutions to problems of forced convection. Some exposure will also be given from the recent literature appearing in the journals.

RECOMMENDED BOOKS:

1. A. Bejan, A. D. Kraus. 2003. Heat Transfer Handbook. 1st Edition. Willy Interscience.

2. A. J. Chapman. 2001. Heat Transfer. Fourth Edition. Prentice Hall .

3. D. R. Pitts, L. E. Sisson. 2001. Schaum's Outlines of Heat Transfer. 1st Edition. Mc-Graw Hill.

4. J. H. Lienhardt IV, J. H. Lienhardt V. 2003 . A Heat Transfer Textbook. 1st Edition. Philogeston Press.

Course Title: **Viscous fluid flow**

Course Code: **MTH-721**

Credit Hours: **3(3-0)**

AIMS AND OBJECTIVES:

The aim of the course is to describe the ideas of viscous flow and indicate their applications in fields such as Fluid Mechanics and Viscous Fluid.

THEORY:

Some examples of viscous flow phenomena. properties of fluids. boundary conditions. equation of continuity. the Navier-Stokes' equations. the energy equation; boundary conditions. orthogonal coordinate system. dimensionless parameters. velocity considerations. two dimensional considerations and the stream functions. Coutte flows. Poissillee flow. unsteady duct flows. similarity solutions. some exact analytic solution from the paper. introduction to laminar boundary layers equations. similarity solutions. two dimensional solutions. thermal boundary layer. Some exposure will also be given from the recent literature appearing in the journals.

RECOMMENDED BOOKS:

1. F. M. White. 2006.Viscous Fluid Flow. 1st Edition. McGraw-Hill .

2. G. K. Batchelor. 2001. An Introduction to Fluid Dynamics. 1st Edition. Cambridge University Press .

3. H. Ockendon. 2001. Viscous flow. 1st Edition. Cambridge University Press .

4. P. K. Kundu. 2001. Fluid Mechanics. 1st Edition. Academic Press .

Course Title: **Convex Analysis**

Course Code: **MTH-722**

Credit Hours: **3(3-0)**

AIMS AND OBJECTIVES:

The aim is to develop the core analytical and algorithmic issues of continuous optimization. duality. and saddle point theory using a handful of unifying principles that can be easily visualized and readily understood.

THEORY:

Convex functions on the real line. continuity and differentiability of convex functions. characterizations. differences of convex functions. conjugate convex functions. convex sets and affine sets. convex functions on a normed linear space. continuity of convex functions on normed linear space. differentiable convex function on normed linear space. support of convex functions. differentiability of convex function on normed linear space. Some exposure will also be given from the recent literature appearing in the journals.

RECOMMENDED BOOKS:

1. A. W. Roberts, D. E. Varberg. 2001. Convex Functions. 1st Edition. Academic Press. New York.

2. J. M. Borwien, A. S. Lewis. 2010. Convex Analysis and Nonlinear Optimization: Theory and Examples. (CMS Books in Mathematics). Edition. Springer.

3. C. P. Niculescu, L. E. Person. 2006. Convex Functions and Their Applications. 1st Edition. Springer -Verlag. New York.

4. R. T. Rockefeller. 2001. Convex Analysis. Princeton University Press. Princeton. N.J.

Course Title: **Inequalities Involving Convex Functions**

Course Code: **MTH-723**

Credit Hours: **3(3-0)**

AIMS AND OBJECTIVES:

The aim of the course is to describe the ideas of Inequalities Involving Convex Functions and indicate Convex functions play an important role in many branches of mathematics. as well as other areas of science and engineering. In this course. we will discuss the definition of convex. look at convex shapes and convex functions. and learn how to identify them through rules and examples.

THEORY:

Jensen’s and related inequalities. some general inequalities involving convex functions. Hadamard’s inequalities. inequalities of Hadamard type I. inequalities of Hadamard type II. some inequalities involving concave functions. miscellaneous inequalities. Some exposure will also be given from the recent literature appearing in the journals.

RECOMMENDED BOOKS:

1. B. G. Pachpatte. 2005. Mathematical Inequalities. North-Holland Mathematical Library. Vol. 67. Elsevier.
2. D. S. Mitrinovic. J. Pecaric, A. M. Fink. 2000. Classical and New Inequalities in Analysis. Kluwer Academic Publishers. Netherlands.
3. J. Pecaric. F. Proschan, Y. C. Tong. 2002. Convex Functions. Partial Orderings and Statistical Applications. Vol. 187 of Mathematics in Science and Engineering. Academic Press Boston Mass. USA.
4. R. Bhatia. 2002. Matrix Analysis. Springer-Verlag. New York.

Course Title: **Perturbation Methods**

Course Code: **MTH-724**

Credit Hours: **3(3-0)**

AIMS AND OBJECTIVES:

The aims of the course are to give a clear and systematic account of modern perturbation theory and to show how it can be applied to differential equations. Perturbation methods underlie numerous applications of physical applied mathematics: including boundary layers in viscous flow. celestial mechanics. optics. shock waves. reaction-diffusion equations. and nonlinear oscillations.

THEORY:

Introduction to perturbation expansion. singular and regular perturbation. boundary layers. harmonic approximations. Beats phenomena. method of averages. perturbation and ordinary differential equation. perturbation and partial differential equation. heat conduction with slow radiation. non-linear Klein-Gordon equation. perturbation for eigen - value problems. integrals. the method of stationary phase. asymptotic analysis of telegraph equations. the method of steepest descent. correlation functions. Wiener-Hopf method. homotopy perturbation method. homotopy analysis method. Some exposure will also be given from the recent literature appearing in the journals.

RECOMMENDED BOOKS:

1. A. H. Nafeh. 2000. Perturbation Methods. 1st Edition. John Wiley & Sons.

2. A. H. Nafeh. 2001. Problems in Perturbation. 1st Edition. John Wiley & Sons.

3. A. W. Bush. 2001. Perturbation Methods for Engineers and Scientists. 1st Edition. John Wiley & Sons.

4. C. M. Bender, S. A. Orszag. 2001. Advanced Mathematical Methods for Scientists and Engineers. 1st Edition. McGraw-Hill. Inc.

5. S. Liao. 2003. Beyond Perturbation. 1st Edition. Chapman & Hall/CRC.

Course Title: **Theory of Interpolation Spaces**

Course Code: **MTH-725**

Credit Hours: **3(3-0)**

AIMS AND OBJECTIVES:

The aim of the course is to describe the ideas of Interpolation Spaces and interpolation space is a space which lies "in between" two other Banach spaces. The main applications are in Sobolev spaces, where spaces of functions that have a noninteger number of derivatives are interpolated from the spaces of functions with integer number of derivatives.

THEORY:

Compatible couples, the sum and intersection spaces, intermediate spaces, interpolation spaces, K-functional, K-interpolation spaces, interpolation of LP-spaces, non-increasing rearrangement elements, formula for the K-functional for the couple (L1 , L∞), Lorentz spaces as

interpolation spaces. Marcinkiewiz interpolation theorem, Holmstedt's formula, the classical reiteration theorem, slowly varying function, Holmstedt's type formulae, the generalized reiteration theorems, reiteration in limiting cases. Some exposure will also be given from the recent literature appearing in the journals.

RECOMMENDED BOOKS:

1. C. Bennett & R. Sharpley. 2000. Interpolation of operators. Academic Press. New York.
2. J. Berg & J. Lofstrom 2000. Interpolation Spaces. An Introduction. Springer-Verlag. New York.
3. J. A. Brudnyi & N. J. Krigliak 2000. Interpolation Spaces and Interpolation Function. North-Holland. Amsterdam.
4. L. Tarter 2007. An Introduction to Sobolev Spaces and Interpolation Spaces. Springer Verlag. Berlin .

Course Title: **Variational Inequalities and its Applications**

Course Code: **MTH-726**

Credit Hours: **3(3-0)**

AIMS AND OBJECTIVES:

The aim of the course is to describe the ideas of Variational Inequalities and they are shown to be extremely useful across a wide variety of subjects, ranging from linear programming to free boundary problems in partial differential equations. Exciting new areas like finance and phase transformations along with more historical ones like contact problems have begun to rely on variational inequalities, making this book a necessity once again.

THEORY:

Basic concepts, existence and uniqueness results. Fixed-points formulation, Wiener-Hopf equations, equivalence between variational inequalities and Wiener-Hopf equations, iterative methods, auxiliary principle techniques, dynamical systems, sensitivity analysis, convergence analysis, numerical solutions of obstacle problems, variational inclusions, resolvent equations, applications , equilibrium problems. Some exposure will also be given from the recent literature appearing in the journals.

RECOMMENDED BOOKS:

1. A. Baiocchi, A. Capelo. 2000. Variational and Quasi-Variational Inequalities. John Wiley and Sons. New York.
2. D. Kinderlehrer, G. Stampacchia. 2000. An Introduction to Variational Inequalities and their Applications. SIAM Publications. Phildelphia.
3. M. A. Noor. 2009. Principles of Variational Inequalities. Lap-Lambert Academic Publishing AG & Co. Saarbrucken.
4. A.S. Kravchuk, P. J. Neittaanmaki. 2007. Variational and Quasi-Variational Inequalities in Mechanics. Springer. Dordrecht.

Course Title: **Integral Equations**

Course Code: **MTH-727**

Credit Hours: **3(3-0)**

AIMS AND OBJECTIVES:

In mathematics, an integral equation is an equation in which an unknown function appears under an integral sign. There is a close connection between differential and integral equations, and some problems may be formulated either way. See, for example, Green's function, Fredholm theory, and Maxwell's equations.

THEORY:

Linear integral equations of the first kind. Linear integral equations of the second kind. Relationship between differential equation and Volterra integral equation. Newmann series. Fredholm Integral equation of the second kind with separable Kernels. Eigenvalues and eigenvectors. Iterated functions. Quadrature methods. Least square methods. Homogeneous integral equations of the second kind. Fredholm integral equations of the second kind. Fredholm integral equations of the first kind. Abel's integral equations. Hilbert Schmidt theory of integral equations with symmetric Kernels. Regularization and filtering techniques. Some exposure will also be given from the recent literature appearing in the journals.

RECOMMENDED BOOKS:

1. C. T. H.Baker.2000. Integral Equations. Clarendon Press.
2. F. Smithies. 2000. Integral Equations. Cambridge University Press.
3. W. Squire. 2000. Integration for Engineers and Scientists. American Elsevier. New
4. A. M. Wazwaz. 2000. A First Course in Integral Equations. World Scientific Pub.
5. W. V. Lovitt. 2005 Linear Integral Equations (Dover Publication). New York.

Course Title: **Theory of Majorization**

Course Code: **MTH-728**

Credit Hours: **3(3-0)**

AIMS AND OBJECTIVES:

The aim of the course is to describe the ideas of Majorization. In mathematics, Majorization is a preorder on vectors of real numbers. Majorization is a partial ordering and precisely defines the vague notion that the components of a vector are "less spread out" or "more nearly equal" than the components of another vector. Functions that preserve the ordering of majorization are said to be Schur-convex or Schur-concave.

THEORY:

Motivation and basic definitions, majorization as a partial ordering, order-preserving functions, partial orderings induced by convex cones, partial orderings, generated by groups of transformations, majorization for vectors of unequal length, majorization for infinite sequences, majorization for matrices, Lorenz ordering, majorization and dilations, convex Majorization. Some exposure will also be given from the recent literature appearing in the journals.

RECOMMENDED BOOKS:

1. A. W. Marshall, I. Olkin, B. Arnold. Inequalities. 2011. Theory of Majorization and Its Applications. 2nd Edition. Springer.
2. R. Bhatia. 2000. Matrix Analysis. Springer-Verlag. New York.
3. J. Pecaric, F. Proschan , Y. C. Tong.2000. Convex Functions. Partial Orderings and Statistical Applications. Vol. 187 of Mathematics in Science and Engineering. Academic Press. Boston Mass. USA.
4. D. S. Mitrinovic, J. Pecaric, A. M. Fink. 2000. Classical and New Inequalities in Analysis. Kluwer Academic Publishers. Netherlands.

Course Title: **Homological Algebra**
Course Code: **MTH-732**
Credit Hours: **3(3-0)**

AIMS AND OBJECTIVES:
Homological algebra is the branch of mathematics that studies homology in a general algebraic setting. It is a relatively young discipline, whose origins can be traced to investigations in combinatorial topology (a precursor to algebraic topology) and abstract algebra (theory of modules and syzygies).

THEORY:

Chain complexes, Snake theorem, resolution, projective, injective and flat modules, Ext and Tor. derived functors, dimension (Projective, Global) of rings, bi-complexes, Kunneth theorems, and spectral sequences. Some exposure will also be given from the recent literature appearing in the journals.

RECOMMENDED BOOKS:

1. J. Rotman. 2008 An Introduction to Homological Algebra. 2nd Edition. Springer.
2. C. A. Weibei. 2000 An Introduction to Homological Algebra. Cambridge University Press.
3. P. J. Hilton, U. Stammbach. 2000. A Course in Homological Algebra. Springer-Verlag.
4. L. R. Vermani. 2003. An Elementary Approach to Homological Algebra. Chapmann & Hall/CRC.

Course Title: **Advanced Number Theory**

Course Code: **MTH-733**

Credit Hours: **3(3-0)**

AIMS AND OBJECTIVES:

Number theory is a vast and fascinating field of mathematics, sometimes called "higher arithmetic," consisting of the study of the properties of whole numbers. Primes and prime factorization are especially important in number theory, as are a number of functions such as the divisor function, Riemann zeta function, and totient function.

THEORY:

A spectacular development (Proof of Fermat's Last Theorem for n=3, 4). Gauss's Quadratic reciprocity law. The Jacobi symbol and applications of Gaussian integers. The ring Z[ ], Finite fields. Primitive polynomials. Irreducibility. Gauss lemma and Eisenstein criterion of irreducibility. Number fields and integral dependence. Integers in number fields. Cyclotomic polynomials and fields Class groups. Discriminants. Some results from geometry of numbers. Dirichlet's theorem. Splitting of rational primes. The group of units and Norm-Euclidean number fields. Some exposure will also be given from the recent literature appearing in the journals.

RECOMMENDED BOOKS:

1. P. Harry, G. D. Harold. 2000. The Theory of Algebraic Numbers (The Mathematical Association of America.
2. G. H. Hardy, E. M. Wright. 2000 . An Introduction to the Theory of Numbers. Oxford University Press.
3. A. M. Daniel. 2000. Number Fields. Springer-Verlag.
4. B. N. Melvyn. 2000. Methods in Number Theory. Springer-Verlag.
5. E. Grosswald. 2000. Topics From The Theory of Numbers.The Macmillan Company. Narosa.

Course Title: **Field Extensions & Galois Theory**

Course Code: **MTH-734**

Credit Hours: **3(3-0)**

AIMS AND OBJECTIVES:

The aim of the course is to describe the ideas of Field Extensions & Galois Theory and in modern mathematics, the theory of fields (or field theory) plays an essential role in number theory and algebraic geometry.

THEORY:

Extension of a field. Degree of an extension. Finite extensions. Algebraic and transcendental elements, Algebraic extension. Roots of a polynomial. Splitting extension. Automorphisms of a field. Fixed field of a group of homomorphisms. Normal extensions. Galois extensions. Fixed field of a group. Galois group of a polynomial. The fundamental theorem of Galois Theory. Some exposure will also be given from the recent literature appearing in the journals.

RECOMMENDED BOOKS:

1. I. N. Herstein. 2000. Topics in Algebra. 2nd Edition. Lexington Xerox College Publishing.
2. E. Artin. 2000. Galois Theory. 2nd Edition. Notre Dame Univ. Indiana.
3. I. Stewart. 2000. Galois Theory. 2nd Edition. Chapman and Hall.
4. W. Ledermann. 2000. Introduction to Group Theory (Oliver and Boyd).
5. F. Borceux , G. Janelidze. 2003. Galois Theories (Cambridge University Press).

Course Title: **Linear Groups & Group Representations**

Course Code: **MTH-735**

Credit Hours: **3(3-0)**

AIMS AND OBJECTIVES:

In the mathematical field of representation theory, group representations describe abstract groups in terms of linear transformations of vector spaces; in particular, they can be used to represent group elements as matrices so that the group operation can be represented by matrix multiplication. They are also important in physics because, for example, they describe how the symmetry group of a physical system affects the solutions of equations describing that system.

THEORY:

Direct Products. Classification of Finite Abelian Groups. Semidirect Products. Extensions. Central and Cyclic Extensions. General Linear Groups. Special and Projective Linear Groups. Tvansvections. Generators of Linear Groups. Exceptional Isomorphism. Simple Linear Groups. Classification of Groups with at most 31 elements. Some exposure will also be given from the recent literature appearing in the journals.

RECOMMENDED BOOKS:

1. G. James, M. Lieback. 2001 Representations and Characters of Groups (Cambridge University Press).
2. H. S. M. Coxeter, W. J. Moser. 2000. Generators and Relations for Discrete Groups (Springer Verlag)
3. J. J. Rotman. 2000. An Introduction to The Theory of Group (Allyn and Bacon).
4. W. Lederman. 2000. Introduction to Group Character (Cambridge University Press).
5. J. L. Alperin , R.B. Bell. 2000. Groups and Representations (Springer).
6. J. F. Humphreys. 2004. A Course in Group Theory (Oxford University Press).

Course Title: **Operator Theory**

Course Code: **MTH-736**

Credit Hours: **3(3-0)**

AIMS AND OBJECTIVES:

In mathematics, operator theory is the study of linear operators on function spaces, beginning with differential operators and integral operators. The operators may be presented abstractly by their characteristics, such as bounded linear operators or closed operators, and consideration may be given to nonlinear operators.

THEORY:

Spectral Theory of Linear operators in Normal spaces: Spectral theory in finite dimensional normed spaces. Basic concepts. Spectral properties of bounded liner operators. Further properties of resolvent and spectrum. Use of complex analysis in spectral theory. Basic algebras. Further properties of Banach algebra. Compact linear Operators on Normed Spaces and their Spectrum: Compact linear operators on normed spaces. Further properties of compact linear operators. Special properties of compact liner operators on normed spaces.

Spectral Theory of Bounded Self-Adjoint Operators linear operators: Spectral properties. Operations of bounded self adjoint linear operators. Positive operators. Square roots of positive operators. Projection operators. Some exposure will also be given from the recent literature appearing in the journals.

RECOMMENDED BOOKS:

1. C. L. DeVito. 2000. Functional Analysis and Linear Operator Theory. Addison Wesley Publishing Co.
2. E. Kreyszig. 2000. Introductory Functional Analysis with Applications. John Wiley.
3. E. B. Davis. 2000. Spectral Theory and Differential Operators. Cambridge University Press.
4. L. Nachbin. 2000. Introduction to Functional Analysis: Branch Spaces and Differential Calculus (Marcel Dekker. Inc).

Course Title: **Fuzzy Algebra**

Course Code: **MTH-737**

Credit Hours: **3(3-0)**

AIMS AND OBJECTIVES:

The main aim of this paper is to discuss the basic ideas and concepts of fuzzy algebra.

THEORY:

Introduction, The Concept of Fuzziness Examples, Mathematical Modeling, Operations of fuzzy sets, Fuzziness as uncertainty. Algebra of Fuzzy Sets: Boolean Algebra and lattices, Equivalence relations and partitions, Composing mappings, Alpha-cuts, Images of alpha-level sets, Operations on fuzzy sets. Fuzzy Relations: Definition and examples, Binary Fuzzy relations Operations on Fuzzy relations, fuzzy partitions. Fuzzy Semigroups: fuzzy ideals of semigroups, Fuzzy quasi-ideals, Fuzzy bi-ideals of Semigroups, Characterization of different classes of semigroups by the properties of their fuzzy ideals fuzzy quasi-ideals and fuzzy bi-ideals. Fuzzy Rings: Fuzzy ideals of rings, Prime, semiprime fuzzy ideals, Characterization of rings using the properties of fuzzy ideals

RECOMMENDED BOOKS:

1. Hung T. Nguyen and A First course in Fuzzy Logic, Chapman and Hall/CRC Elbert A. Walker 1999.

2. M. Ganesh, Introduction to Fuzzy Sets and Fuzzy Logic, Prentice-Hall of India, 2006.

3. John N. Mordeson and Fuzzy Commutative algebra, World Scientific, 1998.D.S. Malik,

4. John N. Mordeson, Fuzzy Semigroups, Springer-Verlage, 2003. D.S. Malik and Nobuki Kuroki

Annexure “A”

COMPULSORY MATHEMATICS COURSES FOR BS (4 YEAR)

(FOR STUDENTS NOT MAJORING IN MATHEMATICS)

Course Title: **Mathematics I**
Course Code: **MTH-321**
Credit Hours: **3(3-0)**

AIMS AND OBJECTIVES:

To prepare the students, not majoring in mathematics, with the essential tools of algebra to apply the concepts and the techniques in their respective disciplines.

THEORY:

Preliminaries: Real-number system, complex numbers, introduction to sets, set operations, functions, types of functions.
Matrices: Introduction to matrices, types, matrix inverse, determinants, system of linear equations, Cramer’s rule.
Quadratic Equations: Solution of quadratic equations, qualitative analysis of roots of a quadratic equations, equations reducible to quadratic equations, cube roots of unity, relation between roots and coefficients of quadratic equations.
Sequences and Series: Arithmetic progression, geometric progression, harmonic progression. Binomial Theorem: Introduction to mathematical induction, binomial theorem with rational and irrational indices.
Trigonometry: Fundamentals of trigonometry, trigonometric identities.

RECOMMENDED BOOKS:

1. J. E .Kaufmann, College Algebra and Trigonometry, PWS-Kent Company, Boston
2. M. P. Dolciani, W.Wooton, E. F.Beckenback, S. Sharron. Algebra 2 and Trigonometry, Houghton & Mifflin, Latest Edition
3. W. E. Swokowski, Fundamentals of Algebra and Trigonometry. PWS-Kent Company, Boston.

Course Title: **Mathematics II**
Course Code: **MTH-322**
Credit Hours: **3(3-0)**

AIMS AND OBJECTIVES:

To prepare the students, not majoring in mathematics, with the essential tools of calculus to apply the concepts and the techniques in their respective disciplines.

THEORY:

Preliminaries: Real-number line, functions and their graphs, solution of equations involving absolute values, inequalities.
Limits and Continuity: Limit of a function, left-hand and right-hand limits, continuity, continuous functions.
Derivatives and their Applications: Differentiable functions, differentiation of polynomial, rational and transcendental functions, derivatives.
Integration and Definite Integrals: Techniques of evaluating indefinite integrals, integration by substitution, integration by parts, change of variables in indefinite integrals.

RECOMMENDED BOOKS:

1. B. G. Thomas. A. R. Finney. Calculus. Addison-Wesley, Reading, Ma, USA. Latest Edition.
2. H. B. Anton, I. Davis.Calculus: A New Horizon. John Wiley. Latest Edition.
3. J. Stewart, Calculus. Brooks/Cole. Latest Edition.
4. W. Swokowski. Calculus and Analytic Geometry. PWS-Kent Company. Boston. Latest Edition.

Course Title: **Calculus and Analytic Geometry**
Course Code: **MTH-323**
Credit Hours: **3(3-0)**

AIMS AND OBJECTIVES:

To prepare the students, not majoring in mathematics, with the essential tools of calculus and geometry to apply the concepts and the techniques in their respective disciplines.

THEORY:

Complex Numbers, DeMoivre's Theorem and its Applications, Simple Cartesian Curves, Functions and Graphs, Symmetrical Properties, Curve Tracing, Limit and Continuity, Differentiation of Functions. Derivative as Slope of Tangent to a Curve and as Rate of Change, Application to Tangent and Normal, Linearization, Maxima/Minima and Point of Inflexion, Taylor and Maclaurin Expansions and their convergence; Integral as Anti-derivative, Indefinite Integration of Simple Functions. Methods of Integration: Integration by Substitution, by Parts, and by Partial Fractions, Definite Integral as Limit of a Sum, Application to Area, Arc Length, Volume and Surface of Revolution.

RECOMMENDED BOOKS:

1. G. B. Thomas, A. R. Finney Calculus,Addison-Wesley, Reading,Ma,USA. Latest Edition.
2. H.B .Anton, I.Davis. Calculus:A New Horizon, John Wiley, Latest Edition.
3. J.Stewart.Calculus, Brooks/Cole. Latest Edition.
4. W.Swokowskie .Calculus and Analytic Geometry , PWS-KentCompany, Boston, Latest Edition.

Course Title: **Mathematics III**
Course Code: **MTH-324**
Credit Hours: **3(3-0)**

AIMS AND OBJECTIVES:

To prepare the students, not majoring in mathematics, with the essential tools of geometry to apply the concepts and the techniques in their respective disciplines.

THEORY:

Geometry in Two Dimensions: Cartesian-coordinate mesh, slope of a line, equation of a line, parallel and perpendicular lines, various forms of equation of a line, intersection of two lines, angle between two lines, distance between two points, distance between a point and a line.
Circle: Equation of a circle, circles determined by various conditions, intersection of lines and circles, locus of a point in various conditions.
Conic Sections: Parabola, ellipse, hyperbola, the general-second-degree equation

RECOMMENDED BOOKS:

1. J. E. Kaufmann, College Algebra and Trigonometry, PWS-Kent Company, Boston, Latest Edition.
2. S. Abraham, Analytic Geometry, Scott, Freshman and Company, Latest Edition.
3. W. E. Swokowski, Fundamentals of Algebra and Trigonometry, PWS-Kent Company, Boston, Latest Edition.

Course Title: **Multivariable Calculus**
Course Code: **MTH-325**
Credit Hours: **3(3-0)**

AIMS AND OBJECTIVES:

To prepare the students, not majoring in mathematics, with the essential tools of calculus and geometry to apply the concepts and the techniques in their respective disciplines.

THEORY:

Functions of Several Variables and Partial Differentiation. Multiple Integrals, Line and Surface Integrals. Green's and Stoke's Theorem. Fourier Series: periodic functions, Functions of any period P-2L, Even & odd functions, Half Range expansions, Fourier Transform; Laplace Transform, Z-Transform.

RECOMMENDED BOOKS:

1. A. Kaseberg. 2004. Intermediate Algebra, Thomson Brooks/COLE.
2. C.H. Edward and E.D Penney, Calculus and Analytics Geometry, Prentice Hall, Inc.
3. E. W. Swokowski, Calculus with Analytic Geometry,PWS Publishers, Boston, Massachusetts.
    A. Jr Frank, Elliott Mendelson, Calculus, Schaum's outlines series, 4th Edition.
4. H. Anton, I. Bevens, S. Davis. 2005. Calculus, 8th Edition, John Wiley &Sons, Inc.
5. Hughes-Hallett, Gleason, McCallum, et al. 2002.Single and Multivariable Calculus. Edition 3rd John Wiley & Sons, Inc. A. Jr.
6. J. Stewart. Multivariable Calculus. Latest Edition. Cengage Learning Publishers.
7. Thomas. 2005. Calculus. 11th Edition. Addison Wesley Publishing Company.