

**UNIVERSITY OF THE PUNJAB**

**NOTIFICATION**

It is hereby notified that the Vice-Chancellor has, in exercise of the powers vested in him under Section 15(3) of the University of the Punjab Act, 1973 and in anticipation of the approval of the Syndicate, approved the recommendations of the Chairman, Department of Mathematics duly forwarded by the Dean, Faculty of Sciences regarding approval of BS 5<sup>th</sup> to 8<sup>th</sup> Semester Syllabus (in replacement of M.Sc. Mathematics) in the Subject of Mathematics for affiliated College with effect from the Academic Session, 2021.

The Syllabus of BS 5<sup>th</sup> to 8<sup>th</sup> Semester in Mathematics is attached herewith vide Annexure-A.

**Admin. Block,  
Quaid-i-Azam Campus,  
Lahore.**

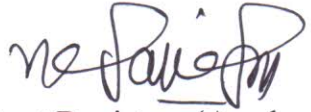
**Sd/-  
Muhammad Rauf Nawaz  
Registrar**

No.D/ 71 /Acad.

**Dated: 06-01-/2022.**

Copy of the above is forwarded to the following for information and further necessary action: -

1. Pro-Chancellor  
Minister of Education, Govt. of the Punjab, Lahore.
2. Members of the Syndicate
3. Dean, Faculty of Science.
4. Chairman, Department of Mathematics
5. Principals, affiliated Colleges.
6. Controller of Examinations
7. Director, Quality Enhancement Cell
8. Director, IT (For uploading on website)
9. Deputy Registrar (Affiliation)
10. Deputy Registrar (General)
11. Secretary to the Vice-Chancellor
12. P.S. to Pro Vice-Chancellor
13. P.S. to the Registrar
14. Admin. Officer Syndicate (with file)
15. Assistant Syllabus

  
Assistant Registrar (Academic)  
for Registrar

**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

<b>BS Mathematics Semester V</b>		
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.

<b>BS Mathematics Semester VI</b>		
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.

<b>BS Mathematics Semester VII</b>		
MATH-401	Set Theory	3 cr.
MATH-402	Partial Differential Equations	3 cr.
MATH-403	Numerical Analysis-I	3 cr.
<b>Any Three of the following:</b>		
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.

  
**CHAIRMAN**  
 Department of Mathematics  
 University of the Punjab  
 Lahore-Pakistan



<b>BS Mathematics Semester VIII</b>		
MATH-416	Measure Theory and Lebesgue Integration	3 cr.
MATH-417	Methods of Mathematical Physics	3 cr.
MATH-418	Numerical Analysis-II	3 cr.
<i>Any Three of the following:</i>		
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.



CHAIRMAN  
Department of Mathematics  
University of the Punjab  
Lahore-Pakistan

## 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  $\mathbb{R}$
- 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*, 3<sup>rd</sup> edition, (McGraw Hill, 1976)
2. R. G. Bartle, *Introduction to Real Analysis*, 3<sup>rd</sup> 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)



CHAIRMAN  
Department of Mathematics  
University of the Punjab  
Lahore-Pakistan



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)



**CHAIRMAN**  
Department of Mathematics  
University of the Punjab  
Lahore-Pakistan

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*, 7<sup>th</sup> 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)

  
**CHAIRMAN**  
Department of Mathematics  
University of the Punjab  
Lahore-Pakistan



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)



**CHAIRMAN**  
Department of Mathematics  
University of the Punjab  
Lahore-Pakistan

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 countability
- 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*, 2<sup>nd</sup> edition, (Prentice Hall Inc., 2003)



**CHAIRMAN**  
Department of Mathematics  
University of the Punjab  
Lahore-Pakistan



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
- Involution 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).



**CHAIRMAN**  
Department of Mathematics  
University of the Punjab  
Lahore-Pakistan

## 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*, 3<sup>rd</sup> edition, (McGraw Hill 1976)
2. R. G. Bartle, *Introduction to Real analysis*, 3<sup>rd</sup> 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)



**CHAIRMAN**  
Department of Mathematics  
University of the Punjab  
Lahore-Pakistan



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)

  
**CHAIRMAN**  
Department of Mathematics  
University of the Punjab  
Lahore-Pakistan

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*, 2<sup>nd</sup> edition, (Narosa Publishing House, 2003)
6. W. Keith Nicholson, *Elementary Linear Algebra*, (PWS-Kent Publishing Company, Boston, 2004)
7. Seymour Lipschutz, *Linear Algebra*, 3<sup>rd</sup> edition, (McGraw Hill Book Company, 2001)



CHAIRMAN  
Department of Mathematics  
University of the Punjab  
Lahore-Pakistan



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)



**CHAIRMAN**  
Department of Mathematics  
University of the Punjab  
Lahore-Pakistan

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*, 7<sup>th</sup> edition, (Thomson Brooks/Coley, USA, 2005)
2. M. R. Spiegel, *Theoretical 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 Publishing Co., 1980)
5. C. F. Chorlton, *Text Book of Dynamics*, (Ellis Horwood, 1983)



**CHAIRMAN**  
Department of Mathematics  
University of the Punjab  
Lahore-Pakistan

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)



**CHAIRMAN**  
Department of Mathematics  
University of the Punjab  
Lahore-Pakistan



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)

  
**CHAIRMAN**  
Department of Mathematics  
University of the Punjab  
Lahore-Pakistan

## 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. Fraenkel, *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).



**CHAIRMAN**  
Department of Mathematics  
University of the Punjab  
Lahore-Pakistan



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*, 2<sup>nd</sup> edition (Prentice Hall Inc., New Jersey, 1987)
6. E. Zauderer, *Partial Differential Equations of Applied Mathematics* (Wiley-Interscience, Englewood Cliff, New York, 2006)



**CHAIRMAN**  
Department of Mathematics  
University of the Punjab  
Lahore-Pakistan



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*, 6<sup>th</sup> edition, (Addison-Wesley Pearson Education, 2003)
2. Richard L. Burden and J. Douglas Faires, *Numerical Analysis*, 6<sup>th</sup> edition, (Brooks/Cole Publishing Company, 1997)
3. John H. Mathews, *Numerical Methods for Mathematics*, 3<sup>rd</sup> 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*, 3<sup>rd</sup> edition, (McGraw Hill International Edition, 1998)



**CHAIRMAN**  
Department of Mathematics  
University of the Punjab  
Lahore-Pakistan

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**

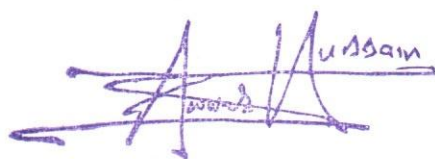
- Uniform and exponential distribution
- Gamma and beta distributions
- Normal distribution

### **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*, 3<sup>rd</sup> edition, (Macmillan Publishing Company London, 1982)
5. M. R. Spiegel and L. J. Stephens, *Statistics*, (McGraw Hill Book Company, 1984)



**CHAIRMAN**  
Department of Mathematics  
University of the Punjab  
Lahore-Pakistan

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**

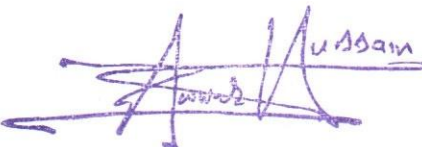
- The block do loop
- Count controlled do loop

### **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

  
**CHAIRMAN**  
Department of Mathematics  
University of the Punjab  
Lahore-Pakistan



### 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).



CHAIRMAN  
Department of Mathematics  
University of the Punjab  
Lahore-Pakistan

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



**CHAIRMAN**  
Department of Mathematics  
University of the Punjab  
Lahore-Pakistan

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

### **Ring Theory**

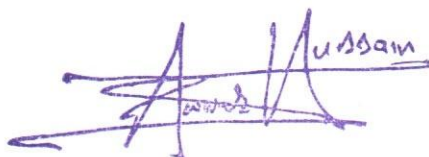
- Construction of new rings
- Direct sums, polynomial rings
- Matrix rings
- Divisors, units and associates
- Unique factorisation domains
- Principal ideal domains and Euclidean domains

### **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)



**CHAIRMAN**  
Department of Mathematics  
University of the Punjab  
Lahore-Pakistan



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*, 6<sup>th</sup> 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)



**CHAIRMAN**  
Department of Mathematics  
University of the Punjab  
Lahore-Pakistan

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).



CHAIRMAN  
Department of Mathematics  
University of the Punjab  
Lahore-Pakistan

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. Saletan 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).

  
**CHAIRMAN**  
Department of Mathematics  
University of the Punjab  
Lahore-Pakistan



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).

  
**CHAIRMAN**  
Department of Mathematics  
University of the Punjab  
Lahore-Pakistan

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 transshipment 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. Lieberman, *Operations Research*, (CBS Publishers and Distributors, New Delhi, 1974)
4. C. M. Harvey, *Operations Research*, (North Holland, New Delhi, 1979)



CHAIRMAN  
Department of Mathematics  
University of the Punjab  
Lahore-Pakistan

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*, 5<sup>th</sup> edition, (Academic Press. Inc., 2002).
3. Richard H. Bartels, John C. Beatty, 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*, 2<sup>nd</sup> edition (Prentice-Hall International Editions, 1992).
5. Steven C. Chapra and Raymond P. Canale, *Numerical Methods for Engineers* 3<sup>rd</sup> edition, (McGraw Hill International Edition, 1998).



**CHAIRMAN**  
Department of Mathematics  
University of the Punjab  
Lahore-Pakistan



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*, 2<sup>nd</sup> edition, (McGraw Hill Book Company, New York, 1991)

  
CHAIRMAN  
Department of Mathematics  
University of the Punjab  
Lahore-Pakistan

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)
- Axially 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*, 8<sup>th</sup> edition (Springer, 2004).
2. Yith Chia-Shun: *Fluid Mechanics* (McGraw Hill, 1974).
3. I. L. Distworth: *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 Lebesgue Integration**

- Review of the Riemann integral
- Lebesgue 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 Lipschutz, *Set Theory and Related Topics*, (Mc-Graw Hill Book Company, 1999)
- 3 H. L. Royden, *Real Analysis*, (Macmillan, 1968)
- 4 D. L. Cohan, *Measure Theory*, (Bir Khauser, 1980)
- 5 P.R. Halmos, *Measure Theory*, (Von Nostrand, New York, 1950)



CHAIRMAN  
Department of Mathematics  
University of the Punjab  
Lahore-Pakistan



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**

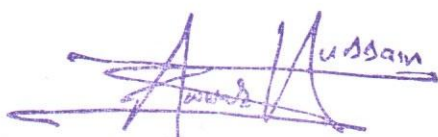
- Perturbation methods for algebraic equations
- Perturbation methods for differential equations

### **Variational Methods**

- Euler-Lagrange equations
- Integrand involving one, two, three and n variables
- Special cases of Euler-Lagrange 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*, 5<sup>th</sup> edition (Academic Press, 2005)
2. W. E. Boyce, *Elementary Differential Equations*, 8<sup>th</sup> 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)



**CHAIRMAN**  
Department of Mathematics  
University of the Punjab  
Lahore-Pakistan

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*, 6<sup>th</sup> edition, (Addison-Wesley Publishing Co. Pearson Education, 2003)
2. Richard L. Burden and J. Douglas Faires, *Numerical Analysis*, 6<sup>th</sup> edition, (Brooks/Cole Publishing Company, 1997)
3. John H. Mathews, *Numerical Methods for Mathematics*, Science and Engineering, 3<sup>rd</sup> edition (Prentice Hall International, 2003)
4. V. N. Vadamurthy 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* 3<sup>rd</sup> edition, (McGraw Hill International Edition, 1998)



**CHAIRMAN**  
Department of Mathematics  
University of the Punjab  
Lahore-Pakistan

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*, 3<sup>rd</sup> edition, (Macmillan Publishing Company London, 1982)
5. M. R. Spiegel, L. J. Stephens, *Statistics*, (McGraw Hill Book Company, 1984)

  
**CHAIRMAN**  
Department of Mathematics  
University of the Punjab  
Lahore-Pakistan



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  
Lagrange interpolation, Newton's divided and forward difference interpolation
- Numerical integration:  
Rectangular rule, Trapezoidal rule, Simpson's rule, Boole's rule, Weddle's 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*, 3<sup>rd</sup> 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)



CHAIRMAN  
Department of Mathematics  
University of the Punjab  
Lahore-Pakistan

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

  
**CHAIRMAN**  
Department of Mathematics  
University of the Punjab  
Lahore-Pakistan


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



CHAIRMAN  
Department of Mathematics  
University of the Punjab  
Lahore-Pakistan



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**

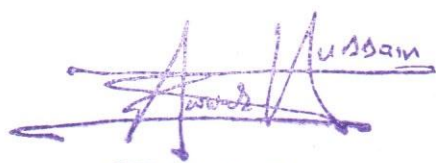
- Equations and Fermat's conjecture for  $n = 2, n = 4$

### **Algebraic Number Theory**

- Polynomials over a field
- Divisibility properties of polynomials
- Gauss's lemma
- The Eisenstein 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*, 6<sup>th</sup> 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)



CHAIRMAN  
Department of Mathematics  
University of the Punjab  
Lahore-Pakistan

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. Hamerka, *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)

  
CHAIRMAN  
Department of Mathematics  
University of the Punjab  
Lahore-Pakistan

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**

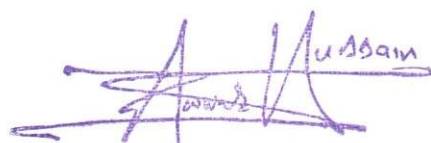
- Relativistic kinematics
- The Doppler shift in relativity
- The Compton effect
- Particle scattering
- Binding energy, particle production and particle decay

### **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)

  
CHAIRMAN  
Department of Mathematics  
University of the Punjab  
Lahore-Pakistan



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 electromotance 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).


  
CHAIRMAN  
Department of Mathematics  
University of the Punjab  
Lahore-Pakistan

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. Lieberman, *Operations Research*, (CBS Publishers and Distributors, New Delhi, 1974)
4. C. M. Harvey, *Operations Research*, (North Holland, New Delhi, 1979)



CHAIRMAN  
Department of Mathematics  
University of the Punjab  
Lahore-Pakistan

Module Code	MATH-428
Module Title	<b>Theory of Approximation and Splines - II</b>
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<sup>nd</sup> 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<sup>th</sup> edition (Academic Press. Inc., 2002).
2. I. D. Faux, *Computational Geometry for Design and Manufacture*, (Ellis Horwood, 1979).
3. Richard H. Bartels, John C. Beatty, 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).

  
**CHAIRMAN**  
 Department of Mathematics  
 University of the Punjab  
 Lahore-Pakistan



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*, 2<sup>nd</sup> edition, (McGraw Hill Book Company, New York, 1991)



CHAIRMAN  
Department of Mathematics  
University of the Punjab  
Lahore-Pakistan

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*, 8<sup>th</sup> edition (Springer, 2004)
2. Yith Chia-Shun: *Fluid Mechanics* (McGraw Hill, 1974)
3. I. L. Distworth: *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)



CHAIRMAN  
Department of Mathematics  
University of the Punjab  
Lahore-Pakistan