# KERALA UNIVERSITY

## SYLLABUS FOR M.Sc. MATHEMATICS

## SEMESTER PATTERN IN AFFILIATED COLLEGES

## 2013 ADMISSION ONWARDS

### M.Sc. MATHEMATICS COURSE STRUCTURE & MARK DISTRIBUTION

| Semester | Paper Code | Title of the Paper | Distribution hrs. per Semester | Instructional hrs./ week | | Dur ESA hrs. | Maximum Marks | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | L | P | | CA | ESA | Total |
| I | MM 211 | Linear Algebra | 108 | 6 | - | 3 hrs | 25 | 75 | 100 |
| | MM 212 | Real Analysis - I | 108 | 6 | - | " | 25 | 75 | 100 |
| | MM 213 | Diff. Equation | 108 | 6 | - | " | 25 | 75 | 100 |
| | MM 214 | Topology - I | 126 | 7 | - | " | 25 | 75 | 100 |
| | | | | | | | | | |
| II | MM 221 | Algebra | 108 | 6 | - | 3 hrs | 25 | 75 | 100 |
| | MM 222 | Real Analysis-II | 108 | 6 | - | " | 25 | 75 | 100 |
| | MM 223 | Topology-II | 108 | 6 | - | " | 25 | 75 | 100 |
| | MM 224 | Computer Programming in C++ | 126 | 5 | 2 | " | 25 | 75 | 100 |
| | | | | | | | | | |
| III | MM 231 | Complex Analysis - I | 126 | 7 | - | 3 hrs | 25 | 75 | 100 |
| | MM 232 | Functional Analysis -I | 108 | 6 | - | " | 25 | 75 | 100 |
| | MM 233 | Elective - I | 108 | 6 | - | " | 25 | 75 | 100 |
| | MM 234 | Elective - II | 108 | 6 | - | " | 25 | 75 | 100 |
| | | | | | | | | | |
| IV | MM 241 | Complex Analysis - II | 126 | 7 | - | 3 hrs | 25 | 75 | 100 |
| | MM 242 | Functional Analysis-II | 108 | 6 | - | " | 25 | 75 | 100 |
| | MM 243 | Elective - III | 108 | 6 | - | " | 25 | 75 | 100 |
| | MM 244 | Elective - IV | 108 | 6 | - | " | 25 | 75 | 100 |
| | | | | | | | | | |
| | MM 245 | Dissertation / Project | | | | | | 80+20 | 100 |
| | | Comprehensive Viva | | | | | | | 100 |
| | | **GRAND TOTAL** | **1800** | | | | | | **1800** |

L: Lecture; P: Practical; CA: Continuous Assessment ; ESA: End Semester Examination

# M.Sc MATHEMATICS

***(Revised Syllabus from 2013 Admissions)***

## LIST OF PAPERS

### SEMESTER - I

MM211 Linear Algebra (Revised Syllabus Attached)
MM212 Real Analysis - I (Revised Syllabus Attached)
MM213 Differential Equations (Original Syllabus Continues)
MM214 Topology – I (Revised Syllabus Attached)

### SEMESTER – II

MM221 Algebra (Revised Syllabus Attached)
MM222 Real Analysis - II(Revised Syllabus Attached)
MM223 Topology – II (Revised Syllabus Attached)
MM224 Computer Programming in C++ (Original Syllabus Continues)

### SEMESTER – III

MM231 Complex Analysis – I (Original Syllabus Continues)
MM232 Functional Analysis – I (Original Syllabus Continues)
MM233 Elective (One among the following)
Automata Theory (Original Syllabus Continues)
Probability (Original Syllabus Continues)
Operations Research (Revised Syllabus Attached)
MM234 Elective (One among the following)
Geometry of numbers (Original Syllabus Continues)
Differential Geometry (Original Syllabus Continues)
Graph Theory (New Syllabus Attached)
Approximation Theory (New Syllabus Attached)

### SEMESTER – IV

MM241 Complex Analysis – II (Original Syllabus Continues)
MM242 Functional Analysis – II (Original Syllabus Continues)
MM243 Elective (One among the following)
Mathematical Statistics (Original Syllabus Continues)
Mechanics (Original Syllabus Continues)
Theory of Wavelets (Original Syllabus Continues)
Coding Theory (Original Syllabus Continues)
Field Theory (Revised Syllabus Attached)
MM244 Elective (One among the following)
Commutative Algebra (Original Syllabus Continues)
Representation Theory of Finite Groups (Original Syllabus Continues)
Category Theory (Original Syllabus Continues)
Advanced Graph Theory (Original Syllabus Continues)
Analytic Number Theory (Original Syllabus Continues)

# MM 211 LINEAR ALGEBRA

**Text: Sheldon Axler, *"Linear Algebra Done Right"* 2nd Edition, Springer.**

## UNIT 1

Vector spaces: Definition, Examples and properties, Subspaces, Sum and Direct sum of subspaces, Span and linear independence of vectors, Definition of finite dimensional vector spaces, Bases: Definition and existence, Dimension Theorems.
[Chapters 1,2 of Text]

## UNIT II

Linear maps, their null spaces and ranges, Operations on linear maps in the set of all linear maps from one space to another , Rank-Nullity Theorem , Matrix of linear map, its invetibilty.
[Chapter 3 of Text]

## UNIT III

Invariant subspaces, Definition of eigen values and vectors, Polynomials of operators, Upper triangular matrices of linear operators, Equivalent condition for a set of vectors to give an upper triangular operator, Diagonal matrices, Invariant subspaces on real vector spaces.
[Chapter 5 of Text]

## UNIT IV

Concept of generalized eigen vectors, Nilpotent operators characteristic polynomial of an operator, Cayley-Hamilton theorem, Condition for an operator to have a basis consisting of generalized eigen vectors, Minimal polynomial. Jordan form of an operator (General case of Cayley-Hamilton Theorem may be briefly sketched from the reference text)
[Chapter 8 of Text]

## UNIT V

Change of basis, trace of an operator, Showing that trace of an operator is equal to the trace if its matrix, determinant of an operator, invertibilty of an operator and its determinant, relation between characteristic polynomial and determinant, determinant of matrices of an operator w.r.t. two base are the same. Determinant of a matrix (The section volumes may be omitted)
[Chapter 10 of Text]

**References**


1. **Kenneth Hoffman and Ray Kunze, "*Linear Algebra*", Prentice Hall, 1981.**
2. **I.N Herstein, "*Linear Algebra*", Wiley Eastern.**
3. **S. Kumaresan, "*Linear Algebra*", Prentice Hal, 2000.**

# MM 212 REAL ANALYSIS-I

**Texts: (1) Tom M. Apostol, *Mathematical Analysis, Second Edition*, Narosa 1974.**
**(2) Sudhir R.Ghorpade and Balmohan V. Limaye, *A course in Multivariate Calculus and Analysis*, Springer, 2010**

## UNIT I

**Functions of Bounded Variation and Rectifiable Curves**. Properties of monotonic functions, Functions of bounded variation, Total variation, Additive property of total variation, Total variation on [a,x] as a function of x, Function of bounded variation expressed as the difference of increasing functions, Continuous functions of bounded variation, Curves and paths, Rectifiable paths and arc-length, Additive and continuity of arc length, Equivalence of paths, Change of parameter.
[Chapter 6 of Text 1]

## UNIT II

**The Riemann-Stieltjles Integral**. The definition of Riemann-Steiltjles integral, Linear properties, Integration by parts, Change of variable in a Riemann –Stieltjes integral, Reduction to a Riemann integral, Step functions as integrators, Reduction of a Riemann-Stieltjes integral to a finite sum, Euler's summation formula, Monotonically increasing integrators, Upper and lower integrals, Additive and linearity properties of upper and lower integrals, Riemann's condition, Comparison Theorems, Integrators of bounded variation, Sufficient conditions for the existence of Riemann-Stieltjes integrals, Differentiation under the integral sign.
[Chapter 7, Sections 7.1-7.16,7.24 of Text 1]

## UNIT III

**Sequences of Functions.** Point-wise convergence of sequences of functions, Examples of sequences of real-valued functions, Definition of uniform convergence, Uniform convergence and continuity. The Cauchy condition for uniform convergence, Uniform convergence of infinite series of functions, Uniform convergence and Riemann-Stieltjes integration, Non-uniformly convergent series that can be integrated term by term, Uniform convergence and differentiation, Sufficient conditions for uniform convergence of a series.
[Chapter 9, Sections 9.1-9.9 except 9.7 of text 1. Do more problems to study the uniform convergence of sequences and series]

## UNIT IV

**Multivariate Calculus: Sequences, continuity and limits.** Sequences in $R^2$, Sub-sequences and Cauchy sequences, Compositions of continues functions, Piecing continuous functions on overlapping subsets, Characterizations of continuity, Continuity and boundedness, Continuity and convexity, Continuity and intermediate value property , Uniform continuity, Implicit function Theorem, Limits and continuity.
[Text 2. Sections 2.1, 2.2 (excluding Continuity and monotonicity, Continuity, Bounded Variation, Bounded Bivariation), 2.3 (Excluding Limits from a quadrant, Approaching Infinity)]

## UNIT V

**Partial and Total Differentiation.** Partial derivative, Directional derivatives, Higher order partial derivatives, Higher order directional derivatives, Differentiability, Taylor's Theorem and Chain rule, Functions of three variables, Extensions and analogues, Tangent planes normal lines to surfaces. [Text2. Chapter 3 excluding section 3.4 and last subsection of section 3.5]

**References.**

**1. J.A Dieudonne, *Foundations of Modern Analysis*, Academic Press.**
**2. W. Rudin, *Real and Complex analysis,* Tata Mc-Graw Hill.**

# MM 213 DIFFERENTIAL EQUATIONS

**Texts (1) G.F Simmons, *Differential Equations (with Applications and Historical Notes),* Tata Mc Graw-Hill**
**(2) T.Amarnath, *An elementary Course in Partial Differential Equations,* Narosa**

## UNIT 1

Solving second order Linear Equations- The method of Undetermined coefficients, The method of variation of parameters, The method of successive approximations and Picards Theorem.
[Chapter 3: Sections 18,19; Chapter11: Sections 55, 56, 57 of Text 1]

## UNIT II

Series solutions of first order equations - ordinary point - regular singular point - Gauss's Hype geometric equations-The point at infinity, Chebyshev polynomials.
[Chapter 5: Sections 25,26,27,28,29,30,31 and appendix D, excluding min max property of Text 1]

## UNIT III

Special functions - Legendre polynomials - Bessel's functions - Gamma functions.
[Chapter 6: Sections 32,33,34,35 of Text 1]

## UNIT IV

First Order PDE - Curves and Surfaces, Genesis of first order PDE, Classifications of integrals-Linear equation of first order- Pfaffian Differential Equations- Compatible systems- Charpits equations, Jacobi's method.
[Chapter 1: Section 1.1 to 1.8 of Text2]

## UNIT V

Second order PDE - Classification of second order PDE - One dimensional wave equations-Vibration of finite string - Vibration of semi infinite string - Vibrations of infinite string, Laplace equations - Boundary value problem, Maximum and minimum principles.
[Chapter 2: Sections 2.1, 2.2, 2.3.1, 2.3.2, 2.3.3, 2.4.1, 2.4.2 of Text 2]

**Reference**

**1] Iat Sneddon,*Elements of Partial Differential Equations* (MC Graw-Hill)**
**2] Phoolan Prasad, Renuka Raveendran, *Partial Differential Equations* (Wiley Eastern)**
**3] Zahir Ahsan, *Differential Equations and their Applications* (Prentice Hall 1999)**
**4] Earl A Coddington, Norman Levinson, *Theory of Ordinary Differential Equations* (Tata Mc Graw Hill)**
**5] G.Birkoff and G.C Rota, *Ordinary Differential Equations* (Wiley and Sons- 3rd Edn (1978)).**
**6] M.Ram Mohan Rao, *Ordinary Differential Equations and Applications.***

# MM 214 TOPOLOGY-I

**Text: Sheldon W.Davis, *Topology,* Tata Mc Graw-Hill Edition 2006, Tata MC Graw-Hill**

## UNIT 1

**Metric spaces:** Definition and Examples, Open sets, Closed sets and their properties, Convergence of sequences in metric spaces.
(Chapter 2 of the Text-up to theorem 2.32)

## UNIT II

Complete metric spaces, Cantor intersection Theorem, Baire category Theorem, Continuity in metric spaces, Uniform continuity, Banach fixed point Theorem.
(Chapter 2 of the Text – from definition 2.33 to corollary 2.51, Chapter 3)

## UNIT III

**Topological spaces:** Definition and Examples, Interior and Closure, Base for topology, Subspaces, Continuity in topological spaces, Product topology
(Chapter 4 and Chapter 5 of the Text)

## UNIT IV

**Separation axioms:** $T_0$, $T_1$, $T_2$, $T_3$ and $T_4$ spaces, Urysohn's Lemma, Tietze extension Theorem.
**Compact spaces:** Heine-Borel theorem, Tychonoff Theorem.
(Chapter 6 and Chapter 7 of the Text)

## UNIT V

Connected spaces, Locally connected spaces, Pathwise connected spaces, Locally pathwise connected spaces.
(Chapter 9 and Chapter 10 of the Text)

**References.**


(1) **G.G Simmons, *Topology and Modern Analysis*, Mc Graw-Hill Inc, New York, 1963**
(2) **Stephen Willard, *General Topology*, Addison-Wesley, Reading, 1970**
(3) **J.Arthur Seebach, *Lynn Arthur Steen, Counter Examples in Topology*, Dover Publications, 1995**

# MM 221 ALGEBRA

**Text books: 1. Joseph A Gallian,** ***Contemporary Abstract algebra, 7th Edition***
**Brooks/Cole, Cengage Learning**
**2. J.B Fraleigh,** ***First Course in Abstract Algebra, 7th Edition*****,**
**PHI Learning**

## UNIT 1

**Groups:** Definition, Examples, Elementary properties of groups. **Subgroups:** Examples, Cyclic groups-properties; Classification of subgroups of cyclic groups, Permutation groups, Cycle notation, Properties of permutation.
(Chapters 2,3,4 and 5 of Text book 1)

## UNIT II

**Isomorphisms:** Definitions, Examples, Cayley's Theorem, Properties, Automorphisms, **Cosets** - properties, Lagrange's Theorem and its consequences. **External direct products-** Properties, Normal subgroups, **Factor groups** – Applications, Internal direct product.
(Chapters 6, 7,8,9 of Text book 1)
Series of groups, solvable groups
(Section 35 of Text 2)

## UNIT III

**Group homomorphisms:** Definition, Examples, Properties. First isomorphism Theorem, Fundamental Theorem of abelian groups, Sylow Theorems, Conjugacy classes, Class equation, Sylow Theorems, Applications, Classification of finite abelian groups up to order 15.
(Chapters 10,11, and 24 of Text 1)

## UNIT IV

**Rings** - Defection, Examples and properties. **Integral Domain** - Definition, Examples, Field-Examples, Characteristics of a ring, Ideals, Factor rings, Prime ideals, Maximal ideals, **Homomorphisms** - Properties, Construction of field of quotients.
(Chapters 12,13,14 and 15 of text 1)

## UNIT V

**Polynomial rings** – Definition, Divisions algorithm, Principal Ideal Domain, Irreducibility, Unique factorization on Z[x], Irreducible polynomials, Unique factorization domains, Euclidean Domain.
(Chapters 16,17 and 18 of Text 1)

**References:**


1. **T W Hungerford,** ***Algebra,*** **Springer 2005**
2. **I N Heirstein,*****Topics in Algebra,*** **John Wiley, Inc**
3. **M Artin,** ***Algebra,*** **Prentice Hall**
4. **M Jacobson,** ***Basic Algebra,*** **Dover Books**

# MM 222 REAL ANALYSIS-II

**Texts: (1) G.de.Barra, *Measure Theory and Integration,* New Age International Publishers, New Delhi, 1981.**

## UNIT I

Lebesgue Outer Measure, Measurable sets, Regularity, Measurable functions, Borel and Lebesque Measurability
(Chapter 2, 2.1-2.5 of Text)

## UNIT II

Integration of Non-negative functions, The General Integral, Integration of Series, Riemann and Lebesgue Integrals, The Four Derivatives, Lebesgue's Differentiation Theorem, Differentiations and Integration.
(Chapter 3, 3.1 to 3.4, Chapter 4, 4.1, 4.4,4.5 of the Text)

## UNIT III

**Abstract Measure Spaces:** Measures and Outer Measures, Extension of a measure, Uniqueness of the Extension, Completion of the Measure, Measure spaces, Integration with respect to a Measure
(Chapter 5, 5.1-5.6 of Text)

## UNIT IV

The $L^p$ Spaces, Convex Functions, Jensen's Inequality, The Inequalities of Holder and Minkowski, Completeness of $L^p(\mu)$.
(Chapter 6, 6.1-6.5 of Text)

## UNIT V

Convergence in Measure, Signed Measures and the Hahn Decomposition, The Jordan Decomposition, The Radon-Nikodym Theorem, Some Applications of the Radon-Nikodym Theorem.
(Chapter 7,7.1 Chapter 8,8.1-8.4 of Text)

**References:**

**(1) H.L.Roydon, *Real Analysis, Third Edition,* Mac-Millan**
**(2) W.Rudin, *Principles of Mathematical Analysis,* Third Edition**
**(3)P.R Halmos, *Measure Theory,* Springer.**

# MM223 TOPOLOGY-II

**Texts: (1) Sheldon W Davis, *Topology,* Tata Mc Graw-Hill Edition 2006, Tata Mc Graw Hill**

**(2) I.M Singer, J.A Thorpe, *Lecture Notes on Elementary Topology and Geometry,* Springer International Edition, Springer ( India) Private Limited, New Delhi, 2004**

## UNIT 1

**Locally Compact Spaces:** Definition and Examples, Alexandroff one-point compactification, Baire-Category Theorem.
(Chapter 8 of Text 1)

## UNIT II

**Quotients and products:** Quotient Topology, Product Topology, Embedding, Embedding Lemma.
(Chapter 15 of Text 1)

## UNIT III

**Convergence:** Net, Limit point and Cluster Point of the Net, Filter, Ultrafilter, Relationship between net and filter.
(Chapter 16 of Text 1)

## UNIT IV

**Fundamental Group and Covering spaces:** Homotopy, Fundamental Group, Covering spaces.
(Chapters 3 of Text 2)- The proof of Theorem 4 is omitted)

## UNIT V

**Simplicial Complexes:** Geometry of Simplicial Complexes, Barycentric Subdivisions, Simplicial approximations Theorem, Fundamental group of a simplicial complex.
(Chapter 4 of Text 2)

**References:**

**(1) Stephen Willard, *General Topology,* Addison-Wesley, Reading, 1970.**
**(2) Satya Deo, *Algebraic Topology A Primer*, Hindustan Book Agency, New Delhi, 2003.**

# M224 COMPUTER PROGRAMMING IN C++

**Texts: 1. Robert Lafore, *Object Oriented Programming in C++ (Third Edition)***
**Galgotia Publications Pvt. Ltd (2003)**
**2: K.V Venugopal and Sunder Arora, *Programming with C,* Tata Mc Graw Hill Outline Series**

## UNIT 1

Characteristics of Object Oriented Languages- C++ Programming Basics, Basic Program Construction- Comments, Variables , Constants, Expressions, Statements, cin and cout, Manipulators, Type conversion, Arithmetic operators, Library functions, Loops and decisions, Relational operators, Logical operators, Other control statements
(Chapters 1, 2, and 3 of Text 1)

## UNIT 2

Structures- Declaring structures, Defining structure variables, Accessing structure members, Other structure features, Structure within structures, Enumerated data types. Functions- Simple functions, Passing a garments to functions, Returning valued from functions, Reference arguments, Overloaded functions, Inline functions, Default arguments, Variables and storage classes, Returning by reference.
(Chapters 4 and 5 of the Text1)

## UNIT 3

Object Classes- Simple class, Specifying the class, C++ objects as physical objects, C++ objects as data types, Constructors, Destructors, Objects as function arguments, Returning objects from functions, Structures and classes, Objects and memory, Static class data, Arrays-Array fundamentals, Multidimensional arrays, Passing arrays to functions, Function declaration with array arguments, Arrays of structures, Arrays as class members data, Arrays of objects, C-strings, Arrays of strings, Strings as class members, a user defined string type.
(Chapters 6 and 7 of Text 1)

## UNIT 4

Operator overloading- Overloading unary operators, Overloading binary operators, Arithmetic operators, Multiple overloading , Data conversion, Inheritance- Derived class and basic class, Derived class constructors, Over riding member function, Class Hierarchies, Public and private inheritance, Levels of inheritance, Multiple inheritance, Class within class.
(Chapters 8 and 9 of Text 1)

## UNIT 5

Pointers-Addresses and pointers, Pointers and arrays, Pointers and functions, Passing simple variable, Passing arrays, Pointers and C type strings, Library string functions, Memory management: New and delete pointers to objects, Pointers to pointers
(Chapter 10 of Text 1)

## PRACTICALS

The following 12 practicals have to be done computer using a Turbo or Borland C++ program

1. Product of two matrices and order
2. Inverse of a square matrix
3. General interactive method to solve f(x)=o by changing it to the form x=g(x)
4. Bisection method
5. Newton-Raphson's method
6. Regula-Falti method
7. Trapezo dal rule of integration
8. Simpsor's one-third rule of integration
9. Simpsor's three-eighth ruleo f integration
10. Euler's method to solve a first order differential equation with a given initial condition
11. Eiler's modified method
12. Runge-Kuta method of order 4

(Text: 2)

**References**


1. **Bjarne Stroustrup, *C++ programming Language,* Addison Weley**
2. **John Hubbard , *Programming with C++,* Shaum's Outline Series**
3. **Namir C Sharma, *Fundamentals of C++ and object oriented programming,* Comdex Computer Publishing Co**
4. **E.Balagurusamy, *Object Oriented Programming with C++,* Tata Mc Graw Hill**
5. **Jain and Iyengar, *Numerical Methods for Scientific and Engineering Computation,* New Age Publishers.**

# MM 231 COMPLEX ANALYSIS – I

**Text: John. B. Conway, *Functions of Complex Variables*, Springer-Verlag, New York, 1973.**
**(Indian Edition: Narosa)**

## UNIT I

Elementary properties and examples of analytic functions, Power series, Analytic function, Riemann-Stieltjes integrals.
(Chapter 3- Sections 1,2 , Chapter 5- Section 1 of Text)

## UNIT II

Power series representation of an analytic function, Zeros of an analytic function, The index of a closed curve.
(Chapter 4 – Sections 2,3,4 of Text)

## UNIT III

Cauchy's Theorem and integral formula, Homotopic version of Cauchy's Theorem, Simple connectivity, Counting zeros: The open Mapping Theorem, Goursat's Theorem.
(Chapter 4- Sections 5 to 8 of Text)

## UNIT IV

Singularities: Classification, Residues, The augument principle.
(Chapter 5 of Text)

## UNIT V

The extended plane and its spherical representation, Analytic function as mapping, Mobius transformations, The maximum principle, Schwarz's Lemma.
(Chapter 1- Section 6, Chapter 3- Section 3, Chapter 4- Sections 1,2 Chapter 6- Section 1 of Text)

**References:**


1. **L.V. Ahlfors, *Complex Analysis,* Mc-Graw Hill (1966)**
2. **S. Lang, *Complex Analysis,* Mc-Graw Hill (1998).**

# MM 232 FUNCTIONAL ANALYSIS – 1

**Text: B.V Limaye, *Functional Analysis (2nd Edition)***

**UNIT I**

Normed Spaces and Continuity of Linear maps. (Section 5 and 6 of the Text, Omitting 6.7 and 6.8)

**UNIT II**

Hahn-Banach Theorem and Banach Spaces. (Section 7 and 8 of the Text, Omitting Subsection Banach limits)

**UNIT III**

Uniform Bounded Principle – Closed and Open Mapping Theorems, Bounded inverse Theorems (Section 9.1,9.2,9.3,10 and 11.1 only)

**UNIT IV**

Spectrum of a Bounded Operator – Dual and Transposes (Sections 12, 13.1, 13.2, 13.3, 13.4 and 13.5 only)

**UNIT V**

Reflexivity – Compact Linear Maps, Spectrum of a Compact Operator (Sections 16.1, 17.1, 17.2, 17.3, 18.1, 18.2 and 18.3)

**References:**


1. **Dunford M and J.T Schwarz, *Linear Operators Part 2*, Wiley.**
2. **Taylor A.E, *Introduction to Functional Analysis,* Wiley.**
3. **G.F. Simmons, *Topology and Modern Analysis,* Mc Graw Hill.**

# MM 241 COMPLEX ANALYSIS – II

**Text: John. B. Conway, *Functions of Complex Variables,* Springer-Verlag, New York, 1973.**
**(Indian Edition: Narosa)**

## UNIT I

Compactness and Convergence in the space of Analytic functions, The space C(G,Ω), Space of Analytic functions, Riemann Mapping Theorem.
(Chapter 7- Sections 1,2 and 4 of the Text)

## UNIT II

Wierstrass factorization Theorem, Factorization of sin function, The Gamma function.
(Chapter 7- Sections 5,6 and 7 of the Text)

## UNIT III

Riemann Zeta function, Runge's Theorem, Simple connectedness, Mittag- Leffler's Theorem.
(Chapter 7- Sections 8 and Chapter 8 of the Text)

## UNIT IV

Analytic continuation and Riemann surfaces, Schwarz Reflexion Principle, Analytic continuation along a path, Monodromy Theorem.
(Chapter 9- Sections 1,2 and 3 of the Text)

## UNIT V

Basic properties of Harmonic functions, Harmonic function on a disc, Jensen's formula, The genus and order of an entire function, Hadamard factorization Theorem.
(Chapter 10- Sections 1,2 and Chapter 11 of the Text)

**References:**


1. **L.V. Ahlfors, *Complex Analysis,* Mc-Graw Hill (1966)**
2. **W. Rudin, *Real and Complex Analysis,* Mc-Graw Hill.**

# MM 242 FUNCTIONAL ANALYSIS – II

**Texts: 1) B.V Limaye, *Functional Analysis (2nd Edition)***
**2) G.F. Simmons, *Topology and Modern Analysis,* International Student Edition, Mc Graw Hill Ltd, New Delhi.**

## UNIT I

Inner Product Spaces Orthonormal Sets. (Section 21 and 22 of Text 1)

## UNIT II

Approximation and Optimization. (Section 23 and 24 of Text 1)

## UNIT III

Bounded Operators and Adjoins - Normal, Unitary and Self-Adjoint Operators
( Section 25 and 26 of Text 1 omitting 26.6)

## UNIT IV

Spectrum and Numerical Range - Compact Self-Adjoint Operators
( Section 27 and 28 of Text 1 omitting 28.7 and 28.8)

## UNIT V

Banach Algebra – Regular and Singular Elements-Topological Divisors of Zero-the Spectrum-The Formula for Spectral Radius-The Radical and Semi Simplicity
( Chapter 12 of Text 2)

**References:**

1. **Dunford M and J.T.Schwarz, *Linear Operators Part 2* , Wiley**
2. **Taylor A.E, *Introduction to Functional Analysis*, Wiley**

# MM 233 AUTOMATA THEORY (Elective)

**Text: J.E. Hoporoft and J.D. Alman, *Introduction to Automata Theory Languages and Computation,* Narosa, 1999.**

## UNIT I

Strings, Alphabets and Languages (Section 1.1 of the Text)
Finite Automata (Chapters 2, Sections 2.1 to 2.4)

## UNIT II

Regular expressions and Properties of Regular sets.(Sections 2.5 to 2.8 and 3.1 to 3.4)

## UNIT III

Context Free grammars (Section 4.1 to 4.5)

## UNIT IV

Pushdown Automata & properties of Context free languages
Theorem 5.3, 5.4 (without proof), (Section is 5.1 to 5.3 and 6.1 to 6.3)

## UNIT V

Turning Machine and Choamski hierarchy, (Sections 7.1 to 7.3 and 9.2 to 9.4)

**References**

1. **G.E Revesz , *Introduction to Formal Languages***
2. **P.Linz , *Introduction to Formal Languages and Automata,* Narosa 2000**
3. **G.Lallment, *Semigroups and Applications***

# MM 233 PROBABILITY (Elective)

**Texts:**

(1) **Laha R.G and Rohaigi V.K ,"** ***Probability Theory",*** **JohnWiley, New York ( 1979)**

(2) **Johnson N.L and Keta,S "*Distributions in Statistics: Discrete Distributions*", John Wiley, New York ( 1969)**

(3) **Johnson N.L, and Kots.S "** ***Distributions in Statistics: Continuous Univariate Distributions",*** **Vol 1 and 2 ,John Wiley, New York ( Paperback, 1970)**

## UNIT I

Probability, lim-inf, lim-sup, and limit of sequence of events, Monotone and continuity property of probability measure, Addition Theorem, Independence of finite number of events, Sequence of events, Borel Cantalls Lemma, Borel Zero one law.

## UNIT II

Random variable, Its probability distribution function, Properties of distribution function, Discrete and continues type random variables, Discrete, Continuous and other types of distributions, Expectation and moments of random variables, Inequalities of Liaponov ( for moments) , Random vectors, Independence of random variables and sequence of random variables, Markov and Chebychev's inequalities.

## UNIT III

Standard distributions and their properties-Bernoulli, Binomial, Geometric, Negative Binomial, Hyper geometric, Beta, Cauchy, Chi square, Double Exponential, Exponential, Fisher's F, Gamma, Log Normal, Normal,, Parents, Students' st, Uniform and heibull.

## UNIT IV

Characteristic functions and their elementary properties, Uniform continuity and non negative definiteness of characteristic functions, Characteristic functions and moments, Statement (without proof) and application of each of the three theorems –Inversion Theorem, Continuity Theorem and Bochner - Khintchine Theorem of characteristic functions, Statement and proof of Fourier Inversion Theorem.

## UNIT V

Stochastic convergence of sequence of random variables, Convergence in distributions, Convergence in probability, Almost sure convergence and convergence in the $r^{th}$ mean, Their inter-relation ship - Examples and counter examples, Slutsky's Theorem.

**References:**


**(1). Ash R.B- *"Basic Probability Theory"*, John wiley, New York (1970)**

**(2). Bhat B.R-*"Modern Probability Theory: An Introduction Text Book",* Wiley Eastern (Second Edition) 1985**

**(3). Gnedenko B.V-"*The Theory of Probability"* , Mir Publishers Moscow (1969)**

**(4). Luckacs.E-*"Characteristic Functions"*, Hafner, New York (Second Edition, 1970)**

**(5). Luckacs. E- *"Stochastic Convergence",* Academic Press (Second Edition, 1975)**

**(6). Johnson N.L, Kots,S and Balakrishnan.N-*"Continuos Univariate Distribution", Vol.1 and 2* , John Wiley, New York (Second Edition, 194 vol.1 1995 Vol.2)**

**(7). Johnson N.L, Kots.S and Kemp A.W-"*Univariate Discrete Distributions",* JohnWiley, New York" Second Edition 1992)**

# MM 233 OPERATIONS RESEARCH (Elective)

**Texts: 1) Ravindran, Philips, Solberg, *Operations Research, Principles and Practice*, Second Edition, John Wiley & Sons.**
**2) K. V. Mital, C. Mohan. *Optimization Methods in Operations Research and Systems Analysis*, Third Edition, New Age International Publishers, New Delhi.**

## UNIT I

**Linear Programming** : Formulation of Linear Programming Models, Graphical solution of Linear Programs in two variables, Linear programs in standard form, basic variable, basic solution, basic feasible solution, Solution of Linear Programming problem using simplex method, Big - M simplex method, The two phase simplex method.
[Chapter 2 of text 1 , sections 2.1 to 2,9 ]

## UNIT II

**Transportation Problems**: Linear programming formulation, Initial basic feasible solution, degeneracy in basic feasible solution, Modified distribution method, Optimality test. **Assignment Problems**: Standard assignment problems, Hungarian method for solving an assignment problem.
[Chapter 3 of text 1, sections 3.1 to 3.3]

## UNIT III

**Project management**; Programme Evaluation and Review Technique (PERT), Critical Path Method (CPM)
[Chapter 3 of text 1, section 3.7]

## UNIT IV

**Kuhn – Tucker Theory and Non-linear Programming**: Lagrangian function, saddle point, Kuhn – Tucker conditions, Primal and dual problems, Quadratic Programming.
[Chapter8 of text 2, sections 1 to 6]

## UNIT V

**Dynamic Programming**: Minimum path, Dynamic Programming problems, Computational economy in DP, serial multistage model, Examples of failure, Decomposition, Backward recursion.
[Chapter 10 of text 2, sections 1 to 10]

**Reference**:

Hamdy A. Taha, *Operations Research*, Fifth edition, PHI

# MM 234 APPROXIMATION THEORY (Elective)

**Text: EW Cheney, *"Introduction to Approximation Theory",* Mc Graw Hill**

## UNIT 1

Metric spaces- An existence Theorem for best approximation from a compact subset; Convexity- Caratheodory's Theorem- Theorem on linear inequalities; Normed linear spaces - An existence Theorem for best approximation from finite dimensional subspaces - Uniform convexity - Strict convexity
(Sections 1,2,5,6 of Chapter 1)

## UNIT 2

The Tchebycheff solution of inconsistent linear equations - Systems of equations with one unknown- Three algebraic algorithms; Characterization of best approximate solution for m equations in n unknowns- The special case m=n+1; Poly's algorithm.
(Section 1,2,3,4,5 of Chapter 2)

## UNIT 3

Interpolation- The Lagrange formula-Vandermonde's matrix- The error formula- Hermite interpolation; The Weierstrass Theorem- Bernstein polynomials- Monotone operators- Fejer's Theorem; General linear families- Characterization Theorem- Haar conditions- Alternation Theorem.
(Sections 1,2,3,4, of Chapter 3)

## UNIT 4

Rational approximation- Conversion or rational functions to continued fractions; Existence of best rational approximation- Extension of the classical Theorem; Generalized rational approximation- he characterization of best approximation- An alternation Theorem- The special case of ordinary rational functions; Unicity of generalized rational approximation.
(Sections 1,2,3,4 of Chapter 5)

## UNIT 5

The Stone Approximation Theorem, The Muntz Theorem - Gram's lemma, Approximation in the mean- Jackson's Unicity Theorem- Characterization Theorem, Marksoff's Therem.
(Section 1,2,6 of Chapter 6)

**Reference:**

**P.J Davis. *"Interpolation and Approximation"*, Blaisdell Publications.**

# MM 234 GEOMETRY OF NUMBERS (Elective)

**Text Book: D.D Olds,Anneli Lax and Guiliana P. Davidoff, *The Geometry of Numbers,* The Mathematical Association of America 2000**

**UNIT 1**

Lattice points and straight lines, Counting of lattice points (Chapters 1 and 2)

**UNIT 2**

Lattice points and area of polygons, Lattice points in circles (Chapter 3 and 4)

**UNIT 3**

Minkowski fundamental Theorem and Applications (Chapters 5 and 6)

**UNIT 4**

Linear transformation and integral lattices, Geometric interpretations of Quadratic forms (Chapters 7 and 8)

**UNIT 5**

Blichfieldts and applications, Tchebychev's and consequences (Chapter 9 and 10)

**References**

1. **J.W.S Cassells, *Introduction to Geometry of Numbers,* Springer Verlag 1997**
2. **C.I Siegel, *Lectures in Geometry of Numbers,* Springer Verlag 1989.**

# MM 234 GRAPH THEORY (Elective)

**Text: Gary Chartrand and Ping Zhang , *Introduction to Graph Theory,* Tata Mc Graw Hill, Edition 2006**

An overview of the concepts-Graphs, Connected graphs, Multi graphs, Degree of a vertex, Degree Sequence, Trees.

**UNIT I**

Definition of isomorphism, Isomorphism as a relation, Graphs and groups, Cut-vertices, Blocks, Connectivity, Menger's Theorem ( without proof)
(Sections 3.1, 3.2, 3.3, 5.1, 5.2, 5.3 and 5.4)

**UNIT II**

Eulerian graphs, Hamilton graphs, Hamilton walks and numbers
(Sections 6.1, 6.2 and 6.3)

**UNIT III**

Strong diagraphs, Tournaments, matching, Factorization, The Petersen graph.
(Sections 7.1, 7.2, 8.1,8.2 and 8.5)

**UNIT IV**

The Four colour problem, Vertex colouring, The Ramsey number of graphs, Turan's Theorem, Rainbow, Ramsey numbers.
(Sections 10.1, 10.2, 10.3, 11.1, 11.2 and 11.3)

**UNIT V**

The centre of a graph, Distant vertices, Locating numbers, Detour and directed distance, Channel assignment, Distance between graphs.
(Sections 12.1, 12.2, 12.3, 12.4, 12.5 and 12.6)

**References:**


1. **Bondy J.A and Murthy U.S.R, *"Graph Theory with Applications",* the Macmillan Press Limited.**
2. **Hararay F.,*"Graph Theory"*, Addison-Wesley**
3. **Suesh Singh G.,*"Graph Theory"*, PHI Learning Private Limited**
4. **Vasudev.C , *"Graph Theory Applications".***
5. **West D.B,*"Introduction to Graph Theory",* PHI Learning Private Limited**

# MM 234 DIFFERENTIAL GEOMETRY (Elective)

**Text: John.A. Thorpe, *Elementary Topics in Differential Geometry,* Springer Verlag**

**UNIT I**

Graphs and level sets, Vector fields, Tangent Spaces . (Chapter 1,2,3 of Text)

**UNIT II**

Surfaces, Vector fields on surfaces, Orientation, The Gauss map (Chapter 4,5 6 of Text)

**UNIT III**

Geodesics, Parallel transport (Chapter 7,8 Text)

**UNIT IV**

The Weingarten map, Curvature of plane curve. (Chapter 9.1 of Text)

**UNIT V**

Arc length, Line integral, Curvature of surfaces (Chapter 11,12 of Text)

**References:**

**[1] I Singer and J.A Thorpe, *Lecture notes on Elementary Topology and Geometry,* Springer-Verlag**

**[2] M Spivak, *Comprehensive introduction to Differential Geometry (Vols 1 to 5),* Publish or Perish Boston.**

# MM 243 MATHEMATICAL STATISTICS (Elective)

**Texts:**

**(1) Lehmann.E.L *"Theory of Point Estimation",* John wiley, New York (1983).**

**(2) Lehmann.E.L *"Testing of Statistical Hypothesis",* John Wiley, New York ( Second Edition 1986)**

**(3) Randles R.H and Wolf D.A-*"Introduction to the Theory of Non Parametric Statistics"*, Wiley, New York (1979)**

**(4) Kendall, M.G and Stuart. A, *"The Advanced Theory of Statistics",* Vol. 2 Mac Millan , New York (Fourth Edition 1979)**

## UNIT I

Problem of point estimation, General properties of estimators unbiasedness, Strong weak and squared error consistency, A sufficient condition for weak consistency, UMVU estimators, BLUE's, Sufficiency and completeness, Exponential family of densities and complete sufficient statistic, Statement of Fisher-Neyman factorization Theorem (Without proof)

## UNIT II

Rao-Blackwell Theorem, Lehmann-Scheffe Theorem and their application to derive UMVU estimators, Ancillary statistic and Basu;s Theorem, Cramer Rao inequality

## UNIT III

Least square estimators, Maximum likelihood estimators and estimators by the method of moments and their properties.

## UNIT IV

Tests of hypothesis: Null and alternate hypotheses, Two kinds of errors, Level of significance Power of test, Power function, Size of a test, Test of a simple hypothesis against a simple alternate hypothesis, Leyman-Pearson Lemma, Test of a composite hypothesis against Composite alternate hypothesis, Likelihood Ratio Test.

## UNIT V

Non Parametric Methods Chi square Test of goodness of fit, Empirical distribution function, $F_n(x)$ as an estimator of population distribution function F(x), its exact and asymptotic distributions for fixed x, Koimogrove test, Sign test, Wilcoxon – Mann-Whitney Test

**References:**


1) **Rohatgi V.K , *" An Introduction to Probability Theory and Mathematical Statistics",* Wiley Eastern New Delhi ( 1985)**
2) **Rao, C.L , *" Liner Statistical Inference and Its Applications* ", Wiley Eastern , New Delhi ( 1974)**
3) **Mood Ali, Gray Bill Fhardoes D.C" , *"Introduction to the Theory of Statistics",* Mc Graw Hill International, New York ( Third Edition, 1972)**

# MM 243 FIELD THEORY (Elective)

**Text: Joseph Rotman, *Galois Theory,* Second Edition, Springer, 1998.**

## UNIT 1

**Solvable groups (Appendix B of the text):** Isomorphism Theorems, Correspondence Theorem, Sylow p-subgroup, commutator subgroups and Higher subgroups, $S_5$ is not solvable.
(The following results are included: $G_5$ , $G_6$ , $G_7$ , $G_8$ , $G_9$ , $G_{14}$ , $G_{15}$ , $G_{16}$ , $G_{17}$ , $G_{18}$ , $G_{19}$ , $G_{20}$ , $G_{21}$ , $G_{22}$, $G_{23}$ , $G_{31}$ , $G_{34}$ , $G_{36}$ , $G_{37}$ , $G_{38}$ ,$G_{39}$ )

## UNIT 2

**Polynomial Rings over Fields:** Principal ideal, Greatest common divisor, LCM, Remainder Theorem, Prime and maximal ideals, Splitting, prime fields, Characteristic, Irreducible and primitive polynomials, Content, Eisenstein Criterion, Cyclotomic polynomial.
(The following results are included: Theorem 13 to Theorem 22, Theorem 24 to Theorem 33, Theorem 35 to Corollary 42)

## UNIT 3

**Splitting Fields:** Degree of an extension, Simple extension, Algebraic extension and transcendental extension, Splitting field, Seperable extension, Galois field, Galois group.
(The following results are included: Lemma 44 to Corollary 53, Lemma 54 to Theorem 58)

## UNIT 4

**Roots of Unity and Solvability by Radicals:** Cyclic group of $n^{th}$ roots of unity, Primitive element, Fobenius automorphism, Radical extension, Solvability by radicals, Unsolvable quintic.
(The following results are included: Theorem 62 to Corollary 72, Lemma 73 to Theorem 75)

## UNIT 5

**Fundamental Theorem of Galois Theory:** Galois extensions, Fundamental Theorem, Fundamental Theorem of algebra, Galois Theorem on solvability.
(The following results are included: Theorem 81 to Corollary 93, Lemma 94 to Theorem 98)

**References:**

**1. Harold M. Edwards, *Galois Theory,* Springer, 1984.**
**2. Joseph . A. Gallian, *Contemporary Abstract Algebra,* 7th Edition, Brooks/Cole.**
**3. J. B. Fraleigh, *A First Course in Abstract Algebra,* 7th Edition, PHI.**
**4. T. W. Hungerford, *Algebra,* Springer 2005.**
**5. O. Zariski and P. Samuel, Commutative Algebra, Vol. I, Springer – Verlag**

# MM 243 MECHANICS (Elective)

**Text: Herbert Gioldstein, *Classical Mechanics,* Addison Wesley**

## UNIT I

Mechanics of a particle, Mechanics of a system of particles, Constraints, D'Alembert's principles and Lagange's Equations, Velocity dependent potentials and dissipation functions, Simple applications of Lagrangian formulation.
(Chapter 1 of Text)

## UNIT II

Hamilton's principle, Derivation of Lagrange's equation, Some techniques of Calculus of Variation, Extension of Hamilton principle, Conservation Theorems.
(Secitons 2.1, 2.2, 2.3, 2.4 and 2.6 of Text)

## UNIT III

The two body Central force problem, Reduction to equivalent one body problem equation of notation, The equivalent one dimensional problem, The Virial Theorems, the differential equations for the orbits , The Keplar problem.
(sections3.1 to 3.6 of Text)

## UNIT IV

The Kinematics of rigid body motion, the independent coordinates of a rigid body orthogonal transformations, The Eulerian angles, The Cayley-Klein parameters, Euler's Theorem on the motion of a rigid body, The Coriolis force
(Sections 4.1, 4.2, 4.4, 4.5, 4.6, 4.9 of Text)

## UNIT V

The rigid body equations of motion, Angular momentum, Tensor and dynamics, The inertia tensor, The eigen values of the inertia tensor, Methods of solving rigid body problem and Euler equations of motion.
(Sections 5.1 to 5.6 of Text)

**Reference:**

**Synge J.L and Griffith B.A, *Principles of Mechanics,* MC Graw-Hill**

# MM 243 THEORY OF WAVELETS (Elective)

**Text Book:**

**Michael Frazier,** ***An Introduction to Wavelets through Linear Algebra,*** **Springer**

Prerequisites: Linear Algebra, Discrete Fourier Transforms, elementary Hilbert Space Theorems (No questions from the pre-requisites)

## UNIT I

Construction of Wavelets on $Z_N$ the first stage. (Section 3.1)

## UNIT II

Construction of Wavelets on Zn the iteration sets, Examples - Shamon, Daubiehie and Haar (Sections: 3.2 and 3.3)

## UNIT III

$\iota^2$ (Z), Complete Orthonormal sets, $L_2[-\pi,\pi]$ and Fourier Series.
(Sections: 4.1,4.2 and 4.3)

## UNIT IV

Fourier Transforms and convolution on $\iota^2$ (Z), First stage wavelets on Z.
(Section: 4.4 and 4.5)

## UNIT V

The iteration step for wavelets on Z, Examples, Shamon Haar and Daubiehie

**References:**

**Mayor (1993),** ***Wavelets and Operators,*** **Cambridge University Press**
**Chui. C( 1992),** ***An Intrioduction to Wavelets,*** **Academic Press, Boston**

# MM 243 CODING THEORY (Elective)

**Text: D.J Hoffman etal., *Coding Theory The Essentials,* Published by Marcel Dekker Inc 1991**

## UNIT I

Detecting and correcting error patterns, Information rate, The effects of error detection and correction, Finding the most likely code word transmitted, Weight and distance, MLD, Error detecting and correcting codes.
(Chapter 1 of the Text)

## UNIT II

Linear codes, bases for C = <S> and $C^{\perp}$, generating and parity check matrices, Equivalent codes, Distance of a linear code, MLD for a linear code, Reliability of IMLD for linear codes.
(Chapter 2 of the Text)

## UNIT III

Perfect codes, Hamming code, Extended codes, Golay code and extended Golay code, Red Hulles Codes.
(Chapter 3 sections: 1 to 8of the Text)

## UNIT IV

Cyclic linear codes, Polynomial encoding and decoding, Dual cyclic codes.
(Chapter 4 and Appendix A of the Text)

## UNIT V

BCH Codes, Cyclic Hamming Code, Decoding 2 error correcting BCH codes
(Chapter 5 of text)

**References**


1. **E.R Berlekamp, *Algebriac Coding Theory,* Mc Graw-Hill, 1968**
2. **P.J Cameron and J.H Van Lint, *Graphs,* Coded and Designs CUP**
3. **H. Hill, *A First Course in Coding Theory,* OUP 1986.**

# MM 244 ADVANCED GRAPH THEORY (Elective)

**Text:**
**Fred Buckley, Frank Harary, *Distance in Graphs,* Addison-Wesley Publishing Company**

## UNIT 1

**Graphs:** Graphs as Models, Paths and connectedness, Cutnodes and Blocks, Graph Classes and Graph Operations, Polynomial Algorithms and NP-Completeness
(Chapter 1 and Section 11.1 of Text)

## UNIT II

The Center and Eccentricity, Self Centered Graphs, The Median, Central Paths Path Algorithms and Spanning Trees, Centers.
(Chapter 2, Sections 2.1, 2.2, 2.2; Chapter 11, Sections 11.2, 11.3)

## UNIT III

**External Distance Problems:** Radius, Small Diameter, Diameter, Long Paths and Long Cycles
(Chapter 5 of Text)

## UNIT IV

**Convexity:** Closure in variants, Metrics on Graphs, Geodetic Graphs, Distance Hereditary Graphs.
**Diagraphs:** Diagraphs and Connectedness, Acyclic diagraphs
(Chapter 7 and sections 10.1, 10.2 of Text)

## UNIT V

**Distance Sequences:** The eccentric sequence s, Distance sequence, The Distance distribution.
Long Paths in Diagraphs, Tournaments
(Sections 9.1, 9.2,9.3,10.3,10.4 of Text)

**References:**


(1) **Bondy and Murthy, *Graph Theory with Applications,* The Macmillan Press Limited, 1976**
(2) **Chartrand G and L.Lesniak, *Graphs and Diagraphs,* Prindle, Weber and Schmidt, Boston 1986**
(3) **Garey M.R, D.S Johnson , *Computers and Intractability*, A Guide to the Theory of NP-Completeness, Freeman, San Francisco 1979.**
**(4) Harary. F, *Graph Theory,* Addison Wesley Reading Mass 1969 ( Indian Edition, Narosa)**
**(5) K.R Parthasarathy, *Basic Graph Theory,* Tata Mc Graw-Hill, Publishing Co, New Delhi, 1994.**

# MM 244 ANALYTIC NUMBER THEORY (Elective)

**Text: Tom.M. Apostol; *Introduction to Analytical Number Theory,* Springer-Verlag**

**UNIT I**

The Fundamethal Theorem of Arithmetic (chapter 1 of Text)

**UNIT II**

Arithmetical function and Dirichlet multiplication
(Section 2.1 to 2.17 of Text)

**UNIT III**

Congruences, Chinese Remainder Theorem
(Sections 5.1 to 5.10 of Text)

**UNIT IV**

Quadratic residues, Reciprocity law, Jacobi symbol
(Sections 9.1 to 9.8 of Text)

**UNIT V**

Primitive roots, Existence and number of primitive roots.
(Sections 10.1 to 10.9 of text)

**References**

**[1] Emd Groswald, *Topics from the Theory of Numbers,* Birkhause**
**[2] G.H Hardy and E.M Wright , *Introduction to the Theory of Numbers,* Oxford**

# MM 244 COMMUTATIVE ALGEBRA (Elective)

**Text: N.S Gopalakrishan, *Commutative Algebra,* Oxonian Press**

**UNIT I**

Modules, Free projective, Tenser product of modules, Flat modules
(Chapter 1 of Text)

**UNIT II**

Ideals, Local rings, Localization and applications
(Chapter 2 of Text)

**UNIT III**

Noetherian rings, modules, Primary decomposition, Artinian modules
(Chapter 3 of Text)

**UNIT IV**

Integral domains, Integral extensions, Integrally closed domain, Finiteness of integral closure
(Chapter 4 of Text)

**UNIT V**

Valuation rings, Dedikind domain
(Chapter 5 of Text, Theorems 4 and 5 omitted)

**Reference:**

**[1] M.F Atiyah and I.G Mac Donald, *Introduction to Communication Algebra,* Addison Wesley**
**[2] T.W Hungerford, *Algebra,* Springer-Verlag**

# MM 244 REPRESENATION THEORY OF FINITE GROUPS (Elective)

**Text: Walter Ledermann, *Introduction to Group Characters,* Cambridge University Press**

**UNIT I**

G-module, Characters, Reducibility, Permutation representations, Complete reducibility, Schur's Lemma
(Sections 1.1 to 1.7 of Text)

**UNIT II**

The commutant algebra, Orthogonality relations, The groups algebra
(Section 1.8, 2.1, 2.2 of Text)

**UNIT III**

Character table, Character of finite abelian groups, The lifting process, Linear characters.
(Section 2.3, 2.4, 2.5, 2.6 of Text)

**UNIT IV**

Induced representations, Reciprocay law, $A_5$, Normal subgroups, Transitive groups , Induced characters of $S_n$
(Sections 3.1, 3.2, 3.3, 3.4, 4.1, 4.2, 4.3 of Text)

**UNIT V**

Group theoretical applications, Brunside's (p,q) Theorem, Frobenius groups.
(Chapter 5 of Text)

**Reference: S.Lang, *Algebra,* Addison Wesley**

# MM 244 CATEGORY THEORY (Elective)

**Text Book: S. Maclane, *Categories for the working Mathematician,* Springer, 1971**

**UNIT-I**

**Categories, Functors and Natural Transformations** - Axioms for categories, categories, Functors. Natural Transformations, Mobics, Epis and Zeros Foundations, Large Categories, Hom-sets.

**UNIT II**

**Constructions on categories -** Duality Contravariance and opposites, Products of Categories. Functor Categories, The category of all categories, Comma categories, Graphs and Free categories, Quotient Categories.

**UNIT III**

**Universals and Limits** - Universal Arrows, Yoneda Lemma Coproduces and Colimits, Products and Limits, Categories with Finite products, Groups in categories.

**UNIT IV**

**Adjoints** – Adjunctions, Examples of Adjoints, Reflective subcategories, Equivalence of categories, Adjoints for pre orders, Cartesian closed categories, Transformations of Adjoints, Compositions of Adjoints.

**UNIT –V**

**Limits** – Creation of Limits by products and Equalizers, Limits with parameters, Preservation of Limits, Adjoints on Limits, Freyd's Adjoint Functor Theorem, Subobjects and Generation, The Special Adjoint Functor Theorem, Adjoint in Topology.

**Refernce:**


1. **M.A. Arbib and E.G Maneswarrows, *Structures and Functors,* The categorical Imperative, Avademic Press-1975**
2. **H. Herrlich and G.E Strecker, *Category Theory,* Allyn & Bacon, 1973**
3. **M. Barmand, C. Wells, *Category Theory for Computer Science,* Prentice Hall , 1990**
4. **F. Borceux, *Handbook of Categorical Algebra,* Vol. I, II, III, Cambridge, University Press, 1994**
5. **P. Frevd, *Abelian Categories,* Harper & Row, 1964**
6. **R.F,C Walters, *Categories and Computer Science,* Cambridge University Press, 1991**