SYLLABUS FOR 4 YEARS BS MATHEMATICS
(SEMESTER SYSTEM PROGRAMME)
AFTER 2 YEARS ASSOCIATE DEGREE PROGRAM (ADP) MATHEMATICS
To be offered in Department of Mathematics, University of the Punjab, Lahore and Affiliated Colleges with effect from 2021 to onwards

Duration of Programme: **2 Years (Four Semesters)**
Medium of instructions: **English**
Credit Hours: **72**

BS Mathematics Semester V		
MATH-301	Real Analysis –I	3 cr.
MATH-302	Group Theory-I	3 cr.
MATH-303	Complex Analysis-I	3 cr.
MATH-304	Vector and Tensor Analysis	3 cr.
MATH-305	Topology	3 cr.
MATH-306	Differential Geometry	3 cr.
		Total = 18 cr.

BS Mathematics Semester VI		
MATH-307	Real Analysis –II	3 cr.
MATH-308	Rings and Vector Spaces	3 cr.
MATH-309	Complex Analysis – II	3 cr.
MATH-310	Mechanics	3 cr.
MATH-311	Functional Analysis-I	3 cr.
MATH-312	Ordinary Differential Equations	3 cr.
		Total = 18 cr.

BS Mathematics Semester VII		
MATH-401	Set Theory	3 cr.
MATH-402	Partial Differential Equations	3 cr.
MATH-403	Numerical Analysis-I	3 cr.
Any Three of the following:		
MATH-404	Mathematical Statistics-I	3 cr.
MATH-405	Fortran Programming	3 cr.
MATH-406	Group Theory-II	3 cr.
MATH-407	Ring Theory	3 cr.
MATH-408	Number Theory-I	3 cr.
MATH-409	Quantum Mechanics-I	3 cr.
MATH-410	Analytical Dynamics	3 cr.
MATH-411	Electromagnetic Theory-I	3 cr.
MATH-412	Operations Research-I	3 cr.
MATH-413	Theory of Approximation and Splines-I	3 cr.
MATH-414	Functional Analysis- II	3 cr.
MATH-415	Fluid Mechanics-I	3 cr.
		Total = 18 cr.

BS Mathematics Semester VIII		
MATH-416	Measure Theory and Lebesgue Integration	3 cr.
MATH-417	Methods of Mathematical Physics	3 cr.
MATH-418	Numerical Analysis-II	3 cr.
Any Three of the following:		
MATH-419	Mathematical Statistics-II	3 cr.
MATH-420	Computer Applications	3 cr.
MATH-421	Group Theory-III	3 cr.
MATH-422	Theory of Modules	3 cr.
MATH-423	Number Theory-II	3 cr.
MATH-424	Quantum Mechanics-II	3 cr.
MATH-425	Special Theory of Relativity	3 cr.
MATH-426	Electromagnetic Theory-II	3 cr.
MATH-427	Operations Research-II	3 cr.
MATH-428	Theory of Approximation and Splines-II	3 cr.
MATH-429	Functional Analysis- III	3 cr.
MATH-430	Fluid Mechanics-II	3 cr.
		Total = 18 cr.

Semester V

Module Code: MATH-301
Module Title: **Real Analysis - I**
Module Rating: 3 Cr. Hours

Real Number System

- Ordered sets, fields, the field of real numbers
- Completeness property of R
- The extended real number system
- Euclidean spaces
- Finite, countable and uncountable sets

Sequences and Series

- Sequences, subsequences, convergent sequences, Cauchy sequences
- Monotone and bounded sequences, Bolzano Weierstrass theorem
- Series, series of non-negative terms
- Partial sums, the root and ratio tests, integral test, comparison test
- Absolute and conditional convergence

Limit and Continuity

- The limit of a function
- Continuous functions
- Types of discontinuity
- Uniform continuity
- Monotone functions

Differentiation

- The derivative of a function
- Mean value theorems, the continuity of derivatives
- Taylor's theorem

Functions of Several Variables

- Partial derivatives and differentiability, derivatives and differentials of composite functions
- Change in the order of partial derivative, implicit functions, inverse functions, Jacobians
- Maxima and minima

Recommended Books

1. W. Rudin, *Principles of Mathematical Analysis*, 3rd edition, (McGraw Hill, 1976)
2. R. G. Bartle, *Introduction to Real Analysis*, 3rd edition, (John Wiley and Sons, 2000)
3. T. M. Apostol, *Mathematical Analysis*, (Addison-Wesley Publishing Company, 1974)
4. A. J. Kosmala, *Introductory Mathematical Analysis*, (WCB Company , 1995)
5. W. R. Parzynski and P. W. Zipse, *Introduction to Mathematical Analysis*, (McGraw Hill Company, 1982)
6. H. S. Gaskill and P. P. Narayanaswami, *Elements of Real Analysis*, (Printice Hall, 1988)

Module Code: MATH-302
Module Title: **Group Theory -I**
Module Rating: 3 Cr. Hours

Groups

- Definition and examples of groups
- Abelian group
- Subgroups lattice, Lagrange's theorem
- Relation between groups
- Cyclic groups
- Groups and symmetries, Cayley's theorem

Complexes in Groups

- Complexes and coset decomposition of groups
- Centre of a group
- Normalizer in a group
- Centralizer in a group
- Conjugacy classes and congruence relation in a group
- Double cosets

Normal Subgroups

- Normal subgroups
- Proper and improper normal subgroups
- Factor groups
- Fundamental theorem of homomorphism
- Automorphism group of a group
- Commutator subgroups of a group

Sylow Theorems

- Cauchy's theorem for Abelian and non-Abelian group
- Sylow theorems

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. P. M. Cohn, *Algebra*, (John Wiley and Sons, London, 1974)
4. P. B. Bhattacharya, S. K. Jain and S. R. Nagpaul, *Basic Abstract Algebra*, (Cambridge University Press, 1986)
5. J. B. Fraleigh, *A First Course in Abstract Algebra*, (Addison-Wesley Publishing Company, 2002)

Module Code: MATH-303
Module Title: **Complex Analysis - I**
Module Rating: 3 Cr. Hours

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

Module Code: MATH-304
Module Title: **Vector and Tensor Analysis**
Module Rating: 3 Cr. Hours

Vector Integration

- Line integrals
- Surface area and surface integrals
- Volume integrals

Integral Theorems

- Green's theorem
- Gauss divergence theorem
- Stoke's theorem

Curvilinear Coordinates

- Orthogonal coordinates
- Unit vectors in curvilinear systems
- Arc length and volume elements
- The gradient, divergence and curl
- Special orthogonal coordinate systems

Tensor Analysis

- Coordinate transformations
- Einstein summation convention
- Tensors of different ranks
- Contravariant, covariant and mixed tensors
- Symmetric and skew symmetric tensors
- Addition, subtraction, inner and outer products of tensors
- Contraction theorem, quotient law
- The line element and metric tensor
- Christoffel symbols

Recommended Books

1. F. Chorlton, *Vector and Tensor Methods*, (Ellis Horwood Publisher, Chichester, U.K., 1977)
2. M. R. Spiegel, *Vector Analysis*, (McGraw Hill Book Company, Singapore, 1981)
3. A. W. Joshi, *Matrices and Tensors in Physics*, (Wiley Eastern Limited, 1991)
4. Hwei P. Hsu, *Applied Vector Analysis*, (Harcourt Brace Jovanovich Publishers, San Diego, New York, 1984)

Module Code: MATH-305
Module Title: **Topology**
Module Rating: 3 Cr. Hours

Topology

- Definition and examples
- Open and closed sets
- Subspaces
- Neighborhoods
- Limit points, closure of a set
- Interior, exterior and boundary of a set

Bases and Sub-bases

- Base and sub bases
- Neighborhood bases
- First and second axioms of countablility
- Separable spaces, Lindelöf spaces
- Continuous functions and homeomorphism
- Weak topologies, finite product spaces

Separation Axioms

- Separation axioms
- Regular spaces
- Completely regular spaces
- Normal spaces

Compact Spaces

- Compact topological spaces
- Countably compact spaces
- Sequentially compact spaces

Connectedness

- Connected spaces, disconnected spaces
- Totally disconnected spaces
- Components of topological spaces

Recommended Books

1. J. Dugundji, *Topology*, (Allyn and Bacon Inc., Boston 1966)
2. G. F. Simmon, *Introduction to Topology and Modern Analysis*, (McGraw Hill Book Company, New York, 1963)
3. Stephen Willard, *General Topology*, (Addison-Wesley Publishing Co., London, 1970)
4. Seymour Lipschutz, *General Topology*, (Schaum's Outline Series, McGraw Hill Book Company 2004)
5. James R. Munkres, *Topology*, 2nd edition, (Prentice Hall Inc., 2003)

Module Code: MATH-306
Module Title: **Differential Geometry**
Module Rating: 3 Cr. Hours

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
- Christoffel symbols of first and second kinds
- The second fundamental form
- Principal, Gaussian, mean, geodesic and normal curvatures
- Gauss and Weingarten equations
- Gauss and Codazzi equations

Recommended Books

1. R. S. Millman and G.D. Parker, *Elements of Differential Geometry* (Prentice-Hall, New Jersey, 1977).
2. A. Goetz, *Introduction to Differential Geometry* (Addison-Wesley, 1970).
3. E. Kreyzig, *Differential Geometry* (Dover, 1991).
4. M. M. Lipschutz, *Schaum's Outline of Differential Geometry* (McGraw Hill, 1969).
5. D. Somasundaram, *Differential Geometry* (Narosa Publishing House, New Delhi, 2005).

Semester VI

Module Code: MATH-307
Module Title: **Real Analysis - II**
Module Rating: 3 Cr. Hours

The Riemann-Stieltjes Integrals

- Definition and existence of integrals
- Properties of integrals
- Fundamental theorem of calculus and its applications
- Change of variable theorem
- Integration by parts

Functions of Bounded Variation

- Definition and examples
- Properties of functions of bounded variation

Improper Integrals

- Types of improper integrals
- Tests for convergence of improper integrals
- Beta and gamma functions
- Absolute and conditional convergence of improper integrals

Sequences and Series of Functions

- Power series
- Definition of point-wise and uniform convergence
- Uniform convergence and continuity
- Uniform convergence and integration
- Uniform convergence and differentiation
- Examples of uniform convergence

Recommended Books

1. W. Rudin, *Principles of Mathematical Analysis*, 3rd edition, (McGraw Hill 1976)
2. R. G. Bartle, *Intoduction to Real analysis*, 3rd edition, (John Wiley and sons, 2000)
3. T. M. Apostol, *Mathematical Analysis*, (Addison-Wesley Publishing Co., 1974)
4. A. J. Kosmala, *Introductory Mathematical Analysis*, (WCB company, 1995)
5. W. R. Parzynski and P. W. Zipse, *Introduction to Mathematical Analysis*, (Mc Graw Hill company, 1982)
6. H. S. Gaskill and P. P. Narayanaswami, *Elements of Real Analysis*, (Printice Hall, 1988)

Module Code: MATH-308
Module Title: **Rings and Vector Spaces**
Module Rating: 3 Cr. Hours

Ring Theory

- Definition and example of rings
- Special classes of rings
- Fields
- Ideals and quotient rings
- Ring homomorphisms
- Prime and maximal ideals
- Field of quotients

Vector Spaces

- Vector spaces, subspaces
- Linear combinations, linearly independent vectors
- Spanning set
- Bases and dimension of a vector space
- Homomorphism of vector spaces
- Quotient spaces

Linear Mappings

- Mappings, linear mappings
- Rank and nullity
- Linear mappings and system of linear equations
- Algebra of linear operators
- Space L(X, Y) of all linear transformations

Matrices and Linear Operators

- Matrix representation of a linear operator
- Change of basis
- Similar matrices
- Matrix and linear transformations
- Orthogonal matrices and orthogonal transformations
- Orthonormal basis and Gram Schmidt process

Eigen Values and Eigen Vectors

- Polynomials of matrices and linear operators
- Characteristic polynomial
- Diagonalization of matrices

Dual Spaces

- Linear functionals
- Dual space
- Dual basis
- 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)

Module Code: MATH-309
Module Title: **Complex Analysis - II**
Module Rating: 3 Cr. Hours

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 $\wp(z)$
- Differential equation satisfied by $\wp(z)$
- Integral formula for $\wp(z)$
- Addition theorem for $\wp(z)$
- Duplication formula for $\wp(z)$
- 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, *Complex Variables*: *Theory and Applications*, (Prentice Hall, 2005)
2. M. R. Spiegel, *Complex Variables*, (McGraw Hill Book Company, 1974)
3. Louis L. Pennisi, *Elements of Complex Variables*, (Holt, Linehart and Winston, 1976)
4. W. Kaplan, *Introduction to Analytic Functions*, (Addison-Wesley, 1966)
5. E. D. Rainville, *Special Functions*, (The Macmillan Company, New York, 1965)
6. E. T. Whittaker and G. N. Watson, *A Course of Modern Analysis*, (Cambridge University Press, 1958)

Module Code: MATH-310
Module Title: **Mechanics**
Module Rating: 3 Cr. Hours

Non Inertial Reference Systems

- Accelerated coordinate systems and inertial forces
- Rotating coordinate systems
- Velocity and acceleration in moving system: coriolis, centripetal and transverse acceleration
- Dynamics of a particle in a rotating coordinate system

Planar Motion of Rigid Bodies

- Introduction to rigid and elastic bodies, degrees of freedom, translations, rotations, instantaneous axis and center of rotation, motion of the center of mass
- Euler's theorem and Chasle's theorem
- Rotation of a rigid body about a fixed axis: moments and products of inertia, hoop or cylindrical shell, circular cylinder, spherical shell
- Parallel and perpendicular axis theorem
- Radius of gyration of various bodies

Motion of Rigid Bodies in Three Dimensions

- General motion of rigid bodies in space: Moments and products of inertia, inertia matrix
- 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, space cone
- Motion of a spinning top and gyroscopes- steady precession, sleeping top

Recommended Books

1. G. R. Fowles and G. L. Cassiday, *Analytical Mechanics*, 7th edition, (Thomson Brooks/Coley, USA, 2005)
2. M. R. Spiegel, *Theoratical Mechanics*, (McGraw Hill Book Company, Singapore, 1980)
3. F. P. Beer and E. Russell Johnston, Jr., *Vector Mechanics for Engineers –Statics and Dynamics*, (McGraw Hill Inc., 1977)
4. H. Goldstein, *Classical Mechanics*, (Addison-Wesley Publisihng Co., 1980)
5. C. F. Chorlton, *Text Book of Dynamics*, (Ellis Horwood, 1983)

Module Code: MATH-311
Module Title: **Functional Analysis - I**
Module Rating: 3 Cr. Hours

Metric Space

- Review of metric spaces
- Convergence in metric spaces
- Complete metric spaces
- Completeness proofs
- Dense sets and separable spaces
- No-where dense sets
- Baire category theorem

Normed Spaces

- Normed linear spaces
- Banach spaces
- Convex sets
- Quotient spaces
- Equivalent norms
- Linear operators
- Linear functionals
- Finite dimensional normed spaces
- Continuous or bounded linear operators
- Dual spaces

Inner Product Spaces

- Definition and examples
- Orthonormal sets and bases
- Annihilators, projections
- Hilbert space
- Linear functionals on Hilbert spaces
- Reflexivity of Hilbert spaces

Recommended Books

1. E. Kreyszig, *Introduction to Functional Analysis with Applications*, (John Wiley and Sons, 2004)
2. A. L. Brown and A. Page, *Elements of Functional Analysis*, (Van Nostrand Reinhold London, 1970)
3. G. Bachman and L. Narici, *Functional Analysis*, (Academic Press, New York, 1966)
4. F. Riesz and B. Sz. Nagay, *Functional Analysis*, (Dover Publications, Inc., New York, Ungar, 1965)
5. A. E. Taylor, *Functional Analysis*, (John Wiley and Sons, Toppan, 1958)

Module Code: MATH-312
Module Title: **Ordinary Differential Equations**
Module Rating: 3 Cr. Hours

First and Second Order Differential Equations

- Review of ordinary differential equations
- Techniques of solving second and higher differential equations

Sturm Liouville Systems

- Some properties of Sturm-Liouville equations
- Regular, periodic and singular Sturm-Liouville systems and its applications

Series Solutions of Second Order Linear Differential Equations

- Review of power series
- Series solution near an ordinary point
- Series solution near regular singular points.

Series Solution of Some Special Differential Equations

- Hypergeometric function $F(a, b, c; x)$ and its evaluation
- Series solution of Bessel equation
- Expression for $J_n(X)$ when n is half odd integer, Recurrence formulas for $J_n(X)$
- Series solution of Legendre equation
- Rodrigues formula for polynomial $P_n(X)$
- Generating function for $P_n(X)$
- Recurrence relations, orthogonal polynomials
- Orthogonality of Bessel functions
- Expansions of polynomials
- The three term recurrence relation

Recommended Books

1. E. D. Rainville, *Special Functions* (Macmillan and Company, 1971)
2. G. E. Andrews, R. Askey and R. Roy, *Special Functions* (Cambridge University Press, 2000)
3. D. G. Zill, *Advanced Engineering Mathematics* (Jones and Bartlett Publishers, 2005)
4. W. E. Boyce and R. C. Diprima, *Elementary Differential Equations and Boundary Value Problems* (John Wiley and Sons, 2005)
5. N. M. Temme, *Special Functions, An Introduction to the Classical Functions of Mathematical Physics* (John Wiley and Sons, 1996)
6. E. T. Whittaker, and G. N. Watson, *A Course of Modern Analysis* (Cambridge University Press, 1958)

Semester VII

Module Code: MATH-401
Module Title: **Set Theory**
Module Rating: 3 Cr. Hours

Cardinality

- Equivalent sets, finite and infinite sets
- Denumerable sets
- Countable and uncountable sets
- Cardinal numbers, addition and multiplication of cardinals, Cartesian product as sets of functions
- Different types of infinity (Cantor's contribution)

Ordinality

- Partially ordered sets, Hasse diagrams
- Totally ordered sets
- Maximal and minimal elements
- Upper and lower bound
- Well-ordered sets
- Transfinite induction
- Ordinal numbers
- Multiplication of ordinal numbers

Axiom of Choice

- Well ordering theorem
- Zorn's lemma

Paradoxes in Set Theory

- Cantor's paradox, Russell's paradox and others.

Recommended Books

1. A. A. Fraenkal, *Abstract Set Theory*, (North-Holland Publishing, Amsterdam, 1966).
2. Patrick Suppes, *Axiomatic Set Theory*, (Dover Publications, Inc., New York, 1972).
3. P. R. Halmos, *Naive Set Theory*, (Van Nostrand, New York, 1960).
4. B. Rotman and G. T. Kneebone, *The Theory of Sets and Transfinite Numbers*, (Oldbourne, London, 1968).
5. Douglas Smith, Maurice Eggen and Richard St. Andre: *A Transition to Advanced Mathematics*, (Brooks/Cole, 2001).

Module Code: MATH-402
Module Title: **Partial Differential Equations**
Module Rating: 3 Cr. Hours
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)

Module Code: MATH-403
Module Title: **Numerical Analysis - I**
Module Rating: 3 Cr. Hours

Number Systems and Errors

- Round off errors and computer arithmetic
- Error estimation
- Floating point arithmetic

Solution of Non-Linear Equations

- Iterative methods and convergence: Bisection method, fixed point iterative method, Regula Falsi, Secant and Newton's method

Systems of Linear Equations

- Direct methods: Gaussian elimination method, Gauss-Jordan method, matrix inversion method, factorization (Doolittle, Crout and Cholesky) method and its various forms
- Iterative methods and convergence: Gauss-Jacobi method and Gauss-Seidel method
- Ill-condition system and condition number
- Eigen values and eigenvectors
- Power and Rayleigh quotient method

Interpolation and Polynomial Approximation

- Difference operators
- Interpolation with unequal intervals: Lagrange's interpolation formula, Newton's divided difference formula, error in polynomial interpolation
- Interpolation with equal intervals: Gregory Newton forward/backward interpolation formula, error in polynomial interpolation
- Central difference interpolation formulae: Gauss's forward/backward interpolation formula, Stirling's formula, Laplace Everett's formula, Bessel's formula

Recommended Books

1. Curtis F. Gerald and Patrick O. Wheatley, *Applied Numerical Analysis*, 6th edition, (Addison-Wesley Pearson Education, 2003)
2. Richard L. Burden and J. Douglas Faires, *Numerical Analysis*, 6th edition, (Brooks/Cole Publishing Company,1997)
3. John H. Mathews, *Numerical Methods for Mathematics*, 3rd edition (Prentice Hall International, 2003)
4. V. N. Vedamurthy and N. Ch. S. N. Iyenger, *Numerical Methods*, (Vikas Publishing House Pvt. Ltd, 2002)
5. Steven C. Chapra and Raymond P. Canale, *Numerical Methods for Engineers*, 3rd edition, (McGraw Hill International Edition, 1998)

Module Code: MATH-404
Module Title: **Mathematical Statistics - I**
Module Rating: 3 Cr. Hours

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)

Module Code: MATH-405
Module Title: **Fortran Programming**
Module Rating: 3 Cr. Hours

Simple Fortran 90 Programs

- Writing a program
- Input statement
- Some FORTRAN 90 program examples

Numeric Constants and Variables

- Constants
- Scalar variables
- Declaring variable names
- Implicit declaration
- Named constants

Arithmetic Expressions

- Arithmetic operators and modes of expressions
- Integer expressions
- Real expressions
- Procedure of operations in expressions
- Assignment statements
- Defining variables
- Mixed mode expressions
- Intrinsic functions

Conditional Statements

- Relational operators
- The block if construct
- Example programs using if structures

Implementing Loops in Programs

- The block do loop
- Count controlled do loop

Logical Expressions and More Control Statements

- Logical constants, variables and expressions
- Precedence rules for logical operators
- The case statement

Functions and Subroutines

- Function subprograms
- Syntax rules for function subprograms
- Generic functions
- Subroutines

Defining and Manipulating Arrays

- Arrays variables
- Use of multiple subscripts
- Do type notation for input/output statements
- Initializing arrays
- Use of arrays in do loops
- Whole array operations

Elementary Format Specifications

- Format description for numerical data; read statement
- Format description for print statement
- Multi-record formats
- Printing character strings

Recommended Books

1. Michel Metcalf, John Reid and Malcolm Cohen, *Fortran 95/2003 Explained*, (Oxford University Press, 2004).
2. V. Rajaraman, *Computer Programming in Fortran 90 and 95*, (Prentice Hall of India, New Delhi, 1999).
3. Larry Nyhoff and Sanford Leestma, *Fortran 90 for Engineers and Scientists*, (Prentice Hall, 1997).
4. Stephen J. Chapman, *Introduction to Fortran 90/95*, (Mc Graw-Hill International Edition, 1998).

Module Code: MATH-406
Module Title: **Group Theory - II**
Module Rating: 3 Cr. Hours
Pre-Requisite: Group Theory - I

Automorphisms and Products in Groups

- Characteristic and fully invariant subgroups
- Normal products of groups
- Holomorph of a group

Permutation Groups

- Symmetric or permutation group
- Permutability of permutations
- Transposions
- Generators of the symmetric and alternating group
- Cyclic permutations and orbits, the alternating group
- Generators of the symmetric and alternating groups
- Simplicity of A_n, $n \geq 5$
- The stabiliser subgroups

Series in Groups

- Series in groups
- Zassenhaus lemma
- Normal series and their refinements
- Composition series

Recommended Books

1. J. Rotman, *The Theory of Groups*, 2nd edition, (Allyn and Bacon, London, 1978)
2. J. B. Fraleigh, *A First Course in Abstract Algebra*, 7th edition, (Addison-Weseley Publishing Co., 2003)
3. I. N. Herstein, *Topics in Algebra*, (Xerox Publishing Company Mass, 1972)
4. J. A. Gallian, *Contemporary Abstract Algebra*, 4th edition, (Narosa Publishers, 1998)
5. J. S. Rose, *A Course on Group Theory*, (Dover Publications, New York, 1994)
6. K. Hoffman, *Linear Algebra*, 2nd edition, (Prentice Hall, 1971)

Module Code: MATH-407
Module Title: **Ring Theory**
Module Rating: 3 Cr. Hours

Ring Theory

- Construction of new rings
- Direct sums, polynomial rings
- Matrix rings
- Divisors, units and associates
- Unique factorisation domains
- Principal ideal domains and Euclidean domains

Field Extensions

- Algebraic and transcendental elements
- Degree of extension
- Algebraic extensions
- Reducible and irreducible polynomials
- Roots of polynomials

Recommended Books

1. I. N. Herstein, *Topics in Algebra*, (Xerox Publishing Company Mass, 1972)
2. B. Hartley and T. O. Hauvkes, *Rings, Modules and Linear Algebra*, (Chapmann and Hall Ltd., London, 1970)
3. R. B. Allenly, *Rings, Fields and Groups:An Introduction to Abstract Algebra*, (Edward Arnold, 1985)
4. J. Rose, *A Course on Rings Theory*, (Cambridge University Press, 1978)
5. G. Birkhoff and S. Maclane, *A Survey of Modern Algebra*, (Macmillan, New York, 1964)

Module Code: MATH-408
Module Title: **Number Theory-I**
Module Rating: 3 Cr. Hours

Congruences

- Elementary properties of prime numbers
- Residue classes and Euler's function
- Linear congruences and congruences of higher degree
- Congruences with prime moduli
- The theorems of Fermat, Euler and Wilson

Number-Theoretic Functions

- Möbius function
- The function [x], the symbols O and their basic properties

Primitive roots and indices

- Integers belonging to a given exponent
- Composite moduli, primitive roots modulo a prime
- Determination of integers having primitive roots indices

Recommended Books

1. W. J. Leveque, *Topics in Number Theory*, (Vols. I and II, Addison-Wesley Publishing Co., 1956)
2. Tom M. Apostol, *Introduction to Analytic Number theory*, (Springer International, 1998)
3. David M. Burton, *Elementary Number Theory*, 6th edition, (McGraw Hill Company, 2007)
4. A. Andrew, *The Theory of Numbers*, (Jones and Barlett Publishers London, 1995)
5. Harry Pollard, *The Theory of Algebraic Numbers*, (John Wiley and Sons, Inc, 1950)

Module Code: MATH-409
Module Title: **Quantum Mechanics-I**
Module Rating: 3 Cr. Hours

Inadequacy of Classical Mechanics

- Black body radiation
- Photoelectric effect
- Compton effect
- Bohr's theory of atomic structure
- Wave-particle duality
- The de Broglie postulate
- Heisenberg uncertainty principle

The Postulates of Quantum Mechanics: Operators, Eigenfunctions and Eigenvalues

- Observables and operators
- Measurement in quantum mechanics
- The state function and expectation values
- Time development of the state function (Schrödinger wave equation)
- Solution to the initial-value problem in quantum mechanics
- Parity operators

Preparatory Concepts: Function Spaces and Hermitian Operators

- Particle in a box
- Dirac notation
- Hilbert space
- Hermitian operators
- Properties of Hermitian operators

Additional One-Dimensional Problems: Bound and Unbound States

- General properties of the 1-dimensional Schrodinger equation
- Unbound states
- One-dimensional barrier problems
- The rectangular barrier: Tunneling

Recommended Books

1. H. D. Dehmen, *The Picture Book of Quantum Mechanics* (Springer, 2001).
2. H. F. Hameka, *Quantum Mechanics: A Conceptual Approach* (Wiley-IEEE, 2004).
3. R. L. Liboff, *Introductory Quantum Mechanics* (Addison-Wesley Publishing Co., 2003).
4. V. K. Thankappan , *Quantum Mechanics* (New Age Publishers, 1993).
5. D. R. Bès, *Quantum Mechanics: A Modern and Concise Introductory Course* (Springer, 2004).

Module Code: MATH-410
Module Title: **Analytical Dynamics**
Module Rating: 3 Cr. Hours

Lagrange's Theory of Holonomic Systems

- Generalized coordinates
- Holonomic and non-holonomic systems
- D'Alembert's principle, d-delta rule
- Lagrange equations
- Generalization of Lagrange equations
- Quasi-coordinates
- Lagrange equations in quasi-coordinates
- First integrals of Lagrange equations of motion
- Energy integral

Hamilton's Theory

- Hamilton's principle
- Generalized momenta and phase space
- Hamilton's equations
- Ignorable coordinates, Routhian function
- Derivation of Hamilton's equations from a variational principle
- The principle of least action

Lagrange's Theory of Non-Holonomic Systems

- Lagrange equations for non-holonomic systems with and without Lagrange multipliers
- Hamilton's Principle for non-holonomic systems

Canonical Transformations

- The equations of canonical transformations
- Examples of canonical transformations
- The Lagrange and Poisson brackets
- Equations of motion, infinitesimal canonical transformations and conservation theorems in the Poisson bracket formulation

Hamilton-Jacobi Theory

- The Hamilton-Jacobi equation for Hamilton's principal function
- The harmonic oscillator problem as an example of the Hamilton-Jacobi method
- The Hamilton-Jacobi equation for Hamilton's characteristic function
- Separation of variables in the Hamilton-Jacobi equation

Recommended Books

1. D. T. Greenwood, *Classical Dynamics* (Dover, 1997).
2. F. Chorlton, *Chorlton Text Book of Dynamics* (Ellis Horwood, 1983).
3. H. Goldstein, C. P. Poole and J. L. Safko, *Classical Mechanics* (Addison-Wesley Publishing Co., 2003).
4. S. D. Lindenbaum, *Analytical Dynamics: Course Notes* (World Scientific, 1994).
5. E. J. Saleton and J. V. José, *Classical Dynamics: A Contemporary Approach* (Cambridge, 1998).
6. J. B. Marion and S. T. Thornton, *Classical Dynamics of Particles and Systems* (Thomson Learning, 2003).

Module Code: MATH-411
Module Title: **Electromagnetic Theory - I**
Module Rating: 3 Cr. Hours

Electrostatic Fields

- Coulomb's law, the electric field intensity and potential
- Gauss's law and deductions, Poisson and Laplace equations
- Conductors and condensers
- Dipoles, the linear quadrupole
- Potential energy of a charge distribution, Dielectrics
- The polarization and the displacement vectors
- General solutions of Laplace's equation
- Solutions of Laplace's equation in spherical coordinates
- Legendre's equation, Legendre's polynomials

Magnetostatic Fields

- The Magnetostatic law of force
- The magnetic induction
- The Lorentz force on a point charge moving in a magnetic field
- The divergence of the magnetic field
- The vector potential
- The conservation of charge and the equation of continuity
- The Lorentz condition
- The curl of the magnetic field
- Ampere's law and the scalar potential

Steady and Slowly Varying Currents

- Electric current, linear conductors
- Conductivity, resistance
- Kirchhoff's laws
- Current density vector
- Magnetic field of straight and circular current
- Magnetic flux, vector potential
- Forces on a circuit in magnetic field

Recommended Books

1. G. E. Owen, *Introduction to Electromagnetic Theory* (Dover, 2003).
2. D. Corrison and P. Lorrison, *Introduction to Electromagnetic Fields and Waves* (W.H. Freeman and Company, London, 1962).
3. J. R. Reitz, F. J. Milford and R. W. Christy, *Foundations of Electromagnetic Theory* (Addison-Wesley Publishing Co., 1993).
4. J. D. Jackson, *Classical Electrodynamics* (Wiley, 1999).
5. D. J. Griffiths, *Introduction to Electrodynamics* (Prentice-Hall, 1999).

Module Code: MATH-412
Module Title: **Operations Research - I**
Module Rating: 3 Cr. Hours

Linear Programming

- Linear programming, formulations and graphical solution
- Simplex method
- M-Technique and two-phase technique
- Special cases

Duality and Sensitivity Analysis

- The dual problem, primal-dual relationships
- Dual simplex method
- Sensitivity and postoptimal analysis

Transportation Models

- North-West corner
- Least-Cost and Vogel's approximations methods
- The method of multipliers
- The assignment model
- The transhipment model
- Network minimization

Recommended Books

1. Hamdy A. Taha, *Operations Research - An Introduction*, (Macmillan Publishing Company Inc., New York, 1987)
2. B. E. Gillett, *Introduction to Operations Research*, (Tata McGraw Hill Publishing Company Ltd., New Delhi)
3. F. S. Hillier and G. J. Liebraman, *Operations Research*, (CBS Publishers and Distributors, New Delhi, 1974)
4. C. M. Harvey, *Operations Research*, (North Holland, New Delhi, 1979)

Module Code: MATH-413
Module Title: **Theory of Approximation and Splines - I**
Module Rating: 3 Cr. Hours
Pre-requisite: Geometry

Euclidean Geometry

- Basic concepts of Euclidean geometry
- Scalar and vector functions
- Barycentric coordinates
- Convex hull, matrices of affine maps: translation, rotation, scaling, reflection and shear

Approximation using Polynomials

- **Curve Fitting**: Least squares line fitting, least squares power fit, data linearization method for exponential functions, nonlinear least-squares method for exponential functions, transformations for data linearization, linear least squares, polynomial fitting
- **Interpolation**: Basic concepts of interpolation, Lagrange's method, error terms and error bounds of Lagrange's method, divided differences method, Newton polynomials, error terms and error bounds of Newton polynomials, central difference interpolation formulae; Gauss's forward interpolation formula, Gauss's backward interpolation formula, Hermite's methods.

Recommended Books

1. David A. Brannan, *Geometry*, (Cambridge University Press, 1999).
2. Gerald Farin, *Curves and Surfaces for Computer Aided Geometric Design: A Practical Guide*, 5th edition, (Academic Press. Inc., 2002).
3. Richard H. Bartels, John C. Bealty, and John C. Beatty, *An Introduction to Spline for use in Computer Graphics and Geometric Modeling*, (Morgan Kaufmann Publisher 2006).
4. John H. Mathews, *Numerical Methods for Mathematics, Science and Engineering*, 2nd edition (Prentice-Hall International Editions, 1992).
5. Steven C. Chapra and Raymond P. Canale, *Numerical Methods for Engineers* 3rd edition, (McGraw Hill International Edition, 1998).

Module Code: MATH-414
Module Title: **Functional Analysis - II**
Module Rating: 3 Cr. Hours
Pre-requisite: Functional Analysis-I

Compact Normed Spaces

- Completion of metric spaces
- Completion of normed spaces
- Compactification
- Nowhere and everywhere dense sets and category
- Generated subspaces and closed subspaces
- Factor Spaces
- Completeness in the factor spaces

Complete Orthonormal set

- Complete orthonormal sets
- Total orthonormal sets
- Parseval's identity
- Bessel's inequality

The Specific geometry of Hilbert Spaces

- Hilbert spaces
- Bases of Hilbert spaces
- Cardinality of Hilbert spaces
- Linear manifolds and subspaces
- Othogonal subspaces of Hilbert spaces
- Polynomial bases in L^2 spaces

Recommended Books

1. G. Bachman and L. Narici, *Functional Analysis*, (Academic Press, New York, 1966)
2. A. E. Taylor, *Functional Analysis*, (John Wiley and Sons, Toppan, 1958)
3. G. Helmberg, *Introduction to Spectral theory in Hilbert spaces*, (North Holland Publishing Company, 1969)
4. E. Kreyszig, *Introduction to Functional Analysis with Applications*, (John Wiley and Sons, 2004)
5. F. Riesz and B. Sz. Nagay, *Functional Analysis*, (Dover Publications, Inc., New York, Ungar, 1965)
6. W. Rudin, *Functional Analysis*, 2nd edition, (McGraw Hill Book Company, New York, 1991)

Module Code: MATH-415
Module Title: **Fluid Mechanics-I**
Module Rating: 3 Cr. Hours

Conservation of Matter

- Introduction
- Fields and continuum concepts
- Lagrangian and Eulerian specifications
- Local, convective and total rates of change
- Conservation of mass
- Equation of continuity
- Boundary conditions

Nature of Forces in a Fluid Field and their Effects

- Surface and body forces
- Stress at a point
- Viscosity and Newton's viscosity law
- Viscous and inviscid flows
- Laminar and turbulent flows
- Compressible and incompressible flows

Irrotational Fluid Motion

- Velocity potential from an irrotational velocity field
- Streamlines
- Vortex lines and vortex sheets
- Kelvin's minimum energy theorem
- Conservation of linear momentum
- Bernoulli's theorem and its applications
- Circulations, rate of change of circulation (Kelvin's theorem)
- Aaxially symmetric motion
- Stokes's stream function

Two-dimensional Motion

- Stream function
- Complex potential and complex velocity, Uniform flows
- Sources, sinks and vortex flows
- Flow in a sector
- Flow around a sharp edge, Flow due to a doublet

Recommended Books

1. H. Schlichting, K. Gersten, E. Krause and H. Oertel, Jr.: *Boundary-Layer Theory*, 8th edition (Springer, 2004).
2. Yith Chia-Shun: *Fluid Mechanics* (McGraw Hill, 1974).
3. I. L. Distsworth: *Fluid Mechanics* (McGraw Hill, 1972).
4. F. M. White: *Fluid Mechanics* (McGraw Hill, 2003).
5. I. G. Curie: *Fundamentals of Mechanics of Fluids, Third edition* (CRC, 2002).
6. R. W. Fox, A. T. McDonald and P. J. Pritchard: *Introduction to Fluid Mechanics* (John Wiley and Sons, 2003).

Semester VIII

Module Code: MATH-416
Module Title: **Measure Theory and Lebesgue Integration**
Module Rating: 3 Cr. Hours

Measurable Sets

- Outer measure, Lebesgue measure
- Lebesgue measurable sets
- Borel sets
- Non measurable sets

Measurable Functions

- Lebesgue measurable functions
- Simple functions, characteristic functions
- Borel measurable function
- Littlewood three principle

The Lebsegue Integration

- Review of the Riemann integral
- Lebsegue integral
- Integral of a non negative function
- Integral of measurable functions
- Convergence in measure

Recommended Books

1 D. Smith, M. Eggen and R. St. Andre, *A Transition to Advanced Mathematics*, (Brooks, 2001)
2 Seymour Lipshcutz, *Set Theory and Related Topics*, (Mc-Graw Hill Book Company, 1999)
3 H. L. Royden, *Real Analysis*, (Macmillam, 1968)
4 D. L. Cohan, *Measure Theory*, (Bir Khauser, 1980)
5 P.R. Halmos, *Measure Theory*, (Von Nostrand, New York, 1950)

Module Code: MATH-417
Module Title: **Methods of Mathematical Physics**
Module Rating: 3 Cr. Hours

Fourier Methods

- The Fourier transform
- Fourier analysis of generalized functions
- The Laplace transform
- Hankel transforms for the solution of PDE 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-Lagrange equations
- Integrand involving one, two, three and n variables
- Special cases of Euler-Lagranges equations
- Necessary conditions for existence of an extremum of a functional
- Constrained maxima and minima

Recommended Books

1. D. L. Powers, *Boundary Value Problems and Partial Differential Equations*, 5th edition (Academic Press, 2005)
2. W. E. Boyce, *Elementary Differential Equations,* 8th edition, (John Wiley and Sons, 2005)
3. M. L. Krasnov, G. I. Makarenko and A. I. Kiselev, *Problems and Exercises in the Calculus of Variations*, (Imported Publications, Inc., 1985)
4. J. W. Brown and R. V. Churchill, *Fourier Series and Boundary Value Problems* (McGraw Hill, 2006)
5. A. D. Snider, *Partial Differential Equations: Sources and Solutions* (Prentice Hall Inc., 1999)

Module Code: MATH-418
Module Title: **Numerical Analysis - II**
Module Rating: 3 Cr. Hours
Pre-Requisite: Numerical Analysis - I

Numerical Differentiation

- Derivatives using: Lagrange's interpolation formula, Newton's divided difference formula, Gregory Newton forward/backward interpolation formula, Gauss's forward/backward interpolation formula, Stirling's formula, Laplace Everett's formula, Bessel's formula

Numerical Integration

- Newton-Cotes formulae
- Trapezoidal rule, Simpson rule, Weddle's rule, Boole's rule
- Errors in quadrature formulae
- Gaussian quadrature formulae

Formulation of Difference Equations

- Analogy of difference equations
- Linear homogeneous difference equations with constant coefficients
- Linear non-homogeneous difference equations with constant coefficients

Ordinary Differential Equations

- Introduction to ODEs
- Taylor's series method: Simultaneous first order differential equations, higher order differential equations
- Euler's, improved Euler's, modified Euler's and Runge-Kutta methods with error analysis
- Predictor-corrector methods for solving initial value problems

Recommended Books

1. Curtis F. Gerald and Patrick O. Wheatley, *Applied Numerical Analysis*, 6th edition, (Addison-Wesley Publishing Co. Pearson Education, 2003)
2. Richard L. Burden and J. Douglas Faires, *Numerical Analysis*, 6th edition, (Brooks/Cole Publishing Company,1997)
3. John H. Mathews, *Numerical Methods for Mathematics*, Science and Engineering, 3rd edition (Prentice Hall International, 2003)
4. V. N. Vedamurthy and N. Ch. S. N. Iyenger, *Numerical Methods*, (Vikas Publishing House Pvt. Ltd, 2002)
5. Steven C. Chapra and Raymond P. Canale, *Numerical Methods for Engineers* 3rd edition, (McGraw Hill International Edition, 1998)

Module Code: MATH-419
Module Title: **Mathematical Statistics - II**
Module Rating: 3 Cr. Hours
Pre-Requisite: Mathematical Statistics - I

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).
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)

Module Code: MATH-420
Module Title: **Computer Applications**
Module Rating: 3 Cr. Hours

Flow Chart, Algorithm and Programming of the following Numerical Methods

- System of linear equations
  Jacobi's iterative method, Gauss-Seidel method
- Solutions of non-linear equations
  Bisection method, Newton-Raphson method, Secant method, Regula Falsi method
- Interpolation
  Langrage interpolation, Newton's divided and forward difference interpolation
- Numerical integration:
  Rectangular rule, Trapezoidal rule, Simpson's rule, Booles rule, Weddles rule
- Differential equations:
  Euler's method, Runge- Kutta methods, predictor-corrector methods
  Mathematica
- Introduction of mathematica, numerical calculations, algebraic calculations, symbolic and numerical mathematics, numbers, mathematical functions, algebraic manipulations, manipulating equations, series, limits and residues, linear algebra, graphs

Recommended Books

1. Michel Metcalf, John Reid and Malcolm Cohen, *Fortran 95/2003 Explained*, (Oxford University Press, 2004)
2. Stephen Wolfram, *The Mathematica*, 3rd edition, (Cambridge University Press 1996)
3. V. Rajaraman, *Computer Programming in Fortran 90 and 95*, (Prentice Hall of India, New Delhi, 1999)
4. Roman E. Maeder, *Computer Science with Mathematics*, (Cambridge University Press, 2000)
5. Martha L. Abell, James P. Braselton, *The Mathematica Handbook*, (Academic Press Inc., 1992)

Module Code: MATH-421
Module Title: **Group Theory - III**
Module Rating: 3 Cr. Hours

Solvable Groups

- Solvable groups, definition and examples
- Theorems on solvable groups
- Super-solvable groups

Nilpotent Groups

- Characterisation of finite nilpotent groups
- Upper and lower central series
- Frattini subgroups, free groups, basic theorems
- Definition and examples of free products of groups

Linear Groups

- Linear groups, types of linear groups
- Representation of linear groups
- Group algebras and representation modules

Recommended Books

1. J. Rotman, *The Theory of Groups*, 2nd edition, (Allyn and Bacon, London, 1978)
2. J. B. Fraleigh, *A First Course in Abstract Algebra*, 7th edition, (Addison-Wesley Publishing Co., 2003)
3. H. Marshall, *The Theory of Groups*, (Macmillan, 1967)
4. J. A. Gallian, *Contemporary Abstract Algebra*, 4th edition, (Narosa 1998)
5. J. S. Rose, *A Course on Group Theory*, (Dover Publications, New York, 1994)
6. K. Hoffman, *Linear Algebra*, 2nd edition, (Prentice Hall, 1971)

Module Code: MATH-422
Module Title: **Theory of Modules**
Module Rating: 3 Cr. Hours

Modules

- Definition and examples
- Submodules
- Homomorphisms
- Quotient modules
- Direct sums of modules.
- Finitely generated modules
- Torsion modules
- Free modules
- Basis, rank and endomorphisms of free modules
- Matrices over rings and their connection with the basis of a free module
- A module as the direct sum of a free and a torsion module

Recommended Books

1. J. Rotman, *The Theory of Groups*, 2nd edition, (Allyn and Bacon, London, 1978)
7. J. B. Fraleigh, *A First Course in Abstract Algebra*, 7th edition, (Addison-Weseley Publishing Co., 2003)
2. H. Marshall, *The Theory of Groups*, (Macmillan, 1967).
3. J. A. Gallian, *Contemporary Abstract Algebra*, 4th edition, (Narosa Publisihng House, 1998)
4. J. S. Rose, *A Course on Group Theory*, (Dover Publications, New York, 1994)
5. K. Hoffman, Linear Algebra, 2nd edition, (Prentice Hall, 1971)

Module Code: MATH-423
Module Title: **Number Theory - II**
Module Rating: 3 Cr. Hours
Pre-Requisite: Number Theory - I

Quadratic Residues

- Composite moduli, Legendre symbol
- Law of quadratic reciprocity
- The Jacobi symbol

Diophantine Equations

- Equations and Fermat's conjecture for $n = 2$, $n = 4$

Algebraic Number Theory

- Polynomials over a field
- Divisibility properties of polynomials
- Gauss's lemma
- The Einstein irreducibility criterion
- Symmetric polynomials
- Extensions of a field
- Algebraic and transcendental numbers
- Bases and finite extensions, properties of finite extensions
- Conjugates and discriminants
- Algebraic integers in a quadratic field, integral bases
- Units and primes in a quadratic field
- Ideals, arithmetic of ideals in an algebraic number field
- The norm of an ideal, prime ideals, units of algebraic number field

Recommended Books

1. W. J. Leveque, *Topics in Number Theory*, Vols. I and II (Addison-Wesley Publishing Co. Publishing Co., 1956)
2. Tom M. Apostol, *Introduction to Analytic Number Theory*, (Springer International, 1998)
3. David M. Burton, *Elementary Number Theory*, 6th edition, (McGraw Hill Company, 2007)
4. A. Andrew, *The Theory of Numbers*, (Jones and Barlett Publishers London, 1995)
5. Harry Pollard, *The Theory of Algebraic Numbers*, (John Wiley and Sons, 1950)

Module Code: MATH-424
Module Title: **Quantum Mechanics - II**
Module Rating: 3 Cr. Hours
Pre-Requisite: Quantum Mechanics - I

Harmonic Oscillator and Problems in Three-Dimensions

- The harmonic oscillator
- Eigenfunctions of the harmonic oscillator
- The harmonic oscillator in momentum space
- Motion in three dimensions
- Spherically symmetric potential and the hydrogen atom

Angular Momentum

- Basic properties
- Eigenvalues of the angular momentum operators
- Eigenfunctions of the orbital angular momentum operators L^2 and L_z
- Commutation relations between components of angular momentum and their representation in spherical polar coordinates

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

Recommended Books

1. R. L. Liboff, *Introductory Quantum Mechanics* (Addison-Wesley Publishing, 2003)
2. H. D. Dehmen, *The Picture Book of Quantum Mechanics* (Springer, 2001)
3. H. F. Hameka, *Quantum Mechanics: A Conceptual Approach* (Wiley-IEEE, 2004)
4. V. K.Thankappan, *Quantum Mechanics* (New Age Publishers, 1993).
5. D. R. Bès, *Quantum Mechanics: A Modern and Concise Introductory Course* (Springer, 2004)

Module Code: MATH-425
Module Title: **Special Theory of Relativity**
Module Rating: 3 Cr. Hours

Introduction

- Fundamental concepts

Derivation of Special Relativity

- Einstein's formulation of special relativity
- The Lorentz transformation
- Length contraction, time dilation and simultaneity
- The velocity addition formulae
- Three dimensional Lorentz transformations

The Four-Vector Formulation of Special Relativity

- The four-vector formalism
- The Lorentz transformations in 4-vectors
- The Lorentz and Poincare groups
- The null cone structure
- Proper time

Applications of Special Relativity

- Relativistic kinematics
- The Doppler shift in relativity
- The Compton effect
- Particle scattering
- Binding energy, particle production and particle decay

Electromagnetism in Special Relativity

- Review of electromagnetism
- The electric and magnetic field intensities
- The electric current
- Maxwell's equations and electromagnetic waves
- The four-vector formulation of Maxwell's equations

Recommended Books

1. M. Saleem and M. Rafique, *Special Relativity* (Ellis Horwood, 1992)
2. W. G. V. Rosser, *Introductory Special Relativity* (Taylor & Francis, 1991)
3. W. Ringler, *Introduction to Special Relativity* (Oxford, 1991)
4. A. Qadir, *An Introduction to Special Theory of Relativity* (World Scientific 1989)
5. G. Barton, *Introduction to the Relativity Principle* (Wiley, 1999)
6. W. Rindler, *Introduction to Special Relativity* (Clarendon Press, Oxford, 1991)

Module Code: MATH-426
Module Title: **Electromagnetic Theory - II**
Module Rating: 3 Cr. Hours
Pre-Requisite: Electromagnetic Theory - I

Steady and Slowly Varying Currents

- The Faraday induction law
- Induced elecromotance in a moving system
- Inductance and induced electromotance
- Energy stored in a magnetic field

The Equations of Electromagnetism

- Maxwell's equations in free space and material media
- Solution of Maxwell's equations

Electromagnetic Waves

- Plane electromagnetic waves in homogeneous and isotropic media
- The Poynting vector in free space
- Propagation plane electromagnetic waves in non-conductors
- Propagation plane electromagnetic waves in conducting media
- Reflection and refraction of plane waves
- Guided waves; coaxial line; hollow rectangular wave guide
- Radiation of electromagnetic waves
- Electromagnetic field of a moving charge

Recommended Books

1. J. R. Reitz, F. J. Milford and R. W. Christy, *Foundations of Electromagnetic Theory* (Addison-Wesley Publishing Co., 1993)
2. D. Corrison and P. Lorrison, *Introduction to Electromagnetic Fields and Waves* (W.H. Freeman and Company, London, 1962).
3. C.G. Someda, *Electromagnetic Waves* (CRC, 2006).
4. J. D. Jackson,*Classical Electrodynamics* (Wiley, 1999).
5. J. V. Stewart, *Intermediate Electromagnetic Theory* (World Scientific, 2001).
6. G. E. Owen, *Introduction to Electromagnetic Theory* (Dover, 2003).

Module Code: MATH-427
Module Title: **Operations Research - II**
Module Rating: 3 Cr. Hours
Pre-Requisite: Operations Research – I

- Shortest-Route algorithms for acyclic networks
- Maximal-flow problem
- Matrix definition of LP problem
- Revised simplex method, bounded variables
- Decomposition algorithm
- Parametric linear programming
- Applications of integer programming
- Cutting-plane algorithms
- Branch-and-bound method
- Zero-one implicit enumeration
- Elements of dynamic programming
- Problem of dimensionality
- Programmes by dynamic programming

Recommended Books

1. Hamdy A. Taha, *Operations Research-An Introduction*, (Macmillan Publishing Company Inc., New York, 1987)
2. B. E. Gillett, *Introduction to Operations Research*, (Tata McGraw Hill Publishing Company Ltd., New Delhi)
3. F. S. Hillier and G. J. Liebraman, *Operations Research*, (CBS Publishers and Distributors, New Delhi, 1974)
4. C. M. Harvey, *Operations Research*, (North Holland, New Delhi, 1979)

Module Code	MATH-428
Module Title	**Theory of Approximation and Splines - II**
Module Rating	3 Cr. Hours
Pre-requisites	Theory of Approximation and Splines - I

Parametric Curves (Scalar and Vector Case)

- Cubic algebraic form
- Cubic Hermite form
- Cubic control point form
- Bernstein Bezier cubic form
- Bernstein Bezier general form
- B-Spline cubic form
- Matrix forms of parametric curves
- Rational quadratic form
- Rational cubic form
- Tensor product surface, Bernstein Bezier cubic patch, quadratic by cubic Bernstein Bezier patch, Bernstein Bezier quartic patch
- Convex hull property
- Affine invariance property
- Variation diminishing property
- Algorithms to compute Bernstein Bezier form

Spline Functions

- Introduction to splines
- Cubic Hermite splines
- End conditions of cubic splines: clamped conditions, natural conditions, 2^{nd} Derivative conditions, periodic conditions, not a knot conditions
- General Splines: natural splines, periodic splines
- Truncated power function, representation of spline in terms of truncated power functions, examples

Recommended Books

1. Gerald Farin, *Curves and Surfaces for Computer Aided Geometric Design: A Practical Guide*, 5^{th} edition (Academic Press. Inc., 2002).
2. I. D. Faux, *Computational Geometry for Design and Manufacture*, (Ellis Horwood, 1979).
3. Richard H. Bartels, John C. Bealty, and John C. Beatty, *An Introduction to Spline for use in Computer Graphics and Geometric Modeling*, (Morgan Kaufmann Publisher, 2006).
4. Carl de Boor, *A Practical Guide to Splines*, (Springer Verlag, 2001).
5. Larry L. Schumaker, *Spline Functions: Basic Theory*, (John Wiley and Sons, 1993).

Module Code: MATH-429
Module Title: **Functional Analysis - III**
Module Rating: 3 Cr. Hours
Pre-Requisite: Functional Analysis - I

Semi-norms

- Semi norms, locally convex Spaces
- Quasi normed linear spaces
- Bounded linear functionals
- Hahn Banach theorem

Conjugate spaces

- Second conjugate space of l_p
- The Riesz representation theorem for linear functionals on a Hilbert spaces
- Conjugate space of $C[a,b]$
- A representation theorem for bounded linear functionals on $C[a,b]$

Uniform Boundedness

- Weak convergence
- The Principle of uniform boundedness
- Consequences of the principle of uniform boundedness
- Graph of a mapping and closed graph theorem

Linear transformation and complete continuity

- The closure of linear transformation
- The class of linear transformations that admit a closure

Recommended Books

1. G. Bachman and L. Narici, *Functional Analysis*, (Academic Press, New York, 1966)
2. A. E. Taylor, *Functional Analysis*, (John Wiley and Sons, Toppan, 1958)
3. G. Helmberg , *Introduction to Spectral theory in Hilbert spaces*, (N. H. Publishing Company 1969)
4. E. Kreyszig, *Introduction to Functional Analysis with Applications*, (John Wiley and Sons, 2004)
5. F. Riesz and B. Sz. Nagay, *Functional Analysis*, (Dover Publications, New York, Ungar, 1965)
6. W. Rudin, *Functional Analysis*, 2nd edition, (McGraw Hill Book Company, New York, 1991)

Module Code: MATH-430
Module Title: **Fluid Mechanics-II**
Module Rating: 3 Cr. Hours
Pre-Requisite: Fluid Mechanics-I

Two and Three-Dimensional Potential Flows

- Circular cylinder without circulation
- Circular cylinder with circulation
- Blasius theorem
- Kutta condition and the flat-plate airfoil
- Joukowski airfoil
- Vortex motion
- Karman's vortex street
- Method of images
- Velocity potential
- Stoke's stream function
- Solution of the Potential equation
- Uniform flow
- Source and sink
- Flow due to a doublet

Viscous Flows of Incompressible Fluids

- Constitutive equations
- Navier-Stokes's equations, exact solutions of Navier-Stokes's equations
- Steady unidirectional flow
- Poiseuille flow
- Couette flow
- Flow between rotating cylinders
- Stokes' first problem
- Stokes' second problem

Simplified Approach to Fluid Flow Problems

- Similarity from a differential equation
- Dimensional analysis
- One dimensional, steady compressible flow

Recommended Books

1. H. Schlichting, K. Gersten, E. Krause and H. Oertel, Jr.: *Boundary-Layer Theory*, 8th edition (Springer, 2004)
2. Yith Chia-Shun: *Fluid Mechanics* (McGraw Hill, 1974)
3. I. L. Distsworth: *Fluid Mechanics* (McGraw Hill, 1972)
4. F. M. White: *Fluid Mechanics* (McGraw Hill, 2003)
5. I. G. Curie: *Fundamentals of Mechanics of Fluids, Third edition* (CRC, 2002)
6. R. W. Fox, A. T. McDonald and P. J. Pritchard: *Introduction to Fluid Mechanics* (John Wiley and Sons, 2003)