Syllabus for
M.Sc. Programme in Mathematics [ PG ]
with effect from 2020 Admission

SUBMITTED BY BOARD OF STUDIES IN MATHEMATICS [ PG ]
<table>
<thead>
<tr>
<th>Semester</th>
<th>Title of the paper</th>
<th>Distribution hrs per semester</th>
<th>Instructional hrs./week</th>
<th>Dur ESA hrs.</th>
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L: Lecture; P: Practical; CA: Continuous Assessment; ESA: End Semester Examination
## M.Sc MATHEMATICS
*(Revised Syllabus from 2020 Admissions)*

### LIST OF COURSES

#### SEMESTER– I

- MM211 Linear Algebra (Previous Syllabus)
- MM212 Real Analysis - I (Revised Syllabus)
- MM213 Ordinary Differential Equations (New Syllabus)
- MM214 Topology – I (Previous Syllabus)

#### SEMESTER – II

- MM221 Abstract Algebra (New Syllabus)
- MM222 Real Analysis - II(Revised Syllabus)
- MM223 Topology – II (Previous Syllabus)
- MM224 Partial Differential Equation and Calculus of Variation( New Syllabus )

#### SEMESTER– III

- MM231 Complex Analysis (Previous Syllabus Complex Analysis- I)
- MM232 Functional Analysis – I (Revised Syllabus)
- MM233 Elective (One among the following)
  - Automata Theory (Previous Syllabus)
  - Probability Theory(Previous Syllabus)
  - Operations Research (New Syllabus)
  - Algebraic Topology (Previous Syllabus )
  - Numerical Analysis with Python(New Syllabus)
  - Algebraic Geometry(New Syllabus)
- MM234 Elective (One among the following)
  - Approximation Theory (Previous Syllabus)
  - Curves, Surfaces and Manifolds(New Syllabus)
  - Geometry of Numbers (Previous Syllabus)
  - Differential Geometry (Revised Syllabus)
  - Graph Theory (Previous Syllabus)
  - Fractal Geometry (New Syllabus)

#### SEMESTER – IV

- MM241 Number Theory (New Syllabus)
- MM242 Functional Analysis – II (Revised Syllabus)
- MM243 Elective (One among the following)
  - Mathematical Statistics (Previous Syllabus)
Difference Equations (Previous Syllabus)
Theory of Wavelets (Previous Syllabus)
Coding Theory (New Syllabus)
Advanced Algebra (New Syllabus)
Mechanics (Previous Syllabus)
Cryptography (New Syllabus)

MM244 Elective (One among the following)

Advanced Graph Theory (Previous Syllabus)
Commutative Algebra (Previous Syllabus)
Advanced Complex Analysis (New Syllabus-previous syllabus of Complex Analysis II)
Representation Theory of Finite Groups (Previous Syllabus)
Category Theory (Previous Syllabus)
Spectral Graph Theory (New Syllabus)
MM 211 LINEAR ALGEBRA

Text

Unit I
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 invertibilty.  
[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 (except the section volumes )  
[Chapter 10 of Text ]

References
MM 212 REAL ANALYSIS-I


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 ]

UNIT II

The Riemann-Stieltjes Integral: The definition of Riemann-Stieltjes 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 ]

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. Do sufficient problems to study the uniform convergence of sequences and series] 

UNIT IV

Multivariable differential Calculus: The directional derivative, Directional derivative and continuity, the total derivative, total derivative in terms of partial derivatives, the matrix of a linear function, the Jacobian matrix, the chain rule, matrix form of the chain rule, the mean value theorem for differentiable functions, sufficient condition for differentiability, sufficient condition for equality of mixed partial derivatives, Taylor’s formula for functions from $\mathbb{R}^n$ to $\mathbb{R}$ Chapter 12(all sections except 12.6) of the text book.

UNIT V

Implicit Functions and Extremum problems: Functions with nonzero Jacobian determinant, the inverse function theorem, the implicit function theorem, Extrema of real valued functions of several variables, extremum problems with side conditions. Chapter 13( all sections) of the text.

References:

2. W.Rudin, Principles of Mathematical Analysis, Third Edition
MM213 ORDINARY DIFFERENTIAL EQUATIONS


Unit I

The Method of Successive Approximations, Picard’s Theorem, Systems. The Second Order Linear Equation, A Review of Power Series, Series Solutions of First Order Equations, Second Order Linear Equations, Ordinary Points, Regular Singular Points, Regular Singular Points (Continued), Two Convergence Proofs. [Chapter 13(sections 69, 70 and 71) and Chapter 5(sections 26, 27, 28, 29, 30 and Appendix A)]

Unit II

Gauss’s Hypergeometric Equation, The Point at Infinity, Legendre Polynomials, Properties of Legendre Polynomials [Chapter 5 (sections 31 and 32), Chapter 8(sections 44 and 45)]

Unit III

Bessel Functions. The Gamma Function, Properties of Bessel Functions, Additional Properties of Bessel Functions[Chapter 8(sections 46 and 47; Appendix C)]

Unit IV

Systems of First Order Equations: General Remarks on Systems, Linear Systems, Homogeneous Linear Systems with Constant Coefficients, Nonlinear Systems, Volterra’s Prey-Predator Equations[Chapter 10 (sections 54, 55, 56 and 57)]

Unit V


References

MM 214: TOPOLOGY I

Text book:
Principles of Topology by Fred H. Croom, Baba Barkha Nath Printers (India), Third Reprint 2009.

In this course we discuss the basics of topology, based on chapters 3 and 6. Students should be motivated as discussed in the first two chapters of the Text book.

Unit I
Metric Spaces:-Definition, Examples, Open sets, Closed sets, Interior, closure and boundary
Sections 3.1, 3.2, 3.3

Unit II
Continuous functions, Equivalence of metric spaces, Complete metric spaces-Cantor's Intersection Theorem.
Sections 3.4, 3.5, 3.7, Exercise 3.7(3).

Unit III
Topological spaces:-Definition, Examples, Interior, Closure, Boundary, Base, Sub base, Continuity, Topological Equivalence, Subspaces.
Sections 4.1, 4.2, 4.3, 4.4, 4.5

Unit IV
Connectedness and disconnected spaces, Theorems on connectedness, Connected subsets of real line, Applications of connectedness, Path connected spaces.
Sections 5.1, 5.2, 5.3, 5.4, 5.5

Unit V
Compact spaces, compactness and continuity, Properties related to compactness, One point compactification.
Sections 6.1, 6.2, 6.3, 6.4

References
1. Gerald Buskes, Arnoud van Rooiji, Topological Spaces from Distance to Neighbourhood
MM221 ABSTRACT ALGEBRA


Unit I

External direct product of groups – Definition and examples, Properties, Representing groups of units modulo n as an external direct product. Normal subgroups and Factor groups, Application of factor groups, Internal direct products, Fundamental theorem of abelian groups, Isomorphism classes, Proof of the fundamental theorem. (Chapter 8, 9 and 11).

Unit II

Sylow theorems, Conjugacy classes, Class Equation, Sylow theorems and Applications. Simple groups, Examples, Non simplicity tests. (Chapter 24 and 25). Theorems 25.1, 25.2 and 25.3 and corollary 1(Index Theorem), corollary 2 (embedding Theorem) may be discussed without proof.

Unit III


Unit IV


Unit V

Fundamental theorem of Galois Theory(without proof), Solvability of polynomials by radicals, Insolvability of Quintic. Cyclotomic polynomials, The Constructible regular n - gons (Chapters 32 and 33).

References:

MM 222 REAL ANALYSIS II


Unit I
Lebesgue Outer Measure, Measurable sets, Regularity, Measurable functions, Borel and Lebesgue Measurability (Chapter 2, sections 2.1 to 2.5 of Text).

Unit II
Integration of non-negative functions, The General Integral, Integration of Series, Reimann and Lebesgue Integrals, The four Derivatives, Lebesgue Differentiation Theorem (theorem7 and 8-statement only), Differentiation and Integration.

(Chapter 3, sections 3.1 to 3.4, Chapter 4, sections 4.1, 4.4 (statements only), 4.5 (up to theorem 15) of Text).

Unit III
Abstract Measure Spaces, Measure and outer Measure, Extension of a Measure, Uniqueness of extension, Completion of Measure, Measure spaces, Integration with respect to a Measure.

(Chapter 5, sections 5.1 to 5.6 of Text).

Unit IV
The $L^p$ spaces, Convex functions, Jensen’ Inequality, The Inequalities of Holder and Minkowski, Completeness of $L^p(\mu)$.

(Chapter 6, sections 6.1 to 6.5 of Text).

Unit V

(Chapter 7 section 7.1, Chapter 8, sections 8.1 to 8.3).

References:
3. P R Halmos, Measure Theory, Springer
MM 223: TOPOLOGY II


Unit I

Product and Quotient spaces:- Finite and arbitrary products, Comparison of topologies, Quotient spaces.
    Sections 7.1, 7.2, 7.3, 7.4 of Text I, (Alexander sub basis theorem and Theorem 7.11 excluded).

Unit II

Separation axioms:- $T_0$, $T_1$, and $T_2$-spaces, Regular spaces, Normal spaces, Separation by continuous functions.
    Sections 8.1, 8.2, 8.3, 8.4 of Text I

Unit III

Convergence, Tychnoff 's Theorem
    Chapter 16, Theorem 18.21 and Theorem 18.22 of Text II

Unit IV

Algebraic topology:- The fundamental group, The fundamental group of $S^1$.
    Sections 9.1, 9.2, 9.3 of Text I

Unit V

Examples of fundamental groups, The Brouwer Fixed Point Theorem.
    Sections 9.4 and 9.5 of Text I

References

1.Gerald Buskes, Arnoud van Rooiji, Topological Spaces from Distance to Neighbourhood


MM 224 PARTIAL DIFFERENTIAL EQUATIONS AND INTEGRAL EQUATIONS

Text 1: An introduction to partial differential equations, Yehuda Pinchover and Jacob, Cambridge University Press, 2005


Unit I

Introduction: Preliminaries, classification, differential operators and the superposition principle.

First-order equations: Introduction, quasilinear equations, the method of characteristics, examples of the characteristics method, the existence and uniqueness theorem, the Lagrange method, General nonlinear equations[Chapter 1(sections 1.1 to 1.3), chapter 2 (sections 2.1, 2.2, 2.3, 2.4, 2.5, 2.6, 2.9, 2.10 from Text 1]

Unit II

Second-order linear equations in two independent variables: Introduction, classification, canonical form of hyperbolic equations, canonical form of parabolic equations, canonical form of elliptic equations, the one-dimensional wave equation: Introduction, canonical form and general solution, the Cauchy problem and d’Alemberts formula, domain of dependence and region of influence, the Cauchy problem for the nonhomogeneous wave equation [Chapter 3, 4 from Text 1]

Unit III


Unit IV

Integral Equations: Introduction, Relations between differential and integral equations,

The Green’s functions, Fredholm equations with separable kernels, Illustrative examples, Hilbert- Schmidt Theory, Iterative methods for solving Equations of the second kind. The
Unit V

**Calculus of variations:** Introduction, some typical problems of the subject, Euler differential equation for an extremal, isoperimetric problems [Chapter 12 (sections 66, 67, and 68) from Text 3]

**References:**


MM 231 COMPLEX ANALYSIS


UNIT I
Elementary properties and examples of analytic functions, Power series, Analytic function, Riemann- Stieltjes integrals.
(Chapter 3- Sections 1, 2 and Chapter 4- 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 and 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, 6, 7 and 8 of Text)

UNIT IV
Singularities: Classification, Residues, The argument principle.
(Chapter 5 Sections 1, 2, and 3 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 6- Section 1 and 2 of Text)

References:
3. S. Ponnusamy & H. Silverman, Complex Variables with Applications, Birkhauser
5. V. Karunakaran, Complex Analysis, Narosa Publishing House, 2002
Text: B. V. Limaye, FUNCTIONAL ANALYSIS (3rd Edition)

A quick review of chapter I of the Text is to be done as a prerequisite to the Functional Analysis course.

UNIT I

Normed spaces and continuity of linear maps. (Section 5 and 6 of the Text, Except 6.5 (d) and Theorem 6.8).

UNIT II

Hahn-Banach theorems and Banach spaces. (Section 7 and 8 of the Text, Theorem 7.12 statement only).

UNIT III

Uniform boundedness principle, closed graph and open mapping theorems (Section 9.1, 9.2, 9.3 and 10 of the Text).

UNIT IV

Bounded inverse theorem, spectrum of a bounded operator (Section 11.1, 11.3, 12 (Except 12.4) and 13.1 of the Text,).

UNIT V

Transpose—Definition as in Section 13 and Theorem 13.5, Weak convergence, reflexivity and compact linear maps (Sections 15.1, 15.2 (a), 16.1, 16.2, 17.1, 17.2 and 17.3, 17.4 (a) of the Text).

References

1. Bryan Rynne, M.A. Youngson, Linear Functional Analysis, Publisher: Springer.
2. Rajendra Bhatia, Notes on Functional Analysis, Publisher: Hindustan Book Agency.
MM 233 AUTOMATA THEORY (Elective)


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 Chomski hierarchy, (Sections 7.1 to 7.3 and 9.2 to 9.4)

References
MM 233 PROBABILITY THEORY (Elective)

Texts:

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 continuous 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’s t, 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 rth mean, Their inter-relation ship - Examples and counter examples, Slutsky’s Theorem.

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


(6). Johnson N.L, Kots S and Balakrishnan N. - "Continuous Univariate Distribution",

(7). Johnson N.L, Kots S and Kemp A.W. - "Univariate Discrete Distributions",
MM 233 OPERATIONS RESEARCH (Elective)


Text 2:

Unit I

Linear Programming - Definitions, Graphical solution methods for LP problems.
Simplex Method - Standard form of an LP problem, simplex algorithm (Maximization case), simplex algorithm (Minimization case) - Two Phase method, Big-M Method
Chapter 3 of text 1 - sections 3.1 to 3.3, Chapter 4 of text 1 - sections 4.1 to 4.4

Unit II

Transportation Problem: Mathematical model of TP, The transportation algorithm, Methods for finding initial solution, Test for optimality
Assignment Problems: Mathematical model of AP, Solution methods of AP
Chapter 9 of text 1 - Section 9.1, 9.2, 9.3, 9.4, 9.5; Chapter 10 of text 1 - Section 10.1, 10.2, 10.3.

Unit III

Project Management: Basic differences between PERT and CPM, Phases of Project Management, PERT/CPM network components and precedence relationships, Critical path analysis
Chapter 13 of text 1 - Section 13.1 to 13.5

UNIT IV

Kuhn Tucker Theory and Nonlinear Programming: Lagrangian function, saddle point, Kuhn Tucker conditions, Primal and dual problems, Quadratic Programming.
Chapter 8 of text 2, sections 1 to 6

UNIT V

Chapter 10 of text 2, sections 1 to 10

Reference:

Hamdy A. Taha, Operations Research, Fifth edition, PHI
MM 233 ALGEBRAIC TOPOLOGY (Elective)

Text Book: *Basic Concepts of Algebraic Topology*, Fred H. Croom Springer – Verlang

**Unit I**

Introduction, Examples, Geometric Complexes and Polyhedra, Orientation of Geometric complexes. (Sections 1.1, 1.2, 1.3, 1.4 of Chapter 1)

**Unit II**

Simplicial Homology Groups - Chains, cycles, Boundaries, Homology groups, examples of Homology Groups, The structure of Homology Groups, The Euler Poincare Theorem, Psudo manifolds and the Homology Groups of $S^n$. (Sections 2.1, 2.2, 2.3, 2.4, 2.5 of chapter 2).

**Unit III**

Simplicial Approximation- Introduction, Simplicial Approximation, Induced Homomorphisms on the Homology groups, the Browerfixed point theorem and related results. (Sections 3.1, 3.2, 3.3, 3.4 of Chapter 3)

**Unit IV**

The Fundamental group - Introduction, Homotopic paths and the fundamental group, the covering homotopy property for $S^1$. Examples of Fundamental group, the relation between $H_1(K)$ and $\pi_1([K])$. (Sections 4.1, 4.2, 4.3, 4.4 and 4.5 of chapter 4)

**Unit V**

Covering Spaces – Definition and examples, basic properties of Covering spaces, Classification of covering spaces, Universal covering spaces, and applications (Section 5.1, 5.2, 5.3, 5.4 and 5.5 of Chapter 5)

References:

Texts:

**Unit I**

In this unit we discuss the basics of python based on chapters 4,5,6,8, 9, 10 and 18 of Text 1. All topics of chapters 4-9 must be discussed using examples from mathematics. In chapter 10, only sections 10.1-10.4 need to be discussed. Chapter 18 also should be discussed to get an overview of the packages in python. The students should be encouraged to write programs related with mathematical problems. (Some of the problems are listed in the syllabus)

**Unit II**

Visualizing Data with Graphs - learn a powerful way to present numerical data: by drawing graphs with Python. The unit is based on Chapter 2 of Text 3. The sections Creating Graphs with Matplotlib and Plotting with Formulas must be done in full. In the section Programming Challenges, the problems Exploring a Quadratic Function Visually, Visualizing Your Expenses and Exploring the Relationship Between the Fibonacci Sequence and the Golden Ratio must also be discussed.

**Unit III**

The unit is based on chapters 4 and 7 of Text 3. Here we discuss Algebra and Symbolic Math with SymPy and Solving Calculus Problems. In Chapter 4 the sections Defining Symbols and Symbolic Operations, Working with Expressions, Solving Equations and Plotting Using SymPy should be done in full. In the section Programming Challenges, the problems Factor inder, Graphical Equation Solver, Summing a Series and Solving Single-Variable Inequalities also should be discussed. In chapter 7, some problems discussed namely, Finding the Limit of Functions, Finding the Derivative of Functions, Higher-Order Derivatives and Finding the Maxima and Minima and Finding the Integrals of Functions are to be done. In the section Programming Challenges, the problems Verify the Continuity of a Function at a Point, Area Between Two Curves and Finding the Length of a Curve also should be discussed.

**Unit IV**

In this unit we discuss some numerical methods for solving system of linear equations, for finding roots of equations and polynomial interpolation from Text 2. We first discuss bisection method, methods of Newton, secant method and method of false position for solving equations of the form $f(x)=0$. The topics can be found in sections 2.1 (only upto example 2) and 2.3. Interpolation and the
Lagrange Polynomial as per section 3.1 (only upto example 2) is to be discussed. Next we discuss Gauss Elimination with backward substitution method and LU decomposition method as per sections 6.1 (only upto Algorithm 6.1) and 6.5 (Theorem 6.19 statement only and exclude subsection Permutation Matrices. Also avoid the discussion of matrix factorization using Maple). Students should be encouraged to do problems and write python program for each method (see ref 1).

Unit V

Here we discuss some numerical methods for integration, differentiation and solving initial value problems of ordinary differential equations from Text 2. The methods for approximating first derivative of a function as per section 4.1 are to be discussed. They include forward-difference formula, \((n+1)\)-point formula, in particular three-point formulas. Rest of the topics in this section need not be discussed. Next we discuss the methods for numerical integration. Trapezoidal rule and simpsons rules are to be discussed from section 4.3. Then we discuss \((n+1)\)-point closed Newton-Cotes formula and derive trapezoidal, Simpson's rule and Simpson's 3/8 rules from it. Remaining topics in the section need not be done. We also discuss Composite Simpson's rule and Composite Trapezoidal rule from section 4.4 (theorems 4.4 and 4.5 only). Our discussion about numerical methods for solving initial value problems of ordinary differential equations include Euler's method, Runge-Kutta methods of second and fourth order. The topics can be found in sections 5.2 (excluding subsection Error Bounds for Euler’s Method) and section 5.4 (only Midpoint Method for Runge-Kutta Methods of order two and Runge-Kutta method of order four need to be discussed without any proof). Students should be encouraged to do problems and write python program for each method (see ref 1).

Some problems for Unit I are listed below

- Factorial of a number
- Checking primality of a number
- Listing all primes below a given number
- Prime factorization of a number
- Finding all factors of a number
- \(\text{gcd}\) of two numbers using the Euclidean Algorithm
- Finding the multiples in Bezout’s Identity
- checking the convergence and divergence of sequences and series.

The course is aimed to give an introduction to mathematical computing with Python as tool for computation.

The students should be encouraged to write programs to solve the problems given in the sections as well as in the exercises.

The end semester evaluation should contain a theory and a practical examinations.

The duration of the theory examination will be 3 hours, with a maximum of 50 marks.

In the question papers for the theory examination, importance should be given to the definition, concepts and methods discussed in each units, and not for writing long programs.

Practical examination shall also be of 3 hours duration for a maximum of 25 marks.

Weightage of marks for theory and a practical examinations is listed below

<table>
<thead>
<tr>
<th>Unit</th>
<th>Theory</th>
<th>Practical</th>
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<tr>
<td>I</td>
<td>10 (one question out of two)</td>
<td>10 (two questions out of four)</td>
</tr>
<tr>
<td>II</td>
<td>5 (one question out of two)</td>
<td>5 (one question out of two)</td>
</tr>
<tr>
<td>III</td>
<td>5 (one question out of two)</td>
<td>5 (one question out of two)</td>
</tr>
<tr>
<td>IV</td>
<td>20 (two questions out of four)</td>
<td>5</td>
</tr>
<tr>
<td>V</td>
<td>20 (two questions out of four)</td>
<td>one question out of two (one from each unit)</td>
</tr>
</tbody>
</table>

Continuous evaluation follows the pattern - 5 marks for attendance, 10 marks for the internal examination and 10 marks for the practical record. The record should contain at least 20 programs.

The practice of writing the record should be maintained by each student throughout the course and it should be dually certified by the teacher in charge/internal examiner and evaluated by the external examiner of practical examination.

References:


2. *NumPy Reference Release 1.17.0*, Written by the NumPy community. (available at https://docs.scipy.org/doc/)

3. https://docs.python.org/3/tutorial/

Text Book

Unit I
Introduction, affine varieties, Hilbert’s Nullstellensatz, polynomial functions and maps.

Unit II
Rational functions and maps, projective space, projective varieties, rational functions and morphisms.

Unit III
Smooth and singular points, algebraic characterizations of the dimension of a variety, plane curves.

Unit IV
Intersection multiplicity, classification of smooth cubics, the group structure of an elliptic curve.

Unit V
The existence of lines on a cubic, configuration of the 27 lines, rationality of cubics.

References
MM 234 APPROXIMATION THEORY (Elective)


UNIT I

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 II

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 III

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 IV

Rational approximation- Conversion or rational functions to continued fractions; Existence of best rational approximation- Extension of the classical Theorem; Generalized rational approximation- the 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 V

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:

**MM 234 CURVES, SURFACES AND MANIFOLDS**

**Text Books**

**Unit - I**
What is a curve, Arc-length, Reparametrization, Closed curves, Level curves versus parametrized curves,
Curvature, Plane curves, Space curves.
[Chapter 1 – Sections 1- 5, Chapter 2 – Sections 1 – 3 from Text – 1]

**Unit - II**
What is a surface, Smooth surfaces, Smooth maps, Tangents and derivatives, Normals and orientability,
Applications of the Inverse Function Theorem.
[Chapter 4 – Sections 1 – 5, Chapter 5 – Section 6 from Text – 1]

**Unit - III**
Lengths of curves on surfaces, The second fundamental form, The Gauss and Weingarten maps, Normal and geodesic curvatures, Gaussian and mean curvatures, Principal curvatures of a surface.
[Chapter 6 – Sections 1, Chapter 7 – Sections 1 – 3, Chapter 8 – Sections 1 – 2 from Text - 1]

**Unit – IV**
Topological Manifolds, Smooth structures, Examples of smooth manifolds,
Smooth functions and smooth maps.
Tangent vectors, Pushforwards, Computations in coordinates. The tangent bundle, Vector fields on manifolds.
[Chapter 1 sections 1, 3, 4, Chapter 2 section 1, Chapter 3 sections 1-3, Chapter 4 sections 1-2 from Text - 2]

**Unit - V**
Covectors, tangent covectors on manifolds, the cotangent bundles, the differential of a function, pullbacks, line integrals.
Maps of constant rank, Embedded submanifolds.
[Chapter 6 sections 1-6, Chapter 7 section 1, Chapter 8 section 1 from Text - 2]

**References**
MM 234 GEOMETRY OF NUMBERS (Elective)


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

MM 234 DIFFERENTIAL GEOMETRY (Elective)


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 9.10 of Text)

UNIT V

Arc length, Line integral, Curvature of surfaces (Chapter 11,12 of Text, except the proofs of Theorem 1, Theorem 2 of Chapter 11 and Theorem 1 of Chapter 12)

References:


MM 234 GRAPH THEORY (Elective)


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. (Sections 3.1, 3.2, 3.3, 5.1, 5.2 and 5.3)

**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. (Sections 7.1, 7.2, 8.1, 8.2)

**UNIT IV**
The Four colour problem, Vertex colouring, The Ramsey number of graphs, Turan’s Theorem. (Sections 10.1, 10.2, 10.3, 11.1 and 11.2)

**UNIT V**
The centre of a graph, Distant vertices, Locating numbers, Detour and Directed distance. (Sections 12.1, 12.2, 12.3, 12.4)

**References:**
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 FRACTAL GEOMETRY (Elective)

Text


Unit I

Basic set theory, Functions and limits, Measures and mass distributions, Box-counting dimensions, properties of box–counting dimensions

(sections 1.1,1.2,1.3,2.1,2.2 of text)

Unit II

Hausdorff measure, Hausdorff dimension, Calculation of Hausdorff dimension, Basic method for calculating dimensions.

(sections 3.1,3.2,3.3,4.1 of text)

Unit III

Iterated functions systems, Dimensions of self similar sets, Some variations, Continued fraction examples

(sections 9.1,9.2,9.3,10.2 of text)

Unit IV

Dimensions of Graphs, The Weierstrass function and self–affine graphs, Repellers and iterated function system, The logistic map

(sections 11.1,13.1,13.2 of text)

Unit V

Sketch of general theory of Julia sets, The Mandelbort set, Julia sets of quadratic functions

(sections 14.1,14.2,14.3 of text)

References


MM 244 NUMBER THEORY


UNIT I

Arithmetical function and Dirichlet multiplication

(Section 2.1 to 2.14 of Text)

UNIT II

Finite Abelian Groups and Their Characters

(Theorem 4.1 of Chapter 4 (Abel's identity), Section 6.5 to 6.10 of Chapter 6
*Theorem 6.6 Statement Only*)

UNIT III

Dirichlet's Theorem on Primes in Arithmetic Progressions

(Section 3.2 of Chapter 3, Sections 7.1 to 7.8)

UNIT IV

Quadratic residues, Reciprocity law, Jacobi symbol

(Sections 9.1 to 9.8 of Chapter 9)

UNIT V

Primitive roots, Existence and number of primitive roots.

(Sections 10.1 to 10.9 and Sections 10.11 to 10.13 of Chapter 10)

References


MM 242: FUNCTIONAL ANALYSIS II

Text: B. V. Limaye, FUNCTIONAL ANALYSIS (3rd Edition)

UNIT I
Spectrum of a compact operator (Section 18.1, 18.2, 18.3, 18.4, 18.5 and 18.7 (a) only).

UNIT II
Inner product spaces, orthonormal sets (Section 21 and 22 of the Text, omitting 21.3 (d), 22.3 (b), 22.8 (c), 22.8 (d), 22.8 (e)).

UNIT III
Approximation and optimization, projection and Riesz representation theorems. (Section 23 and 24 of the Text, omitting 23.6).

UNIT IV
Bounded operators and adjoints, normal, unitary and self-adjoint operators (Section 25 and 26.1 to 26.5 of the Text omitting 25.4 (b)).

UNIT V
Spectrum and numerical range, compact self-adjoint operators (Section 27.1, 27.2, 27.4(statement only), 27.5, 27.7, 28.1, 28.4, 28.5, 28.6 of the Text).

References
1. Bryan Rynne, M.A. Youngson, Linear Functional Analysis, Publisher: Springer.
2. Rajendra Bhatia, Notes on Functional Analysis, Publisher: Hindustan Book Agency.
MM 243  MATHEMATICAL STATISTICS (Elective)


Unit I: The theory of point estimation:

The problem of point estimation, properties of estimates, unbiased estimation, unbiased estimation (continued): A lower bound for the variance of an estimate, the method of moments, maximum likelihood estimates.(Chapter 8 (Sec 8.2 – sec 8.7) of text)

Unit II: Neyman – Pearson theory of testing of hypothesis:

Introduction, some fundamental notions of hypothesis testing, the Neyman – Pearson Lemma, families with monotone likelihood ration, unbiased and invariant tests.(Chapter 9 of text)

Unit III: Some further result on hypothesis testing:

Introduction, the likelihood ratio tests, the Chi-square tests, the t-tests, the F-tests, Bayes and minimax procedure.(Chapter 10 of text)

Unit IV: Confidence estimation:

Introduction, Some fundamental notions of confidence estimation, shortest length confidence intervals, relation between confidence estimation and hypothesis testing, unbiased confidence intervals, Bayes confidence intervals(Chapter 11 of text)

Unit V: Nonparametric statistical inference:

Introduction, nonparametric estimation, some single – sample problems, some two – sample problems, tests of independence.(Chapter 13 (Sec 13.1 – 13.5) of text)

References:


Unit – I: Linear Difference Equations of Higher Order
Difference calculus – General theory of linear difference equations – Linear homogenous equations with constant coefficients – Linear non-homogenous equations – Method of undetermined coefficients. (Chapter 2: Sections: 2.1 to 2.4)

Unit – II: System of Linear Difference Equation
Autonomous (time invariant) systems – The basic theory – The Jordan form: Autonomous (time-invariant) systems - Linear Periodic Systems. (Chapter 3: Sections: 3.1 to 3.4)

Unit – III: The Z-Transform Method

Unit – IV: Oscillation Theory
Three-term difference equations – Self-adjoint second order equations – Nonlinear difference equations. (Chapter 7: Sections: 7.1 to 7.3)

Unit – V: Asymptotic Behaviour of Difference Equations
Tools of approximations - Poincare’s theorem – Asymptotically diagonal systems. (Chapter 8: Sections: 8.1 to 8.3)

Book for Study

Books for Reference

E – Learning source:
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 ZN 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
ι2 (Z), Complete Orthonormal sets, L2[-π,π] and Fourier Series.
(Sections: 4.1, 4.2 and 4.3)

UNIT IV
Fourier Transforms and convolution on ι2 (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:
MM 243       CODING THEORY(Elective)

Text:  Coding Theory – An Introduction,  San Ling and Chaoping Xing

Unit I
Introduction to Coding theory - Error Detection, Correction and Decoding - Basics of Finite Fields.
(Chapters 1, 2 and Sections 3.1, 3.2, 3.3 of the Text)

Unit II
Linear Codes – Generator and Parity check matrices – Coding and decoding of linear codes.
( Chapter 4 of the Text)

Unit III
Some Bounds in Coding theory – Sphere Covering bound – Hamming bound and Perfect codes
– Binary Hamming codes – Singleton bound and MDS codes.
( Sections 5.1, 5.2, 5.3.1, 5.4 of the Text)

Unit IV
Reed – Muller Codes – Cyclic codes – Generator and Parity check polynomials – Generator
and parity check matrices – Decoding of Cyclic codes.
( Sections 6.2, 7.1, 7.2, 7.3, 7.4 of the Text)

Unit V
(A review of Section 3.3 of the Text is to be done as a prerequisite to this Unit)
BCH Codes – Decoding of BCH Codes – Reed-Solomon Codes
(Sections 8.1, 8.2 of the Text)
(Simple exercise problems of the corresponding sections are to be practiced).

References:
MM 243 ADVANCED ALGEBRA (Elective)


UNIT I

Basic theory of field extensions, Algebraic extensions,
(Sections 13.1, 13.2)

UNIT II

Straight edge and compass constructions, Splitting fields and algebraic closures, Cyclotomic fields,
(Sections 13.3, 13.4)

UNIT III

Seperable and inseparable extensions, Existence and uniqueness of finite fields,
(Section 13.5)

UNIT IV

Cyclotomic polynomials and extensions, Basic definitions and examples related to fundamental theorem of Galois theory
(Section 13.6, 14.1)

UNIT V

The fundamental theorem of Galois theory, Finite fields
(Sections, 14.1,14.2,14.3)

References

MM 244 MECHANICS (Elective)


**Unit I:** Mechanics of a particle, Mechanics of a system of particles, Constraints, D'Alembert's principle and Lagrange's equations, Velocity dependent potentials and the dissipation function, Simple applications of the lagrangian formulation.(Chapter 1 of text)

**Unit II:** Hamilton's principle, Some techniques of the calculus of variations, derivation of Lagrange's equation from Hamilton's principle, Extending Hamilton's principle to systems with constraints, Conservation theorems and symmetry properties. (Sections 2.1, 2.2, 2.3, 2.4 and 2.6)

**Unit III:** Reduction to the equivalent one body problem, the equations of motion and first integrals, the equivalent one dimensional problem and classification of orbits, the Virial theorem, the differential equation for the orbits and integrable power law potentials, the Kepler problem: Inverse square law of force.(Sections 3.1, 3.2, 3.3, 3.4, 3.5 and 3.7)

**Unit IV:** The independent coordinates of a rigid body, orthogonal transformation, the Euler angles, the Cayley – Klein parameters and related quantities, Euler's theorem on the motion of a rigid body, the coriolis effect. (Sections 4.1, 4.2, 4.4, 4.5, 4.6, 4.10)

**Unit V:** Angular momentum and kinetic energy of motion about a point, tensors, the inertial tensor and the moment of inertia, the eigen values of the inertial tensor and the principal axis transformation, solving rigid body problems and the Euler equations of motion.

(Sections 5.1 to 5.5)

**References:**

244 CRYPTOGRAPHY (Elective)


Unit 1

Cryptosystems and Basic Cryptographic Tools: Secret-key Cryptosystems, Public-key Cryptosystems, Block and Stream Ciphers, Hybrid Cryptography, Message Integrity, Message Authentication Codes, Signature Schemes, Nonrepudiation, Certificates, Hash Functions, Cryptographic Protocols, Security


Unit 2

Cryptanalysis: Cryptanalysis of the Affine Cipher, Cryptanalysis of the Substitution Cipher, Cryptanalysis of the Vigenère Cipher, Cryptanalysis of the Hill Cipher, Cryptanalysis of the LFSR Stream Cipher

Shannons Theory: Elementary Probability Theory, Perfect Secrecy, Entropy, Huffman Encodings, Properties of Entropy, Spurious Keys and Unicity Distance, [Chapter 2 (section 2.2 ) and Chapter 3]

Unit 3


Unit 4


Unit 5

The RSA Cryptosystem and Factoring Integers: Introduction to Public-key Cryptography, More Number Theory, The Chinese Remainder Theorem, Other Useful Facts, The RSA Cryptosystem, Implementing RSA, Primality Testing, Legendre and Jacobi Symbols, The

References


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

(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 sequences, Distance sequence, The Distance distribution, Long Paths in Diagraphs, Tournaments
(Sections 9.1, 9.2,9.3,10.3,10.4 of Text)

References:

MM 244 COMMUTATIVE ALGEBRA (Elective)


UNIT I

Modules, Free projective, Tensor 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)

References:

MM 244: ADVANCED COMPLEX ANALYSIS (Elective)


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- Section 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:

4. H. A. Priestley, Introduction to Complex Analysis, Oxford University Press
5. V. Karunakaran, Complex Analysis, Narosa Publishing House,
MM 244 REPRESENTATION 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, Reciprocity law, A5, Normal subgroups, Transitive groups, Induced characters of Sn
(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)


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.

References:

MM 244 SPECTRAL GRAPH THEORY


Unit I

A quick review of chapter I, Invariants - Chromatic number and independence number (Section 2.1 of Chapter II), Eigenvalues of graphs – Adjacency and Laplacian eigenvalues, First properties, First examples (Chapter 7).

Unit II

Eigenvalue computations - Cayley graphs and bi-Cayley graphs of abelian groups, Strongly regular graphs, Two gems, Design graphs (Chapter 8) (Except Example 8.10 and Example 8.23).

Unit III

Largest eigenvalues - Extremal eigenvalues of symmetric matrices, Largest adjacency eigenvalue, The average degree, A spectral Turán theorem, Largest Laplacian eigenvalue of bipartite graphs, Sub graphs, Largest eigenvalues of trees (Chapter 9).

Unit IV

More eigenvalues - Eigenvalues of symmetric matrices: Courant–Fischer, A bound for the Laplacian eigenvalues, Eigenvalues of symmetric matrices: Cauchy and Weyl, Sub graphs (Chapter 10).

Unit V

Spectral bounds - Chromatic number and independence number, Isoperimetric constant, Edge counting (Chapter 11).

References: