ABDUL WALI KHAN UNIVERSITY MARDAN
DEPARTMENT OF MATHEMATICS
BS-Scheme of Studies in Mathematics

Semester-wise break up

First Year

Semester-I						Semester-II					
Code	**Title**	**Credit hours**				**Code**	**Title**	**Credit hours**			
EW-301	English-I	3	0	3		EW-302	English-II	3	0	3	
CV-301	Islamic Studies	3	0	3		CV-302	Pak Studied	3	0	3	
code	QR-I	3	0	3		Code	QR-II	3	0	3	
code	SS-I	3	0	3		Code	AH-II	3	0	3	
code	AH-I	3	0	3		Code	NS-I	3	0	3	
Total Cr. Hrs		**15**	**0**	**15**		**Total Cr. Hrs**		**15**	**0**	**15**	

Second Year

Semester-III						Semester-IV					
Code	**Title**	**Credit Hours**				**Code**	**Title**	**Credit hours**			
MATH-401	Mechanics-I	3	0	3		MATH-451	Research Methods	3	0	3	
MATH-402	Calculus	3	0	3		MATH-452	Topology-I	3	0	3	
code	NS-II	3	0	3		MATH-453	Advanced Calculus	3	0	3	
EW-303	English-III	3	0	3		MATH-454	Group Theory-I	3	0	3	
code	SS-II	3	0	3		MATH-455	Differential Equations-I	3	0	3	
Total Cr. Hrs		**15**	**0**	**15**		**Total Cr. Hrs**		**15**	**0**	**15**	

Third Year

Semester-V						Semester-VI					
Code	**Title**	**Credit hours**				**Code**	**Title**	**Credit hours**			
MATH-501	Real Analysis	3	0	3		MATH-551	Linear algebra II	3	0	3	
MATH-502	Group Theory II	3	0	3		MATH-552	Complex Analysis	3	0	3	
MATH-503	Diff. Geometry	3	0	3		MATH-553	Mechanics-II	3	0	3	
MATH-504	Linear Algebra -1	3	0	3		MATH-554	Numerical Methods	3	0	3	
MATH-505	Diff. Equations-II	3	0	3		MATH-555	Functional Analysis I	3	0	3	
MATH-506	Multivariable Calculus	3	0	3		MATH-556	Part. Diff. Equations	3	0	3	
Total Cr. Hrs		**18**	**0**	**18**		**Total Cr. Hrs**		**18**	**0**	**18**	

Fourth Year

Semester-VII						Semester-VIII				
Code	**Title**	**Credit hours**				**Code**	**Title**	**Credit hours**		
MATH-	Elective I	3	0	3		MATH-	Elective V	3	0	3
MATH-	Elective II	3	0	3		MATH-	Elective VI	3	0	3
MATH-	Elective III	3	0	3		MATH-	Elective VII	3	0	3
MATH-	Elective IV	3	0	3		MATH-	Elective VIII	3	0	3
MATH-799	Project	3	0	3		MATH-799	Project	3	0	3
Total Cr. Hrs		**15**	**0**	**15**		**Total Cr. Hrs**		**15**	**0**	**15**

Note: ***Student coming from other disciplines in associate degree program should take the following courses as bridging semester for enrolment into BS in Mathematics.***

Bridging Semester				
Code	**Title**	**Credit hours**		
MATH-401	Mechanics-I	3	0	3
MATH-402	Calculus	3	0	3
MATH-451	Research Methods	3	0	3
MATH-452	Topology-I	3	0	3
MATH-453	Advanced Calculus	3	0	3
MATH-454	Group Theory-I	3	0	3
MATH-455	Differential Equations-I	3	0	3

List of Mathematics Core Courses

S. No	Subject Code	Subject	Cr. Hrs
1	MATH-401	Mechanic-1	3
2	MATH-402	Calculus	3
3	MATH 451	Research Methods	3
4	MATH-452	Topology-I	3
5	MATH-453	Advanced Calculus	3
6	MATH-454	Group Theory-I	3
7	MATH-455	Differential Equations-I	3
8	MATH-501	Real Analysis	3
9	MATH-502	Group Theory II	3
10	MATH-503	Diff. Geometry	3
11	MATH-504	Linear Algebra -1	3
12	MATH-505	Diff. Equations-II	3
13	MATH-506	Multivariable Calculus	3
14	MATH-551	Linear Algebra II	3
15	MATH-552	Complex Analysis	3
16	MATH-553	Mechanics-II	3
17	MATH-554	Numerical Methods	3
18	MATH-555	Functional Analysis I	3
19	MATH-556	Part. Diff. Equations	3

List of Mathematics Elective Courses

S. No	Subject Code	Subject	Cr. Hrs
1	MATH-601	Numerical Analysis	3
2	MATH-602	Mathematical Statistics-I	3
3	MATH-603	Mathematical Statistics-II	3
4	MATH-604	Operations Research	3
5	MATH-605	Optimization theory	3
6	MATH-606	Commutative Rings and Algebraic Field Extension	3
7	MATH-607	Introduction to Algebraic Coding Theory	3
8	MATH-608	Advanced Algebraic Coding Theory	3
9	MATH-609	Theory of Modules	3
10	MATH-610	Primary Decomposition of Rings and Modules	3
11	MATH-611	Measures and Integrations	3
12	MATH-612	Introduction to Probability Models	3
13	MATH-613	Introduction to Combinatorics	3
14	MATH-614	Group Algorithms Programming	3
15	MATH-615	Algebraic Topology	3
16	MATH-616	Advanced Topology	3
17	MATH-617	Advanced Functional Analysis	3
18	MATH-618	Advanced Group Theory	3
19	MATH-619	Rings and Fields	3
20	MATH-620	Elasticity Theory	3
21	MATH-621	Analytical Dynamics	3
22	MATH-622	Introduction to Quantum Mechanics	3
23	MATH-623	Integral Equation	3
24	MATH-624	Fluid Mechanics-I	3
25	MATH-625	Fluid Mechanics-II	3
26	MATH-626	Electromagnetism	3
27	MATH-627	Riemannian Geometry	3
28	MATH-628	Special Relativity	3
29	MATH-629	General Relativity	3
30	MATH-630	Continuous Groups	3
31	MATH-631	Fuzzy Set Theory	3
32	MATH-699	Project	3
33	MATH-699	Viva	3
			3

MATH-401 MECHANICS-I

Prerequisites: Calculus I and Basic Mathematics

Specific Objectives of course: 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.

Vectors Part

Vector algebra: Scalar and vector product Scalar triple product and vector triple product, Applications to geometry, Vector equation of a line and plane, Scalar and vector fields, The gradient, divergence and curl, Expansion formulas.

Mechanics Part:

Forces: Fundamental concepts and principles, Inertial-non-inertial frames, Newton's laws Resultant of several concurrent forces, The parallelogram law of forces, Resolution of a forces, triangle of forces, Lamy's theorem, polygon of forces, Conditions of equilibrium for a particle, External and internal forces, principle of transmissibility, Resultant of like and unlike parallel forces, Moment of forces about a point, Varigon's theorem, Moment of a couple, equivalent couples, composition of couples, Reduction of coplanar forces to a force or a couple

Friction: Dry friction and fluid friction, Laws of dry friction, coefficients of friction, angle of friction, Equilibrium of a particle on a rough inclined plane, Particle on a rough inclined plane acted on by an external force, Conditions for sliding or titling

Centre of Mass and Gravity: Discrete and continuous systems, density of rigid and elastic bodies, Centroid. Discrete and continuous systems, solid region, region bounded by planes, Semicircular regions, sphere, hemisphere, cylinder and cone

Recommended Books:

1. Murray R. Spiegel, Vector Analysis,Schaum's Outline SeriesMcGraw Hill Book Company, 2005.
2. Fowles, G.R, Cassiday, G.L. Analytical Mechanics, 7 Edition, Thomson Brook Cole, 2005.
3. Jafferson, B. Beasdsworth, T. Further Mechanics, Oxford University Press280.
4. Murray R. Spiegel, Theoretical Mechanics,Schaum's Outline Series, Me Graw Hill Book Company.
5. D.K. Anand and P.F. Cunnif, Statics and Dynamics, Allyn and Becon, lac. 1914.

MATH-402 CALCULUS

Credit Hours 03

Prerequisites: Basic Mathematics

Specific Objectives of course: This is continuation of Basic Mathematics, it focuses on techniques and applications of Differentiation. The course also aims at introducing the students to Limits and continuity.

Course Outline

Limits and continuity, rates of change and limits, calculating limits using limits laws, one sided limits and limits at infinity, vertical asymptotes, Continuity, Tangents and derivatives, derivatives as function, Differentiation rules, the derivatives as rate of change, derivatives of trigonometric functions, the chain rule and parametric equations, implicit differentiation, related rates, extreme values of functions, the mean value theorem, monotonic function and first order derivative test, Intermediate forms and L' Hopital's rule, antiderivatives

Recommended Books:

1. Frank A. Jr, Elliott Mendelson, Calculus, Schaum's outlines series, 4th Edition, 1999.
2. E. W. Swokowski, Calculus and Analytic Geometry, PWS Publishers, Boston Massachusetts, **1983**
3. C.H. Edward and E.D Penney, Calculus and Analytics Geometry, Prentice Hall, Inc. 1988.
4. E. W. Swokowski, Calculus and Analytic Geometry, PWS Publishers, Boston Massachusetts, 1983
5. Thomas, Calculus, 11th Edition. Addison Wesley Publishing Company, 2005.

MATH-451 RESEARCH METHODS

Matlab, Mathematica, Latex, Scientific Work Place

MATH-452 TOPOLOGY-I

Course Outline

Topological space, Open and closed sets, subspaces, Neighborhoods, limit points, closure of a set, Interior, exterior and boundary of a set, Base and sub base, Neighborhood bases, First and second axioms of countability, Definition and various examples of metric spaces, Open ball (or open sphere) and closed balls, Separable spaces, Continuous functions and homeomorphism, Separation axioms T1 and T2 spaces and their characterization, Regular spaces, connected spaces, disconnected spaces. Topology induced by a metric, Cauchy sequence, complete metric spaces.

MATH-453 ADVANCED CALCULUS

Credit Hours: 3

Prerequisites: Calculus

Specific Objectives of course: This is second course of Calculus and builds up on the concepts learned in calculus. The students would be introduced to techniques and applications of integrals. The course also aims at introducing the students to Analytical Geometry and applications.

Course Outline:

Integration; Estimating with finite sums; sigma notation and limits of finite sums; the definite integral; the fundamental theorem of calculus; indefinite integrals and substitution rule; substitution and area between curves; Application of definite integrals; Volumes by slicing and rotation about an axis; Volume by cylindrical shells; Length of plane curves; Inverse function and their derivatives; Natural logarithms; the exponential

functions; a^x and $\log_a x$; Inverse trigonometric functions; Hyperbolic functions; Basic Integration formulas; Integration by parts; Integration of rational functions by partial fractions; Trigonometric integrals; Trigonometric substitutions; Numerical integrals; Improper integrals; Slopes Fields and separable differential equations; First order differential equation;

Recommended Books;

1. Thomas, Calculus, 11th Edition. Addison Wesley Publishing Company, 2005
2. H.Anton, I. Bevens, S. Davis, Calculus, 8th Edition, John Wiley & Sons, In. 2005
3. Adler, Andrew, Coury, John E. The Theory of Numbers, Jones and Barttlet Publishers, Boston, 1995.
4. Burton, D.M. Elementary Number Theory McGraw Hill, 2000.

MATH-454: GROUP THEORY-1

Credit Hours 03

Prerequisites: Basic Mathematics

Specific Objectives of course: This course introduces basic concepts of groups and their homomorphism. 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. After completion of this course, they would be familiar the basic concept of homeomorphisms.

Course outline;

Binary operation, Groups and their examples, Order of group, order of an element of a group, Subgroups, cyclic groups, Abelian group, Normal subgroups, Centre of a group, Normalizer and centralizer of a group, Cosets, Lagrange's Theorem, Derived subgroup, Factor or Quotient groups, Homomorphism, kernel of a homomorphism, isomorphism Theorems, permutation groups.

Recommended Books:

1. C. F. Gardiner, A First Course in Group Theory. Springer. (1980).
2. J. H. Farleigh: A first course in abstract algebra, 7th Edition. (1989)
3. J. A. Gallian, Contemporary Abstract Algebra, 8th Edition. 2013
4. J. S. Milne, Group Theory, World Scientific Publisher (2020).

MATH-455: DIFFERENTIAL EQUATIONS-I

Credit Hours: 3

Prerequisites: Calculus I

Specific Objectives of course: 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 non- homogeneous differential equations and solving differential equations using power series methods.

Course Outline:

Introduction to Differential Equations: Historical background and motivation, Basic mathematical models: Directional fields, Classification of differential equations, Formation of differential equation

First Order Differential Equations: Modeling with first order differential equations, Applications of first order ODEs in problems of decay and growth, population dynamics, logistic equation, Separable equations, Homogeneous and non-homogeneous equations, Linear and nonlinear equations, Exact and non-exact equations and integrating factors, Orthogonal trajectory, Bernoulli, Ricatti, Clairaut's equations

Second Order Differential Equations; Homogenous equations, Homogenous equations with constant coefficients, Fundamental solutions of linear homogenous equations, Operator method, Method of undetermined coefficients, Cauchy Euler's equation, Linear independence and the wronskian, Variation of parameters, reduction of order, Applications to mechanical and electrical systems

Higher Order Linear Differential Equations; General theory of nth order linear differential equations, Homogenous equations with constant coefficients, The methods of undermined coefficients, The method of variation of parameters.

Recommended Books

1. W.E. Boyce and Diprima, Elementary Differential Equations, 8th Edition, John Wiley & Sons, 2005
2. Erwin, Kreyszig, Advanced Engineering Mathematics, John Wiley and Sons, 2004
3. Dennis G.Zill & Michael R. Cullen, Differential Equation With Boundary Value Problems, PWS Publihing Company, 2000

MATH-501: REAL ANALYSIS

Credit hours: 3

Contents: Real number and real number system, supremum and infimum of sets, limits and continuity, properties of continuous functions on closed bounded intervals; Sequences and series derivatives in one variable; the mean value theorem; Taylors Theorem and the infinite Taylor series with applications. Point-wise and uniform convergence. Concept of Riemann integration, proper and improper integrals, Functions of several Variables; limits and continuity in several variables, differentiation in n-space; the Taylor series in R^n with applications; the inverse and implicit function theorems.

Recommended books:

1. R. L. Brabenec: Introduction to real analysis, (1997).
2. Asfandyar Khan: Fundamentals of Real Analysis (2020)
3. R. G. Bartle and D. R. Sherbert: Introduction to real analysis (1999).
4. Thomas and Finney: Calculus and Analytic Geometry 9^{th} and 11^{th} editions.
5. Dipak Chatterjee: Real Analysis 2^{nd} edition (2012).

MATH-502: GROUP THEORY- II

(Credit hours: 3)

Pre-requisites: MATH-454

Contents: Conjugate subgroups, Conjugacy classes, Class equation of a group, Sylow theorems and its applications, Groups of Auto morphisms and extensions, characteristic subgroups, internal and external direct product of groups, free groups and their relationships. Group series, normal series, abelian series, maximal series.

Recommended Books:

1. J. S. Rose: A course in Group Theory (Dover Books on Mathematics) 2012.
2. J. A. Gallian, Contemporary Abstract Algebra, 8th Edition. 2013
3. I. N. Herstein, Topics in Algebra, John Wiley & Sons; 2nd Edition, (1975).

J. S. Milne, Group Theory, World Scientific Publisher (2020).

MATH-503: DIFFERENTIAL GEOMETRY

Credit hours: 3

Contents: Curve Theory: Types of curves.Arc length of a regular curve, Paramets reparametric representation and reparametrization of a regular curve , curvature and torsion of the space curves and their importance in the curve theory; Frenet-Serret equations ,their applications; some global properties of plane curves and of space curves if time permits. Surface Theory: first and second fundamental forms, their applications:curvature of curves on a surface, normal curvature , Gaussian and mean curvatures, catgories of special surfaces;

Introduction to tensors, tensor algebra, connection symbols, differentiation and covariant differentiation of tensors, geodesics.

Recommended Books:

1. R. S. Millman and G. D. Parker: Elements of Differential Geometry,
2. M. P. DoCarmo: Differential Geometry of Curves and Surfaces,
3. A. Pressley: Elementary Differential Geometry, (2001).
4. D. J. Struik: Lectures on Classical Differential Geometry, (1977).

R. L. Bishop and S. I. Goldberg: Tensor Analysis on Manifolds, (1980).

MATH-504: LINEAR ALGEBRA-I

Credit hours: 3

Contents: Introduction to linear systems, Gauss Elimination, Numerical Solutions, Vector operations, Dot products, Span, Linear Independence, Cross product, Matrix operations, Matrix inverse, Elementary and invertible matrices, LU factorization, Vector Spaces, Subspaces of Vector Space $\mathbf{R}^n$, Linear independence and Bases, Dimension, Coordinate Vectors and change of basis, Rank and Nullity,

Recommended Books:

1. G. Nakose and D. Joyner: Linear Algebra with Applications, (1998).
2. W. Keith Nicholson: Elementary linear algebra with applications, (1994)
3. Richard O. Hill: Elementary linear algebra with applications, 3rd edition, (1995).
4. Steven J. Leon: Linear algebra with applications, 6th edition, (2002).
5. Shifrin T. and Adams R. M.: Linear Algebra, A Geometric Approach, (2002).

J. R. Durbin: Modern Algebra: An Introduction, 3rd Edition, (1992).

MATH-505: DIFFERENTIAL EQUATIONS-II

Credit hours: 3

Pre-requisites: Differential Equations I

Preliminaries: Review of the basic definitions and introduction to ordinary differential equations (ODEs).

Fourier Series: Orthogonal functions and polynomials, periodic functions, trigonometric and Fourier series, Fourier series of functions with arbitrary periods, half-range expansions: the cosine and sine series, generalized Fourier series, solutions of the endpoint value problems using Fourier series.

Eigen-Value Problems: Introduction to eigen-value problems, adjoint and self-adjoint operators, self-adjoint differential equations (D. Eqs.), eigen-values and eigen-functions.

Series Solutions of Linear Equations: Review of power series, definitions of ordinary and singular points, Existence of power series solutions, power series solutions, types of singular points, Frobenius theorem, Existence of Frobenius series solutions, solutions about singular points (Frobenius series solutions), Green functions for ordinary differential equations.

Recommended Books:

1. D. G. Zill and M. R. Cullen: Differetial Equations with Boundary-Value Problems (2008).
2. C. H. Edwards and D. E. Penney: *Elementary Differential Equations with Boundary Value Problems,* (2003).
3. M. Morris and O. E. Brown: Differential Equations, (1964).
4. M. R. Spiegel: Applied Differential Equations, (1967).
5. F. Chorlton: Ordinary Differential and Difference Groups, (1965).
6. L. Brand: Differential and Difference Equations, (1966).

E. D. Rainville and P. E. Bedient: Elementary Differential Equations, (1963).

MATH-506: MULTIVARIABLE CALCULUS

Credit hours: 3

Pre-requisite: MATH-402, MATH-453

Contents: Infinite sequences and series; The integral test; Comparison test; The Ratio test; Alternating series; Absolute and conditional convergence; power series; Tylor and Maclaurin series; Convergence of Tylor series; Error estimation; Three Dimensional coordinate systems; Vectors; the dot product; The cross product; Lines & planes in space; cylinders and Quadratic surface; Vector Functions; Arc length and the unit tangent vector; Partial derivatives; Functions of several variables; Limits and continuity in Higher dimensions; the chain rule; Directional derivatives; Gradient vectors; Tangent planes and differentials; Extreme values and saddle points; Lagrange multipliers; Double integral; Double integrals in polar from; Polar coordinates; Areas and length in polar coordinates; Conic section in polar coordinates.

MATH-551: LINEAR ALGEBRA-II

Credit hours: 3

Pre-requisites: MATH-504

Contents: Ring Theory, Definition and example of rings, Special classes of rings, Fields, Vector Spaces, subspaces, Linear combinations, linearly independent vectors, Spanning set, Bases and dimension of a vector space, Orthogonal matrices and orthogonal transformations, Orthonormal basis and Gram Schmidt process Linear Mappings, Matrices and Linear Operators, Eigen Values and Eigen Vectors, Polynomials of matrices and linear operators, Characteristic polynomial,

Diagonalization of matrices, Dual Spaces, Linear functional, Dual space, Dual basis, Linear functional, Annihilators.

Recommended Books

1. J. Rose, A Course on Group Theory, (Cambridge University Press, 1978)
2. I. N. Herstein, Topics in Algebra, (Xerox Publishing Company, 1964)
3. G. Birkhoff and S. Maclane, A Survey of Modern Algebra, (Macmillan, New York, 1964)
4. P. B. Battacharya, S. K. Jain and S. R. Nagpaul, Basic Abstract Algebra, (Cambridge University Press, 1986)
5. V. Sahai and V. Bist, Algebra, 2nd edition, (Narosa Publishing House, 2003)
6. W. Keith Nicholson, Elementary Linear Algebra, (PWS-Kent Publishing Company, Boston, 2004)
7. Seymour Lipschutz, Linear Algebra, 3rd edition, (McGraw Hill Book Company, 2001)

MATH-552: COMPLEX ANALYSIS

Credit hours: 3

Contents:

Complex Number: Algebra of Complex Numbers, Geometric Representations of Complex Numbers, Powers and Roots of Complex numbers.

Functions of a Complex Variable: Definition, Limits, Continuity and Derivatives of Function, The Cauchy-Riemann (C-R) conditions, The exponential, Trigonometric.

Integrals: Contours, Contour Integration, Simply and Multiply Connected Domains, Cauchy's Integral Theorem, Cauchy's integral Formula, Morera's Theorem, Liouville's Theorem.

Series: Taylor's and Laurent's Series, Power Series (Definition and Properties), Integration and Differentiation of Power Series.

Residues and Poles: Residues and its theorems, Types of isolated singular points, Residues at poles.

Recommended Books:

1. J. W. brown and R. Churchill: Complex Variables and Applications, (2008).
2. J.H. Mathews and R.W. Howell: Complex Analysis for Mathematics and Engineering (2006).
3. E.B.Saff and A.D. Snider: Fundamentals of Complex Analysis with Applications to Engineering, Science and Mathematics, (2003)
4. T.W. Gamelin: Complex Analysis, (2001),
5. S.D. Fisher: Complex Variables, (1999).

S.A. Lang: Complex Analysis, (1998).

MATH-553: MECHANICS-II

Credit hours: 3

Kinematics, Rectilinear motion, simple Hormonic motion, Projectile motion, Constrained motion, Orbital motion, Motion of a rigid body and a system, Impulsive motion. Work, power and energy.

Recommended Books

1. Q. K. Ghori: Mechanics, West Pakistan Publications

2. M. Hussain: Vector Analysis, Caravan Book Publications, Lahore.
H. Goldstein: Classical Mechanics, National Book Foundation, 3th Edition, (2006).

MATH-554: Numerical Methods

Credit hours: 3

Pre-requisite: C^{++}, Mat lab

Contents: Computer arithmetic, approximations and errors; methods for the solution of nonlinear equations and their convergence: bisection method, regula falsi method, fixed point iteration method, Newton-Raphson method, secant method; error analysis for iterative methods. Interpolation and polynomial approximation: Lagrange interpolation, Newton's divided difference, forward difference and backward difference formulae, Hemite interpolation, Numerical integration and error estimates: rectangular rule, trapezoidal rule, Simpson's 1/3 and 3/8 rules. Numerical solution of systems of algebraic linear equations: Gauss elimination method, Gauss-Jordan method; matrix inversion; LU-factorization; Doolittle's, Crount's, Choleskys's methods; Gauss-Seidel and Jacobi methods; matrix norms; method of least squares;

Recommended Books:

1. K.E. Atkinson: An introduction to numerical analysis, (1989
2. R. L Burden and J.D. Faires: Numerical analysis, (1993).
3. S.C. Chapra and R.P. Canale: Numerical methods for engineers, (1988)
4. S. D. Conte and C. de Boor: Elementary Numerical Analysis, (1972).

C. F. Gerald: Applied Numerical Analysis, (1984).

MATH-555: FUNCTIONAL ANALYSIS I

Credit hours: 3

Contents: Norm, Normed linear spaces, complete spaces, Banach spaces, boundedness and continuity of linear operators, inner product spaces, Hilbert spaces, orthogonal complements, projection theorem, consequences of Hahn-Banack theorem, minimizing vector theorem, open mapping and closed grapk theorems.

Recommended Books:

1. Ervin Kreyszic: Int**r**oductory Functional Analysis with applications, (1978).
2. W. Rudin: Functional Analysis, (1983).
3. A-E, Taylor and D. C. Lay: Introduction of Functional Analysis, (1979).

G. F. Simmon: Introduction to Topology and Modern Analysis, (1983).

MATH-556: PARTIAL DIFFERENTIAL EQUATIONS

Credit hours: 3

Contents:

First Order PDE'S

Introduction, Formation of partial differential equations, Solutions of partial differential equations of first order, The Cauchy problem for first order equations, First order nonlinear equations, Charpit's method, Special types of first order equations,

Second Order PDE'S

Basic concepts and definitions, Mathematical problems, Linear operators, Superposition,

Mathematical Models (The classical equations, the vibrating string, the vibrating membrane, conduction of heat solids)

Classification of second order PDE

Second order PDE in two independent variables, canonical forms and variable, Equations with constant coefficients, General solution, the Cauchy problem.

Methods of Separation of variables

Solutions of elliptic differential equations, solutions of parabolic differential equations, solutions of hyperbolic differential equations, both in cylindrical and Cartesian coordinate system

Laplace Transform

Introduction, properties of Laplace transform, transform of some elementary functions and periodic functions, transform of Error function, transform of Dirac Delta function, inverse Laplace transform, convolution theorem, solution of PDE'S (Diffusion and wave equations)

Fourier Transform

Introduction, Fourier integral representation, Fourier sine and cosine representation, Fourier transform pair, transform of elementary functions, properties of Fourier transform, convolution theorem, transform of Dirac Delta function, multiple Fourier transforms, finite Fourier transforms, (finite Fourier sine transform, finite Fourier cosine transform), solutions of heat, wave and Laplace equations**.**

Recommended Books:

1. Tyn Myint-U and Lokenath Debnath: Partial Differential Equations for scientist and Engineers, (1987).
2. Mark A Pinsky: Partial Differential Equations and Boundary value problems with applications, (1984).
3. Sankara Rao: Introduction to Partial Differential Equations, (2006).

Richard Haberman**:** Introduction to PDE, (1983).

MATHEMATICS (ELECTIVE COURSES)

MATH-601: NUMERICAL ANALYSIS

Credit hours: 3

Contents: Introduction to Numerical Differentiation, difference methods for numerical differentiations. Differentiation using discrete data. Ordinary differential equations: Predictor methods, modified Euler's method, truncation error and stability, the Taylor series method, Runge-Kutta methods, differential equations of higher order, system of differential equations, shooting methods, boundary value problems.
Eigenvalue problems: Estimation of eigenvalues and corresponding error bounds, Gerschgorin's theorem and its applications, Schur's theorem, power method, shift of origin, deflation method for the subdominant eigenvalues

Recommended Books.

1. S. D. Conte and C. de Boore: Elementary Numerical Analysis, (1972).
2. R. L. Burden, J. D. Fairs and A. M. Burden: Numerical Analysis, (2016)
3. C. E. Foberg: Introduction to Numerical Analysis, (1972)
4. A.R. Gourlay and G. A. Watson: Computational Methods for Matrix Eigenvalue Problems, (1973).
5. G. D. Smith: Numerical Solutions of Partial Differential Equations,
6. A. R. Mitchell and D. F. Griffiths: Finite Difference Methods in Partial Differential Equations, (1980).

MATH-602: MATHEMATICAL STATISTICS-I

Contents: Interpretations of Probability. Experiments and events. Definition of probability. Finite sample spaces. Counting methods. The probability of a union of events. Independent events. Definition of conditional probability. Baye's' theorem. Random variables and discrete distributions. Continuous distributions. Probability function and probability density function. The distribution function. Bivariate distributions. Marginal distributions. Conditional distributions. Multivariate distributions. Functions of random variables. The expectation of a random variable. Properties of expectations. Variance. Moments. The mean and the median. Covariance and correlation.

Recommended Books.

1. A. M. Mood, F. A.. Graybill and D. C. Boes: Introduction to the Theory of Statistics, (1974).
2. M. H. Degroot: Probability and Statistics, (1986).
3. K. V. Mardia, J. T. Kent and J. M. Bibby: Multivariate Analysis, (1979).

MATH-603: MATHEMATICAL STATISTICS-II

Credit hours: 3

Contents: Statistical inference. Maximum likelihood estimators. Properties of maximum likelihood estimators. Unbiased estimators. Sufficient statistics. Jointly sufficient statistics. Minimal sufficient statistics. The sampling distribution of a statistic. The chi square distribution. Joint distribution of the sample mean and sample variance. The **t** distribution. Confidence intervals. Testing simple hypotheses. Uniformly most powerful tests. The t test. The F distribution. Comparing the means of two normal distributions. Tests of goodness of fit. Equivalence of confidence sets and tests. Kolmogorov-Smirnov tests. The Wilcoxon Signed-ranks test.

Recommended Books.

1. A. M. Mood, F. A. Graybill and D. C. Boes: Introduction to the Theory of Statistics, (1974).
2. M. H. Degroot: Probability and Statistics, (1986).
3. K. V. Mardia, J. T. Kent and J. M. Bibby: Multivariate Analysis, (1979).

MATH-604: OPERATIONS RESEARCH

Credit hours: 3

Contents: Introduction to Operations Research and real life Phases, Introduction to Linear Programming (LP) with examples, Graphical Solutions to Mathematical Model with Special Cases, Simplex Algorithm and its different cases, Big M Method and Two Phase Method, Sensitivity Analysis/ Post Optimality Analysis, Duality and its Economic Interpretation, Dual Simplex Method, Scheduling and Biending Problems, The Transportation Problems, The Transshipment Problems, The Assignment Problems, Integer Programming. Network Models, Inventory Models, Dynamic Programming and Queuing Theory.

Reference Books:

1. Wayne L. Winston: Operations Research: Applications and Algorithms, (2003)
2. Hamdy A. Taha: Operations Research: An Introduction, (2006).
3. An Introduction to Operation Research (Virtual University of Pakistan)
4. Operation Research, Schaum's Outlines, Second Edition by Richard Bronson and Govindasami Naadimuthu (McGraw-Hill).

MATH-605: OPTIMIZATION THEORY

Credit hours: 03

Contents: Introduction to optimization. Relative and absolute extrema. Convex, concave and unimodal functions. Constraints. Mathematical programming problems. Optimization of one, two and several variables functions and necessary and sufficient conditions for their optima. Optimization by equality constraints**:** 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 Lagrange equations.

Recommended Books:

1. B. S. Gotfried and J. Weisman: Introduction to Optimization Theory, (1973).
2. L. Elsgolts: Differential Equations and the Calculus of variations, (1970).
3. A. D. Wismer and R. Chattergy: Introduction to Nonlinear Optimization, (1978).
4. M. D. Intriligator: Mathematical Optimization and Economic Theory, (1971).

MATH-606: COMMUTATIVE RINGS AND ALGEBRAIC FIELD EXTENSION

Credit hours: 3

Contents: Definitions and basic concepts, Commutative rings with identity, Integral domain and Field, Units, prime and irreducible elements in a commutative ring with identity, Rings of residue modulo m and their characteristics, Fundamental Theorems of ring homomorphisms, Euclidean domain, PID, Polynomial rings, unique factorization domain, Criterion for Irreducible polynomials, Divisibility in integral domains, extension fields, algebraic and transcendental elements, simple extension, Finite field extension.

Recommended books:

1. J. A. Fraleigh: A First Course in Abstract Algebra, (1982).
2. I. N. Herstein: Topics in Algebra, (1975).
3. S. Lang: Algebra, Addison Wesley, (1965).
4. B. Hartley and T. O. Hawkes: Ring, Modules and Linear Algebra, (1980).

MATH-607: INTRODUCTION TO ALGEBRAIC CODING THEORY

Credit hours: 3

Contents: A very short review of integral domains, fields, finite prime fields, ideals, PIDs, Vector spaces and subspaces, Bases and dimension, Polynomial algebra, Linear Transformation and its matrix representation.

Linear codes, Binary linear codes, linear transformations, generator polynomial, generator matrix, Parity Check matrix, Encoding and Decoding, Dual codes, Syndrome, Cyclic codes,

Recommended Books:

1. R. Laatsch: An introduction to abstract algebra, (1968).
2. David M Burton: Abstract and Linear Algebra, (1972).
3. S. Roman: Introduction to coding and information (1997).
4. J. B. Durbin: Modern algebra, An introduction, (1992).

MATH-608: ADVANCED ALGEBRAIC CODING THEORY

Credit hours: 3

Contents: Finite commutative rings, finite local ring, polynomial rings, Factor rings, Galois field.Codes over a Galois field, Binary linear codes, Short exact sequence of linear spaces and linear transformations on algebra of finite fields, generator polynomial, generator matrix, Parity Check matrix, Encoding and Decoding, Dual codes, Syndrome, Cyclic codes. **Construction** of BCH-Codes, hamming distance, Hamming weight, Types of BCH-Codes, RS-Codes. Alternant, Goppa Codes and Srivastava codes.

Recommended Books:

1. R. Laatsch: An introduction to abstract algebra, (1968).
2. David M Burton: Abstract and Linear Algebra, (1972).
3. S. Roman: Introduction to coding and information (1997).
4. J. B. Durbin: Modern algebra, An introduction, (1992).
5. S. R. Nagpaul and S. K. Jain: Topics in Applied Abstract Algebra, (2005).

MATH-609: THEORY OF MODULES

Credit hours: 3

Contents: Elementary notions and examples, Modules, submodules, quotient modules, finitely generated and cyclic modules, exact sequences and elementary notions of homological algebra, Noetherian and Artinian rings and modules, radicals, semi simple rings and modules.

Recommended Books:

1. J. Adamson: Rings and modules. (1977).
2. B. Hartley and T. O. Hawkes: Rings, Modules and Linear algebra, (1980).
3. I. N. Herstein: Topics in Algebra, (1975).

MATH-610: PRIMARY DECOMPOSITION OF RINGS AND MODULES

Credit hours: 3

Contents: Elementary notions and examples of commutative rings and modules over commutative rings, Ring and modules homomorphisms, Fraction rings and fraction modules, Noetherian rings and modules, Laskerian rings and modules, Strongly Laskerian rings and modules, Prime ideals, maximal ideals, irreducible ideals, Primary ideals and Primary submodules, radical of an ideal and radical of a submodule, Primary decomposition of rings and modules, reduced primary decomposition, Associated prime ideals.

Recommended Books:

1. H. Matsumura: Commutative Algebra, (1980).
2. N. Bourbaki: Commutative Algebra, (1972).

MATH-611: MEASURE AND INTEGRATION

Credit hours: 3

Contents: Measure Spaces: Definition and example of algebras and -algebras, Basic properties of measurable spaces, Definition and examples measure spaces, outer measure, Lebesgue measure, Measurable sets, Complete measure spaces.

Measurable Functions: Some equivalent formulations of measurable functions, Examples of measurable functions, Various characterization of measurable functions, Property that holds almost everywhere, Egorov's theorem.

Lebesgue Integration: Definition of Lebesgue integral, Basic properties of Lebesgue integrals, Comparison between Riemann integration and Lebesgue integration. L2-space. The Riesz-Fischer theorem.

Recommended Books:

1. D.L. Cohn: Measure Theory, (1980).
2. Elias M. Stein and Rami Shakarchi: Real Analysis: Measure Theory, Integration, and Hilbert Spaces, (2005).
3. Heinz Bauer and Robert B. Burckel: Measure and Integration Theory, (2002).
4. Eric M. Vestrup: The Theory of Measures and Integration, (2003).
5. Michael Eugene Taylor: Measure Theory and Integration, (2006).

MATH-612: INTRODUCTION TO PROBABILITY MODELS

Credit hours: 3

Contents: Short review of Probability, Random variables, and Conditional Probability. Short review of Linear Spaces, Finite Algebra, Linear Transformation, and Eigen values of a linear transformations, An introduction of Markov Chains, Types of Transition atrices, Steady level vector, Equilibrium of a system Applications in: Economics, Coding Theory.

Recommended Books:

1. Sheldon M. Ross: Introduction to Probability Models**, (**2007).
2. G. Williams: Linear Algebra with Applications, (2008).
3. B. Kolman and D. R. Hill: Introductory Linear Algebra with Applications,

MATH-613: INTRODUCTION TO COMBINATORICS

Credit hours: 3

Contents: 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 Eratostheories, Euler φ-function, The Problems des Manages. Ordinary Generating Functions, Modelling 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, (1985).
2. C.C. Chen and K.M.Koh: Principles and Techniques in Combinatorics, (1992).
3. V.K.Balakrishnan: Theory and Problems of Combunatorics, (1995).
4. C.L.Liu: Introduction to Combinatorial Mathematics, (1968).
5. J.H.Van Ling and R.M. Wilson: A course on Combinatorics, (2001).

MATH-614: GROUP ALGORITHMS PROGRAMMING

Credit hours: 3

Contents: Algorithms and its Analysis – Basic concepts and its applications, Mathematical Foundations: Growth of functions, Asymptotic functions, Summations, Recurrences, Counting and probability. Divide-and-Conquer algorithms; General method and its analysis, Binary search and its analysis, Merge sort and its analysis, Quick sort and its analysis, Insertion sort and its analysis. Advanced Design and Analysis Techniques: Dynamic Programming, Greedy algorithms and its applications in scheduling, Generating functions and its application in Recurrences, Permutation Algorithms and its application in sorting, Amortized analysis, Worst-case analysis, Average case analysis, Graph algorithms: Basic search techniques, Algorithmic binary tees and its application, breadth-first search, Depth-first search, Planner graphs, Graph colouring, Minimum Spanning Trees, Single source shortest paths.

Special Topics: Algorithms for parallel computers. Matrix Operations. Polynomials and the FFT. Number-Theoretic algorithms. NP-completeness. Approximations algorithms. Encyption/Decryption algorithms.

Recommended Books:

1. H. C. Thomas and Charles E. Leiserson: Introduction to Algorithms, (1990).
2. H. Sedgwick: Analysis of Algorithms, (1995).
3. K. Rosen: Discrete Mathematics and its Applications, (1999).

MATH-615: ALGEBRAIC TOPOLOGY

Credit hours: 3

Contents: Pathwise connectedness; Notion of homotopy, Homotopy classes, Path homotopy, Path homotopy classes; Fundamental groups, Covering maps, Covering spaces, Lifting properties of covering spaces, Fundamental group of a circle, $\pi_1(S^n)$.

Recommended Books:

1. C. Kosniowski: A first course in algebraic topology, (1980).
2. M. J. Greenberg: Algebraic topology, A first course, (1967).
3. A. H. Wallace: Algebraic Topology, Homology and Cohomology, (1968).

MATH-616: ADVANCED TOPOLOGY

Credit hours: 3

Contents: 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_2-spaces, local connectedness, path-connectedness, components. Homotopic maps, homotopic paths, loop spaces, fundamental groups, covering spaces, the lifting theorem, fundamental groups of the circle, torus etc. Chain complexes, notion of homology.

Recommended Books:

1. M. J. Greenberg: Algebraic topology, A first course, (1967).

2. A. H. Wallace: Algebraic Topology, Homology and Cohomology, (1968)
3. M. C. Gemignan: Elementry Topology, (1972).

MATH-617: ADVANCED FUNCTIONAL ANALYSIS

Credit hours: 3

Contents: The Hahn-Banach theorem, principle of uniform boundedness, open mapping theorem, closed graph theorem, Weak topologies and the Banach-Alouglu theorem, extreme points and the Klein-Milman theorem.The dual and bidual spaces, reflexive spaces, compact operators, Spectrum and eigenvalues of an operator, elementary spectral theory.

Recommended Books:

1. E. Kreyszing: Introductory Functional Analysis and Applications, (1973).
2. A. E. Taylor and D. C. Lay: Introduction of Functional Analysis, (1979).
3. H. G. Heuser: Functional Analysis, (1982).
4. C. W. Groetsch: Elements of Applicable Functional Analysis, (1980).

MATH-618: ADVANCED GROUP-THEORY

Credit hours: 3

Contents: Action of a group on a set G-spaces, G-morphisms. The symmetric and alternating groups, orbits, stabilizers of a group, the relation of stabilizer and orbits, The formulae for counting orbits, transitivity, Linear groups and their types, Graphical representation of group.

Recommended Books:

1. J. S. Rose: A course on group theory, (1978).
2. W. Magnus, A. Karrass and Solitar: Combinatorial group theory, (1966).
3. Taqdir Husain: Introduction to topological groups, (1966).

MATH-619: RINGS AND FIELDS

Credit hours: 3

Contents: Definitions and basic concepts, Integral domain and Field, Units, prime, homomorphisms, homomorphism theorems, polynomial rings, unique factorization domain, factorization theory, Fundamental Theorems of ring homomorphisms, Euclidean domains, arithmetic in Euclidean domains, extension fields, algebraic and transcendental elements, simple extension, introduction to Galois theory.

Recommended Books:

1. J. A. Fraleigh: A First Course in Abstract Algebra, (1982).
2. I. N. Herstein: Topies in Algebra, (1975).
3. S. Lang: Algebra, Addison, (1965).
4. B. Hartley and T. O. Hawkes: Ring, Modules and Linear Algebra, (1980).

MATH-620: ELASTICITY THEORY

Credit hours: 3

Contents: 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, compatibility equations; plane stress and plane strain problems; two dimensional problems in rectangular and polar co-ordinates; torsion of rods and beams.

Recommended Books:

1. Sokolinikoff.: Mathematical theory of Elasticity.
2. E. Dieulesaint and D. Royer: Elastic Waves in Solids, (1980).
3. Y. C. Funk: Foundations of Solid Mechanics, (1965).

MATH-621: ANALYTICAL DYNAMICS

Credit hours: 3

Contents: Constraints, generalized co-ordinates, generalized forces, general equation of dynamics, Lagrange's equations, conservation laws, ignorable co-ordinates, explicit form of Lagrange's equation in terms of tensors. Hamilton's principle, principle of least action, Hamilton's equations of motion, Hamilton-Jacobi Method. Poisson Brackets (P. B's); Poisson's theorem; Solution of mechanical problems by algebraic technique based on (P.B's). Small oscillations and normal modes, vibrations of strings, transverse vibrations, normal modes, forced vibrations and damping, reflection and transmission at a discontinuity, Longitudinal vibrations, Rayleigh's principle.

Recommended Books:

1. F. Chorlton,: Textbook of Dynamics, (1963).
2. W. Chester: Mechanics, (1979).
3. H. Goldstein: Classical Mechanics, (1980).
4. G.L. Meirovitch: Methods of Analytical Dynamics, (1970)

MATH-622: INTRODUCTORY QUANTUM MECHANICS

Credit hours: 3

Contents: Basic postulates of quantum mechanics. State vectors. Formal properties of quantum mechanical operators. Eigenvalues and eigenstates, simple harmonic oscillator. Schrodinger representation. Heisenberg equation of motion Schrodinger equation. Potential step, potential barrier, potential well. Orbital angular momentum. Motion in a centrally symmetric field. Hydrogen atom. Matrix representation of angular momentum and spin. Time independent perturbation theory, degeneracy. The Stark effect. Introduction to relativistic Quantum Mechanics.

Recommended Books:

1. Fayyazuddin and Riazuddin: Quantum Mechanics, (1990).
2. E. Merzbacher: Quantum Mechanics, (1970).
3. R. L. Liboff: Introductory Quantum Mechanics, (1991).
4. P.M.A. Dirac: Principles of Quantum Mechanics,

MATH-623: INTEGRAL EQUATIONS

Credit hours: 3

Contents: Integral equation formulation of boundary value problems, classification of integral equations, method of successive approximation, Hilbert-Schmidt theory, Schmidt's solution of non- homogeneous integral equations, Fredholm theory, case of multiple roots of characteristic equation, degenerate kernels. Introduction to Wiener-Hopf technique.

Recommended Books:

1. W. V. Lovitt: Linear integral equations, (1950).
2. F. Smith: Integral equations,
3. F. G. Tricomi: Integral equations, Interscience, (1957).
4. B. Noble., Methods based on the Wiener-Hopf technique, (1988).
5. Abdul J. Jerri: Introduction to integral equations with applications, (1985)

MATH-624: FLUID MECHANICS-I

Credit hours: 3

Contents: Introduction, definition of fluid, scope of fluid Mechanics, basic equations, methods of analysis, (System and control volume, differential versus integral approach, methods of description) fluid as continuum, velocity field, one, two, three dimensional flows, time lines, path lines, streak lines and stream lines, stress field, shear stress in a moving fluid, density, viscosity, difference between solids and fluids, surface tension, equation of state of perfect gas, Newtonian and non-Newtonian fluids, description and classification of fluid motion, viscous and inviscid flows, Laminar and Turbulent flows, compressible and incompressible flows, internal and external flows.

Fluid Statics

The basic equation of fluid static's, pressure and pressure gradient, hydrostatic pressure distribution or pressure variation in static fluid, application to manometry, hydrostatic forces on plane and curved surfaces, hydrostatic forces in layered fluids, Buoyancy and stability, pressure distribution in rigid body motion

Introduction to differential analysis of fluid motion

Conservation of mass in rectangular and cylindrical coordinate systems, stream functions for two dimensional incompressible flows, motion of fluid element, fluid translation, acceleration of a fluid particle in a velocity field, fluid rotation, fluid deformation

Incompressible Inviscid fluid

Momentum equation, force acting on a fluid particle, momentum equation for frictionless flow, Euler's equation, Euler's equation in stream lines coordinates,

Bernoulli equation

Integration of Euler's equation along a stream line for steady flow, derivation using streamline coordinates, derivation using rectangular coordinates, static, stagnation and dynamic pressure, cautions on use of Bernoulli equation, unsteady Bernoulli equation, integration of Euler's equation along a stream line, irrigational flow, Bernoulli equation applied to irrigational flow, velocity potential, stream function and velocity potential for

two dimensional, irrigational, incompressible flow, Laplace equation, elementary plane flows, nature of dimensional analysis, Bukingham Pi theorem.

Recommended Books:

1. **F.** Chorlton: Textbook of fluid Dynamics, (1967).
2. M. Thomson: Theoretical Hydrodynamics, (1979).
3. W. Jaunzemics: Continuum Mechanic, (1967).
4. L. D. Landau and E. M. Lifshitz: Fluid Mehanics, (1966).
5. G. K. Batchelor: An Introduction to Fluid Dynamics, (1969).

MATH-625: FLUID MECHANICS-II

Credit hours: 3

Contents: Constitutive equations; Navier-Stoke's equations; Exact solutions of Navier-Stoke's equations; Steady unidirectional low; Poiseuille flow; Couette flow; Unsteady unidirectional low; sudden motion of a plane boundary in a fluid at rest; Flow due to an oscillatory boundary; Equations of motion relative to a rotating system; Ekman flow; Dynamical similarity and the Reynold's number; Flow over a flat plate (Blasius' solution); Reynold's equations of turbulent motion.

Recommended Books:

1. L.D. Landau and E.M. Lifshitz: Fluid Mechanics, (1966).
2. G. K. Batchelor: An Introduction to Fluid Dynamics, (1969).
3. Walter Jaunzemis: Continuum Mechanics, (1967).
4. Milne-Thomson: Theoretical Hydrodynamics, (1967).

MATH-626: ELECTROMAGNETISM

Credit hours: 3

Contents: Electrostatic Fields in Vacuum, Coulomb's law, electric field concept, Gauss's law and its applications, Electrostatic and magneto static Fields in Polarizable matter, Dielectrics, Dipole Field, Polarization, multipole Expansion, Field Energy, Magnetic Field of steady Electric Currents, Ampere's law, Vector Potential, Gauge Transformation, Biot-Savat Equation, maxwell's Equations, Faraday law of induction and Loreutz Force, The Continuity Equation, Maxwell's Displacement Current, Electromagnetic waves, Poynting Victor, Planar Electromagnetic waves, Superposition Principle, Hertz's Oscillator, Synchrotron Radiation.

Recommended Books:

1. D. Griffiths: Introduction to Electrodynamics, (1998).
2. J. Schwinger: Classical Electrodynamics, (1998).

MATH-627: RIEMANNIAN GEOMETRY

Prerequisite: A course on Differential Geometry

Credits: 3

Contents: Definition and examples of manifolds, differential maps, submanifolds, tangents, coordinate vector fields, tangent spaces, dual spaces, multilinear functions, algebra of tensors, vector fields, tensor fields, integral curves, flows, Lie derivatives,

brackets, differential forms, introduction to integration theory on manifolds, Riemannian and semi-Riemannian metrics, flat spaces, affine connections, parallel translations, covariant differentiation of tensor fields, curvature and torsion tensors, connection of a semi-Riemannian tensor, Killing equations and Killing vector fields, geodesics, sectional curvature.

Recommended Books:

1. R. L. Bishop and S. I. Goldberg: Tensor Analysis on Manifolds (1980).
2. M. P. Do Carmo: Riemannian Geometry, (1992)
3. D. Lovelock and H. Rund: Differential Forms and Variational Principles, (1975)
4. D. Langwitz; Differential and Riemannian Geometry, (1970)
5. R. Abraham, J. E. Marsden and T. Ratiu: Manifolds, Tensor Analysis and Applications, (1983).

MATH-628: SPECIAL RELATIVITY

Prerequisite: A Course on Riemannian Geometry

Credits: 3

Historical background and fundamental concepts of special theory of relativity, Lorentz transformations (one dimensional), 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 spacetime and null cone, 4-velocity, 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: Relativity: An Introduction to the Special Theory, (1989)
2. R. D. Inverno: Introducing Einstein's Relativity, (1992)
3. H. Goldstein: Classical Mechanics (1962).
4. J. D. Jackson: Classical Electrodynamics, (1962).
5. W. Rindler: Essential Relativity, (1977).

MATH-629: GENERAL RELATIVITY

Prerequisite: A Course on Riemannian Geometry

Contents: Review of special relativity, tensors, Isometries and killing equations. Einstein's field equations, Schwarzschild solution, solution of the Einstein-Maxwell field equations, Gravitational defection of light, Block holes, The Kerr-Newmarn solution (without derivation), Penrose diagrams.

Recommended Books

1. A. Qadir: Relativity: An introduction to the General Theory, Lecture Notes.

2. R.D. Inverno: Introducing Einstein's Relativity, (1992).

3. S. W. Hawking and G.F.R. Ellis: The Large Scale Structure of Spacetime,

4. C.W. Misner, K.S. Thorne and J.A. Wheeler:

MATH-630: CONTINUOUS GROUPS

Credit hours: 3

Contents: Continuous Groups; Gl(n,$\mathbb{R}$), Gl(n,$\mathbb{C}$), So(p,q), Sp(2n); generalities on continuous groups; groups of isometries, classification of two and three dimensional Euclidean space according to their isometries; introduction to Lie groups with special emphasis on matrix Lie groups; relationship of isometries 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: Introduction to compact transformation groups, (1972).
2. L. P. Eisenhart: Continuous groups of transformations, (1933).
3. L. S. Pontrjagin: Topological groups, (1939).
4. Taqdir Husain: Introduction to Topological Groups, (1966).
5. Miller Willard, Jr.: Symmetry groups and their application, (1972).

MATH-631: FUZZY SET THEORY

Credit hours: 3

Course Contents

Introduction and history of Fuzzy sets with their properties and operations, Lattice Fuzzy sets, theoretical operations, Negation, triangular norms and co-norms, Archimedean t-Norms and t-Conorms, Fuzzy Implications, Fuzzy Equivalence, Fuzzy Numbers and their properties, Type of fuzzy numbers, L-R Fuzzy Numbers, Fuzzy Relations, Cardinality of Fuzzy Relations, Operations on Fuzzy Relations, Properties of Fuzzy Relations, Fuzzy Equivalence Relations, Fuzzy Cartesian Product and Composition, Properties of Composition, Fuzzy Arithmetic, Zadeh's Extension Principle, The Sum and Scalar Multiplication, The Product of Two Fuzzy Numbers, Difference of Fuzzy Numbers, Extensions of Fuzzy Set Theory, Lattice Valued Fuzzy Sets (L-Fuzzy Sets), Intuitionistic Fuzzy Sets, Interval Type II Fuzzy Sets, Fuzzy Sets of Type 2, Cubic Sets, Bipolar Fuzzy sets

Books Recommended:

1. Fuzzy Logic with Engineering Applications 3rd Edition, 2010, Wiley, India.
2. Bede. B, Mathematics of Fuzzy sets and Fuzzy Logic, 2013, Springer, New York, USA.
3. Hohl. U and Rodabaug, S. E, Mathematics of Fuzzy set (Logic, Topology, Measure Theory), 2010, Springer Science and Business Media, LLC.