UNIVERSITY DEPARTMENT OF MATHEMATICS
L.N.M.U. DARBHANGA

Course of Studies

For

M.A./M.Sc. in Mathematics

Under Semester System

The programme of P.G. Mathematics will be of two years duration divided into two academic sessions called previous and final year respectively. The previous year divided into two semester known as First & Second Semester and the Final year also divided into two Semester known as Third and Fourth Semester.

There shall be sixteen papers in P.G. Mathematics Programme comprising four papers in each semester. The papers shall be of two categories (a) Compulsory papers & (b) Elective papers.

Number of compulsory papers shall be Thirteen & Elective papers shall consist of three papers.

The students shall be required to study any one paper in each elective paper as the availability of teaching in the department.

RULES :

(1) The duration of M.A./M.Sc. in Mathematics under semester system shall be of two academic session/ four semester. Each semester shall be of 16 to 18 weeks of actual study.

(2) Each academic session shall consist of two semesters I & III from July to December and II & IV from January to June.

(3) The M.A./M.Sc. course shall consist of 16 papers spread over four semesters with four papers in each semester. Full marks of each paper is 100. Hence the entire curriculum shall be of 1600 marks.

(4) The examination for Master's degree (M.A./M.Sc.) will be at the end of each Semester.

Evaluation of paper under Semester System :

1. The performance of a student in each paper will be assessed on the basis of Continuous Internal Assessment (CIA) of 30 marks and the End of Semester Examination (ESE) consisting of 70 marks.

The components of CIA shall be

(a) Two Mid-Semester written tests of one hour duration each 15 marks

(b) Seminar/Quiz 05 marks

(c) Assignments 05 marks

(d) Regularity & Punctuality 05 marks

Total 30 marks

2. The component of End of Semester Examination is divided into three parts of 3 hours duration

Part – A : Ten objective type questions — 10 x 2 = 20 marks
(Two questions from each unit)

Part – B : Five short answer questions — 4 x 5 = 20 marks
Four to be answered.
(One question from each unit)

Part – C : Three long answer questions — 3 x10 = 30 marks
Out of five to be answered.
(One questions from each unit)

Total — 70 marks

3. The concerned teacher of the paper shall be responsible for conducting the mid-semester tests and other components of the CIA. The teacher shall show the answer scripts of the mid semester written tests to the students of the class.

Examinations :

1. The End Semester Examination will be conducted by the University.
2. The End of Semester Examination (ESE) shall be named as follows
   (a) M.A./M. Sc. Semester- I
   (b) M.A./M. Sc. Semester- II
   (c) M.A./M. Sc. Semester- III
   (d) M.A./M. Sc. Semester- IV
3. The End of Semester examination of Semester I & III shall be generally held in the month of November- December whereas that of Semester II & IV shall be in the month of May – June.
4. There shall be no supplementary examination in any of the Semesters (I, II, III & IV).
5. Those who have appeared at the CIA and attended the required minimum percentage (75%) of attendance of lectures shall be permitted to appear in the End Semester Examination.

Result :

1. After appearing at the End Semester Examination, the candidates can be placed in the following categories as :

Letter Grade	Percentage Range	Numerical of letter Grade	Description of Grade
A	100-90	10	Outstanding
B	80-89	9	Excellent
C	70-79	8	Very Good
D	60-69	7	Good
E	50-59	6	Average
P	45-49	5	Pass
F	Less than 45	Less than 5	Fail

2. A student will be declared to have passed the individual paper if the student secures at least 40% marks separately both in the End Semester Examination as well as continuous internal assessment and a minimum of 45% in total.
3. If a candidate passes in at least two papers in his/her First, Second and Third Semesters, he/she shall be promoted to the next Semester. But his/her final result will only be declared when he/she has cleared all their backlog papers.
4. Candidates shall have to clear their backlog paper/papers in the next End Semester Examination of that Semester whenever it is available.
5. The Final result will be published on the basis of performance in all the 16 papers spread over four Semesters.
6. Since it is a continuous evaluation programme, so student shall be awarded Semester Grade Point Average (SGPA) at the End of each Semester Examination and Cumulative Grade Point Average (CGPA) at the Final End Semester Examinations in 10 point scoring system.
7. There shall be no supplementary examination.
8. If a student fails to secure minimum 40% marks in CIA of any paper his result will be declared as fail in that paper. Students shall have to reappear in that paper in the same Semester of next academic Session. The name of the promoted candidate/candidates will not be included in the merit list of that subject.
9. If a student passes in CIA but fails in End Semester Examination in a paper, he/she shall be declared fail in that paper and will be reappear in the End Semester examination in that paper in the next examination of that Semester.

Improvement of Result :

If candidate passes in End Semester Examination, he/she may apply for the improvement of his/her result in maximum of two papers of the Semester. He/She can avail this facility only twice during the duration of whole course. Better of the two results will be treated as final result of candidates in those papers.

Note :

1. Each student in Semester I & Semester III shall take one foundation course.
2. In this foundation course if a student secures 45% marks he/she will be declared pass, otherwise he/she will be treated as fail. The marks of this paper will not be included in the final result. For more details see the syllabus of foundation course.

Course Structure : PG Mathematics Programme

SEMESTER – I

Paper	**Name of the Course**	**Marks (ESE+CIA)**	**Cr. Hr. CR(T+p)**	**Paper Code**
Paper– I	Advance abstract Algebra	70+30	6(6+0)	MAT 511
Paper– II	Measure Theory	70+30	5(5+0)	MAT 512
Paper– III	Real Analysis	70+30	5(5+0)	MAT 513
Paper– IV	Operation Research	70+30	4(4+0)	MAT 514
	Total	**400**	**20(20+0)**	

SEMESTER – II

Paper	**Name of the Course**	**Marks (ESE+CIA)**	**Cr. Hr. CR(T+p)**	**Paper Code**
Paper – V	General Topology	70+30	5(5+0)	MAT 521
Paper – VI	Functional Analysis	70+30	5(5+0)	MAT 522
Paper– VII	Fundamentals of Computer	70+30	6(6+0)	MAT 523
Paper–VIII	Computer Science Practical	70+30	4(0+4)	MAT 524
	Total	**400**	**20(16+4)**	

SEMESTER – III

Paper	**Name of the Course**	**Marks (ESE+CIA)**	**Cr. Hr. CR(T+p)**	**Paper Code**
Paper – IX	Integration Theory	70+30	6(6+0)	MAT 531
Paper – X	Complex Analysis	70+30	5(5+0)	MAT 532
Paper – XI	Partial Differential Equations	70+30	4(4+0)	MAT 533
Paper – XII	Axiomatic Set Theory	70+30	5(5+0)	MAT 534
	Total	**400**	**20(20+0)**	

SEMESTER – IV

Paper	**Name of the Course**	**Marks (ESE+CIA)**	**Cr. Hr. CR(T+p)**	**Paper Code**
Paper – XIII	Elective – I	70+30	5(5+0)	MAT 541
Paper – XIV	Elective – II	70+30	6(6+0)	MAT 542
Paper – XV	Elective – III	70+30	4(4+0)	MAT 543
Paper – XVI	Graph Theory	70+30	5(5+0)	MAT 544
	Total	**400**	**20(20+0)**	

Note :

If a student chooses computer as elective paper in paper XIII, he/she has to choose computer as elective in papers XIV and XV also and vice-versa.

SEMESTER – I

PAPER – I

ADVANCED ABSTRACT ALGEBRA

Full Marks – 70 **Time – 3 Hours**

Paper Code- MAT 511 **Credit : 6(6+0)**

The content of this paper has been divided into five units. The pattern of questions to be set and the details of the units are as mentioned below:

Question 1 is compulsory and consists of ten objective questions, with two chosen from each unit and each objective question carries 2 marks.

10 x 2 = 20

Question 2 consists of five short answer type questions, one selected from each unit and each question carries 5 marks. An examinee is required to answer any four out of them.

4 x 5 = 20

Question 3 consists of five long answer type questions, one selected from each unit and each question carries 10 marks. An examinee is required to answer any three out of them.

3 x 10 = 30

Unit : (1) Commutators and commutator sub groups of a group and their properties, solvable groups, Relation between commutator sub groups and solvability, Some important properties of solvable groups, Normal and composition series and their important properties.

Unit : (2) Similarity of linear transformations over a finite dimensional vector space, canonical forms, Invariant sub spaces, Triangular matrix of a linear transformation, Nilpotent transformations and index of nilpotency, Invariants of a linear transformation, primary decomposition theorem.

Unit : (3) Concept of divisibility in a ring and associates, irreducible and reducible elements, unique factorization domain (U.F.D.), Principal ideal domain (P.I.D.), Euclidean domain, Unique factorization theorem in an Euclidean domain, Relationship between U.F.D., P.I.D. and Euclidean domain.

Unit : (4) Concept of extension of a field, finite extension and transitivity of finite extensions, Algebraic elements, The field F(a) obtained by adjoining an element a to F, Finiteness of F(a) and algebraicity of a, Algebraic extension and related results, simple extensions.

Unit : (5) Roots of a polynomial over a field F in an extension field of f and related results, splitting field for a polynomial over a field F, Existence of multiple roots of a polynomial and irreducibility of the polynomial, Fixed field G(K,F) of a group of automorphisms of a field K, finiteness of G(K, F), Normal extension.

Recommended Books:

1. I. N. Herstein – Topics in Algebra, BLAISDELL PUBLISHING COMPANY, New York.
2. P.B. Bhattarcharya – Basic Abstract Algebra Cambridge University Press, India.
3. K.K. Jha – Advanced Course in Modern Algebra, Nav Bharat Prakashan, Delhi-6.

SEMESTER – I
Paper – II
Measure theory

Full Marks – 70 **Time – 3 Hours**
Paper Code- MAT 512 **Credit : 5(5+0)**

The content of this paper has been divided into five units. The pattern of questions to be set and the details of the units are as mentioned below:
Question 1 is compulsory and consists of ten objective questions, with two chosen from each unit and each objective question carries 2 marks.

10 x 2 = 20

Question 2 consists of five short answer type questions, one selected from each unit and each question carries 5 marks. An examinee is required to answer any four out of them.

4 x 5 = 20

Question 3 consists of five long answer type questions, one selected from each unit and each question carries 10 marks. An examinee is required to answer any three out of them.

3 x 10 = 30

Unit : (1) Lebesgue Measurable sets and their properties, Measurable functions, Lebesque outer measure.

Unit : (2) Borel sets and their measurability, Characterization of measurable sets, Non-measurable sets.

Unit : (3) Lebesgue integral, Riemann integral properties of Lebesgue integral for Bounded Measurables functions.

Unit : (4) Convergence theorem in Lebesgue integral theory, Lebesgue's monotone convergence theorem, Lebesgue's dominated convergence theorem, Fatou's theorem, Fatou-Lebesgue theorem.

Unit : (5) Function of Bounded variation, Lebesgue differentiation theorem, Differentiation of an integral, Differentiation and integration.

Recommended Books:

1. Dr. K. K. Jha, Advanced course in Real Analysis and higher analysis Macmallan Company Ltd. India.
2. P. R. Halmos - Measure Theory.
3. P.K. Jain & V.P. Gupta – Lebasgue Measure and integration. New Age International (p) Limited, New Delhi.
4. H, L, Royden – Real Analysis.

Books for References :

1. Richard - Wheden and Antoni Zygmund - Measure and integral: An Introduction to Real Analysis Marcel Dekker inc. 1977.
2. J. H. Willinamson, Lebesgue Integration, Holt Rinehart & Winston, Inc. New York 1962.
3. G. de Barra - Measure Theory and Integration, Wiley Eastern Limited - 81

SEMESTER – I
Paper – III
Real analysis

Full Marks – 70 **Time – 3 Hours**
Paper Code- MAT 513 **Credit : 5(5+0)**

The content of this paper has been divided into five units. The pattern of questions to be set and the details of the units are as mentioned below:

Question 1 is compulsory and consists of ten objective questions, with two chosen from each unit and each objective question carries 2 marks.

10 x 2 = 20

Question 2 consists of five short answer type questions, one selected from each unit and each question carries 5 marks. An examinee is required to answer any four out of them.

4 x 5 = 20

Question 3 consists of five long answer type questions, one selected from each unit and each question carries 10 marks. An examinee is required to answer any three out of them.

3 x 10 = 30

Unit : (1) Riemann-Stieltje's Integral : Definition and existence of the Riemann-Steieltje's integral, Linearity properties of the integral, Integration and differentiation, The fundamental theorem of calculus.

Unit : (2) Rearrangements of term of a series, Riemann's theorem, Power series, Uniqueness theorem for power series, Abel's and Tauber's theorems.

Unit : (3) Sequences and series of function : Point wise and uniform convergence, Cauchy criterion for uniform convergence, Weierstrass M-test, Abel's and Dirichlet's tests for uniform convergence, Uniform convergence and continuity, Uniform convergence & Integration, Uniform convergence & differentiation, Weierstrass approximation theorem.

Unit : (4) Functions of several variables : Linear transformations, Derivatives in an open subset of **R**, Chain rule, Partial derivatives interchange of the order of differentiation derivatives of higher orders, Taylor's theorem for functions of two variables.

Unit : (5) Jacobians and functions with non-zero Jacobians, Inverse function theorem, Implicit function theorem, Extremum problems with constraints, Lagrange's multiplier method.

Recommended Books :

1. W. Rudin – Principles of Mathematical Analysis McGrow-Hill book company, INC.
2. T.M. Apostol – Mathematical Analysis. Narosa Publishing House, New Delhi.

References :

1. E. Hewitt and K. Stromberg – Real and Abstract Analysis.
2. L.P. Natanson – Theory of functions of a Real Variable, Vol.-I. Leo F. Boron, New York.

SEMESTER – I
Paper – IV
Operation Research

Full Marks – 70 **Time – 3 Hours**
Paper Code- MAT 514 **Credit : 4(4+0)**

The content of this paper has been divided into five units. The pattern of questions to be set and the details of the units are as mentioned below:
Question 1 is compulsory and consists of ten objective questions, with two chosen from each unit and each objective question carries 2 marks.

10 x 2 = 20

Question 2 consists of five short answer type questions, one selected from each unit and each question carries 5 marks. An examinee is required to answer any four out of them.

4 x 5 = 20

Question 3 consists of five long answer type questions, one selected from each unit and each question carries 10 marks. An examinee is required to answer any three out of them.

3 x 10 = 30

Unit : (1) Origin and development of O.R. applications of O.R., Nature and features of O.R., Model in O.R. and its classification, advantages and limitations, Hyperplane, supporting and separating hyper planes, Hyper sphere, convex sets and their properties, convex combination of vectors.

Unit : (2) Simplex method for solving a linear programming problem, Basic solution, Degenerate solution, Basic feasible solution, fundamental theorem of linear programming, conditions of optimality, Two-phase method, Big-M method of solving a linear programming problem.

Unit : (3) Duality in linear programming, Duality theorems, existence theorem, Dual simplex method, Integer programming, fractional cut method, Branch and bound method.

Unit : (4) Dynamic programming and its characterizations, Optimal sub-division problem, Two-Person zero-sumgames, the maximin-minimax principle, Saddle point, Graphic solution of 2 x n and m x 2 games, Dominance property, Solution of a game by linear programming method.

Unit : (5) General non-linear programming problem, Lagrange's multipliers, Conditions for a general non-linear programming problem, Kuhn-Tucker conditions for general non-linear programming, Conditions for non-negative saddle point.

Recommended Books:

1. Hamdy A. Taha Operations Research - An introduction, Macmillan Co. INC, New York.
2. Dr. B. S. Geoel & S. K. Mittal - Operations Research Pragati Prakashan.

References:

1. F. S. Hillier and G. 1. Lieberman - Introduction to operations research (Sixth edition), McGraw Hill international edition industrial engineering series, 1955. (This book comes with a CC containing tutorial software).
2. G. Hadley - Linear Programming, Narosa Publishing House, 1995.
3. G. Hadley - Nonlinear and Dynamic Programming, Addison Wesley, Reading Mass.
4. Mokhtar S. Bazaraa. Jonh J. Jarvis and Hanif D. Sherali Linear Programming and Network flows, John Wiley and Sons, New York, 1990.
5. Kanti Sarup, P. K. Gupta and Man Mohan – Operations Research, Sultan Chand and Sons, New Delhi.
6. S.S. Rao- Optimization Theory and Applications. Wikey Eastern Ltd. New Delhi.
7. Prem Kumar Gupta and D.S. Hira – Operations Research- An Introduction, S. Chand and Company Ltd. New Delhi.
8. N.S. Kambo – Mathematical Programming Techniques, Affiliated East- West Press Pvt. Ltd. New Delhi, Madras.
9. LINDO Systems Product (Visit Website http://www.lindo.com/productsfhrml)

SEMESTER – II
PAPER – V
GENERAL TOPOLOGY

Full Marks – 70 **Time – 3 Hours**
Paper Code- MAT 521 **Credit : 5(5+0)**

The content of this paper has been divided into five units. The pattern of questions to be set and the details of the units are as mentioned below:

Question 1 is compulsory and consists of ten objective questions, with two chosen from each unit and each objective question carries 2 marks.

10 x 2 = 20

Question 2 consists of five short answer type questions, one selected from each unit and each question carries 5 marks. An examinee is required to answer any four out of them.

4 x 5 = 20

Question 3 consists of five long answer type questions, one selected from each unit and each question carries 10 marks. An examinee is required to answer any three out of them.

3 x 10 = 30

Unit : (1) Notion of a topological space, open set topology and fundamental concepts of open sets, closed sets, neighbourhoods, adherent points, accumulation points, closure, interior and boundary in a topological space, subspace. Important interrelations between fundamental concepts.

Unit : (2) Convergence of sequences in a topological space, continuity and homomorphism, characterisations of continuity and homeomorphism, base and subbase of a topology, continuity and sequential continuity.

Unit : (3) Separation axioms in a topological space, T_0, T_1, T_2, Regular find normal space and their mutual implication relationships, unique limit of sequences in a Hansdorff (T_2) space. Hereditary and topological properties.

Unit : (4) Compactness concept in a topological space, compact subsets of a topological space with Hansdorff property, characterization of compactness by closed sets with finite intersection property, compactness and continuity, compact sets in real line R (under usual topology)

Unit : (5) Connected and disconnected spaces, connectedness and continuity, characterizations of connected and disconnected spaces, connected sets in a topological space, sufficient conditions under which union of connected sets is connected, connected sets in R (under usual topology).

Recommended Books:

1. Prof. K.K. Jha – Advanced General Topology, Nav Bharat Prakashan, Delhi-6.
2. G.F.Simmons – Introduction to General Topology and Modern Analysis, McGraw Hill Book Company, INC.

Reference Books:

1. Prof. R. Shukla – General Topology, Macmillan Company of India Ltd.
2. W.J. Pervin – Foundations of General Topology, Academic Press, London.
3. J.L. Kelley – General Topology, Affiliated East-West Press Pvt. Ltd., New Delhi.

SEMESTER – II
Paper – VI
Functional Analysis

Full Marks – 70 **Time – 3 Hours**
Paper Code- MAT 522 **Credit : 5(5+0)**

The content of this paper has been divided into five units. The pattern of questions to be set and the details of the units are as mentioned below:
Question 1 is compulsory and consists of ten objective questions, with two chosen from each unit and each objective question carries 2 marks.

10 x 2 = 20

Question 2 consists of five short answer type questions, one selected from each unit and each question carries 5 marks. An examinee is required to answer any four out of them.

4 x 5 = 20

Question 3 consists of five long answer type questions, one selected from each unit and each question carries 10 marks. An examinee is required to answer any three out of them.

3 x 10 = 30

Unit : (1) Definition, examples and counter examples of normed linear spaces and Banach spaces, continuity of vector addition scalar multiplication and the norm function in a normed linear space, quotient space of a normed linear space, Lemma of F. Riesz.

Unit : (2) Continuous linear transformation and functional & normed linear spaces of bounded linear transformations, dual spaces with examples, uniform boundedness theorem and some of its consequences, open mapping and closed graph theorems, Hahn- Banach theorem for real linear spaces, complex linear spaces and normed linear spaces.

Unit : (3) Definition and examples of inner product spaces and Hilbert spaces, Cauchy-Schwrz inequality, continuity of inner product function, Parallelogram law, Polarisation identity, Lemma of F. Riesz on closed convex set in H.

Unit : (4) Orthogonal complements, Projection theorem in a Hilbert space, Orthonormal sets, Bessel's inequalities, characterization on theorem for complete orthonormal set in a Hilbert space, Frechet Riesz representation theorem for bounded linear functionals in H.

Unit : (5) Adjoint of an operator on H, self-adjoint operators and positive operators in H, normal operators, Unitary operators.

Recommended Books:

1. K. K. Jha - Functional Analysis with Applications, Students Friends, Patna
2. A. H. Siddiqui, Functional Analysis with Applications, Tata McGraw Hill, Publishing Company Ltd., New Delhi
3. G. F. Simmons, Introduction to Topology and Modern Analysis, McGraw Hill Book Company, New York, 1963.
4. P. K. Jain, O.P. Ahuja and Khalial Ahmad, Functional Analysis, New Age International (P) Ltd. And Wiley Eastern Ltd. New Delhi, 1997.

References:

1. G. Bachman and L. Narici, Functional Analysis, Academic Press 1966.
2. C. Coffman and G. Pedrik, First Couse in Functional Analysis, Preatice Hall of India, New Delhi, 1997.
3. R. E. Edwards, Functional Analysis, Holt Rinehart and Winstorn, New York, 1965
4. B. K. Lahiri, Elements of functional Analysis, The World Press Pvt. Ltd Calcutta, 1994.
5. B. Choudhary and Sudarsan Nanda, Functional Analysis with applications, Wiley Eastern Ltd. 1989.
6. B.V. Limaye, Functional Analysis, Wiley Eastern Ltd.
7. L.A. Lustenik and V.J. Sovolev, Elements of Functional Analysis. Hindustan Publishing Corporation, New Delhi, 1971.
8. A. E. Taylor, Introduction to Functional Analysis, John Wiley and Sons, New, York, 1958
9. K. Yosida, Functional Analysis 3rd. Edition Springer Verlag, New York.
10. J. B. Conway, A Course in Functional Analysis, Springer Verlag, New York, 1990.
11. Walter Rudin, Functional Analysis. Tata McGraw Hill Publishing Company Limited New Delhi 1973
12. A. Wilansky, Functional Analysis Blaisdell Publishing Co. 1964.

Semester – II
Paper VII
Fundamentals of Computer

Full Marks – 70 **Time – 3 Hours**
Paper Code- MAT 523 **Credit : 6(6+0)**

The content of this paper has been divided into five units. The pattern of questions to be set and the details of the units are as mentioned below:
Question 1 is compulsory and consists of ten objective questions, with two chosen from each unit and each objective question carries 2 marks.

10 x 2 = 20

Question 2 consists of five short answer type questions, one selected from each unit and each question carries 5 marks. An examinee is required to answer any four out of them.

4 x 5 = 20

Question 3 consists of five long answer type questions, one selected from each unit and each question carries 10 marks. An examinee is required to answer any three out of them.

3 x 10 = 30

Unit 1 : Computer Fundamentals

1.1. History of Computers
1.2. Types of Software
1.3. Memory Types
1.4. Uses of Computer

Unit 2 : Languages

2.1. Generations of Computers
2.2. Machine Language
2.3. Assembly Language
2.4. High Level Language

Unit 3 : Components

3.1. Input Unit
3.2. Output Unit
3.3. CPU
3.4. Input and Output Devices
3.5. Memory

Unit 4 : Number System

4.1. Decimal
4.2. Binary
4.3. Octal
4.4. Hexadecimal
4.5. Number Conversion

Unit 5 : Computer Communication & Internet

5.1. Basic of Computer Networks
5.2. Types of Computer Networks
5.3. Internet
5.4. Application of Internet
5.5. Communication on Internet

Reference Books:

1. Introduction to Information Technology, ITL Education Solutions Ltd., Pearson Education India.
2. Pradip K. Sinha, Computer Fundamentals, BPB Publications,
3. Seema Thareja – Computer Fundamentals, Oxford Publication

Semester – II
Paper VIII
Computer Science Practical

Full Marks – 70 **Time – 3 Hours**
Paper Code- MAT 524 **Credit : 4(0+4)**

Application of Ms- Dos. Windows 95, 2000, Ms- word 97, Excel 97 for writing letters, preparing prints, Level, preparing report, Graph and preparing chart. Fox Pro (Interactive).

Recommended books :

1. Visual Fox Pro – Susan : L. Reber and Robert Nicholas Kulik.
2. Advanced Ms Dos – Ray Duncan.
3. Learn Ms Word 5.0 – Russel A. Stulz.
4. Excel for Windows's 95 – Laurie : A Perry.

SEMESTER - III
Paper-IX
Integration Theory

Full Marks – 70 **Time – 3 Hours**
Paper Code- MAT 531 **Credit : 6(6+0)**

The content of this paper has been divided into five units. The pattern of questions to be set and the details of the units are as mentioned below:
Question 1 is compulsory and consists of ten objective questions, with two chosen from each unit and each objective question carries 2 marks.

10 x 2 = 20

Question 2 consists of five short answer type questions, one selected from each unit and each question carries 5 marks. An examinee is required to answer any four out of them.

4 x 5 = 20

Question 3 consists of five long answer type questions, one selected from each unit and each question carries 10 marks. An examinee is required to answer any three out of them.

3 x 10 = 30

Unit : (1) Signed measure, Hahn decomposition theorem, Mutually singular measures.

Unit : (2) Radon - Nikodym theorem, Lebesgue decomposition, Reisz representation theorem, Extension theorem (Cartheodory).

Unit : (3) Lebesgue-Stieltjes integral, Product measures, Fubini's theorem, Differentiation and integration.

Unit : (4) Decomposition into absolutely continuous parts, Bair sets, Baire measure, Continuous functions with compact support.

Unit : (5) Regularity of measure on locally compact spaces. Integration of continuous functions with compact support. Riesz Markoff theorem.

Recommended Books:

1. H. L. Royden - Real Analysis, Mecmillan Publishing Co. INC
2. S. K. Berberian - Measure and Integration, Chelsea Pub. Co. N.Y.
3. Inder K. Rana – An Introduction to Measure and Integration, Narosa Pub. House, Delhi.

References :

1. G.D. Barra, Measure Theory and Integration, Willey Easter Limited, 1981.
2. P. K. Jain and V. P. Gupta, Lebesgue Measure and Integration, New Age International (P) Limited. New Delhi, 2000.
3. K. R. Parthasarthy, Introduction to probability and Measure, McMillan Company of India Limited, 1977.
4. Serge Lang, Analysis I and II, Addison - Wisley Pub. Corpor, Inc. 1967.
5. Walter Rudin, Real and Complex Analysis, Tata McGraw Hill Pub. Com.
6. Edwin Hewitt and K. Stromberg, Real and Abstract Analysis, Springer - Verlag, New York.

SEMESTER – III
Paper – X
Complex Analysis

Full Marks – 70 **Time – 3 Hours**
Paper Code- MAT 532 **Credit : 5(5+0)**

The content of this paper has been divided into five units. The pattern of questions to be set and the details of the units are as mentioned below:
Question 1 is compulsory and consists of ten objective questions, with two chosen from each unit and each objective question carries 2 marks.

10 x 2 = 20

Question 2 consists of five short answer type questions, one selected from each unit and each question carries 5 marks. An examinee is required to answer any four out of them.

4 x 5 = 20

Question 3 consists of five long answer type questions, one selected from each unit and each question carries 10 marks. An examinee is required to answer any three out of them.

3 x 10 = 30

Unit : (1) Complex integration, Cauchy-Goursat theorem, Cauchy's integral formula, Higher order derivatives, Morera's theorem.

Unit : (2) Cauchy inequality, Liouville's theorem, Fundamental theorem of Algebera, Taylor's theorem, Laurents series, Maximum modulus principle, Schwarz lemma.

Unit : (3) Singularities, Zeros & poles, Residues, Cauchy's residue theorem, Evaluation of real integrals, Branches of many valued functions with special reference to argz, Log z and z^n.

Unit : (4) Meromorphic functions, Principle of argument, analytic continuation, uniqueness of direct analytic continuation.

Unit : (5) Bilinear transformation, their properties and classifications, Definition and examples of conformal mappings, Necessary and sufficient condition of conformal mappings, Preservance of cross-ratio under the bilinear transformation.

Recommended Books :

1. Shanti Narayan – Theory of functions of a complex variable S. Chand and company Ltd., New Delhi.
2. John W. Dettman – Applied complex variable, Macmillan Company, New York.

References:

1. H. A. Prinstly, Introduction to complex analysis, Clarendon press, oxford, 1990.
2. J. B. Conway, functions of one complex variable, Springer Verlag, International Student - Edition, Narosa Publishing House, 1980.
3. Liang - Shin Hann & Bernard Estein, Classical Complex Analysis, Jones and Barlett Publishers International, London, 1966
4. L. V. Ahlfors, Complex Analysis, McGraw Hill, 1979,
5. S. Lang, Complex Analysis, Addison Wesley, 1977,

6, D. Sarason, Complex Function Theory, Hindustan Book Agency, Delhi, 1994.
7. Mark, J. Ablowltz and A. S. Fokas, Complex Cariables Introduction and Applications, Cambridge University Press, South Asian Edition. 1998.
8. Ellille, Analytic Function Theory (2Vols.) Gonn & Co., 1959
9. W.H,J, Fuchs. Topic in the Theory of Functions of one complex variable. D. Van. Nostrand Co. 1967.
10. C. Caratheodory, Theory of Functions (2 Vols.) Gonn & Co., 1959.
11. M. Heins, Complex Function Theory. Academic Press, 1968.
12. Walter Rudin, Real and Complex Analysis, McGraw Hill, Book Col, 1966.
13. S. Saks and A. Zygmund, Analytic Functions. Mongrafile Matematyzne, 1962,
14. E. C. Titachmarsh, The Theory of Functions, Oxford University Press London.
15. W. A. Veech, A second Course in Complex Analysis, W. A. Benjamin, 1967.
16. S. Pormusamy, Function of Complex Analysis, Narosa Publishing House, 1997.

Semester – III
Paper – XI
Partial Differential Equations

Full Marks – 70 **Time – 3 Hours**
Paper Code- MAT 533 **Credit : 4(4+0)**

The content of this paper has been divided into five units. The pattern of questions to be set and the details of the units are as mentioned below:

Question 1 is compulsory and consists of ten objective questions, with two chosen from each unit and each objective question carries 2 marks.

10 x 2 = 20

Question 2 consists of five short answer type questions, one selected from each unit and each question carries 5 marks. An examinee is required to answer any four out of them.

4 x 5 = 20

Question 3 consists of five long answer type questions, one selected from each unit and each question carries 10 marks. An examinee is required to answer any three out of them.

3 x 10 = 30

Unit : (1) Partial differential equations of the first order, Integral surface, Orthogonal surfaces, Non-linear Partial differential equations, Charpit's method, Jacobi's method.

Unit : (2) **Linear Partial differential equations with constant co-efficients.**
Homogeneous and non Homogeneous linear partial differential equation with constant co-efficients, Methods for finding C.F. and P.I. of linear homogeneous Partial Differential Equations.

Unit : (3) **Partial Differential equations of order two**
Solution of equations under given geometrical conditions. Monge's method for integration of the equation $Rr+Ss + Tt = V$.

Unit : (4) **Classification of Partial Differential Equation.**
Classification and solution of Partial Differential Equations of order two and their examples. Cauchy's problem for seemed order Partial Differential Equations characteristic equation and characteristic curves of the second order Partial Differential Equations. Reduction of linear Partial Differential Equations. in two variables to canonical form and then classifications into elliptic, parabolic and hyperbolic forms.

Unit : (5) **Boundary Value Problem**
Laplace's, heat and wave equations in one and two dimensions in Cartesian, polar and cylindrical forms, Solution of Laplace' s equation, heat equations and wave equations.

Reference Books:

1. M.D. Raisinghania – Ordinary and partial Differential Equation, S. Chand & Company Ltd.
2. Bhargava & Chandramouli – Differential Equation, Pragati Prakashan
3. Garrett Birknoff – Ordinary Differential Equation, John Wiley Sons
4. R.K.Gupta – Partial Differential Equation, Krishna Publication.
5. Pundir & Pundir – Advanced Partial Differential Equation, Pragati Prakashan.

SEMESTER – III
Paper – XII
Axiomatic set theory

Full Marks – 70 **Time – 3 Hours**
Paper Code- MAT 534 **Credit : 5(5+0)**

The content of this paper has been divided into five units. The pattern of questions to be set and the details of the units are as mentioned below:
Question 1 is compulsory and consists of ten objective questions, with two chosen from each unit and each objective question carries 2 marks.

10 x 2 = 20

Question 2 consists of five short answer type questions, one selected from each unit and each question carries 5 marks. An examinee is required to answer any four out of them.

4 x 5 = 20

Question 3 consists of five long answer type questions, one selected from each unit and each question carries 10 marks. An examinee is required to answer any three out of them.

3 x 10 = 30

Unit : (1) Study of various paradoxes of Cantor's theory of sets, Russel's paradox, Paradox of grounded sets, Paradox of non-circular sets, Burali Forti paradox, Cardinal paradox.

Unit : (2) Ordinal paradox, Richard's paradox, Russel's vicious circle principle and zig-zag theory and some of their draw backs, Formal language for axiomatising set theory.

Unit : (3) Axioms for ZFS-system of theory of sets and resolution of paradoxes, modifications in the definition of naïve set theoretic concepts.

Unit : (4) Construction of natural numbers theorem of recursion and arithmetic of natural numbers.

Unit : (5) Zorn's lemma and principle axiom of choice, Von Neumann's theory of cardinal and ordinal numbers and their properties.

Books Recommended :

1. R. Shukla – Lectures on set theory – Pothishata Pvt. Ltd. Allahabad
2. Dr. K. K. Jha - Advanced Set Theory and the foundations of mathematics - P. C. Dwadash shreni and company Pvt Ltd., Aligarh.

References:

1. P. R. Halmos - Naive Ser Theory - D. Van Nostrand Company INC, New York.
2. Bernays P. - Axiomatic set theory - North Holland, Amsterdam
3. Suppes P. - Axiomatic Set Theory - D. Van Nostrand Company, New York.

List of Elective Paper – XIII

Paper Code- MAT 541 **Credit : 5(5+0)**

(i) Programming in C
(ii) Advanced functional analysis
(iii) Theory of differential equations
(iv) Space dynamics
(v) Information theory
(vi) Algebraic topology

Semester – IV

Progamming in C

Full Marks – 70 **Time – 3 Hours**

The content of this paper has been divided into five units. The pattern of questions to be set and the details of the units are as mentioned below:

Question 1 is compulsory and consists of ten objective questions, with two chosen from each unit and each objective question carries 2 marks.

10 x 2 = 20

Question 2 consists of five short answer type questions, one selected from each unit and each question carries 5 marks. An examinee is required to answer any four out of them.

4 x 5 = 20

Question 3 consists of five long answer type questions, one selected from each unit and each question carries 10 marks. An examinee is required to answer any three out of them.

3 x 10 = 30

Unit 1 : Introduction

1.1. Problem Solving Using Algorithm
1.2. Problem Solving Using Flowchart
1.3. Introduction of Programming Language
1.4. Introduction to C Language
1.5. C Programming Environment

Unit 2 : Variables and Operators

2.1. C character set & Keywords
2.2. Constants, Variables & Data Types
2.3. Operator and their types
2.4. Expression and their evaluation
2.5. Type conversion in expressions
2.6. Operator precedence & associativity

Unit 3 : Branching & Looping

3.1. If statement
3.2. If-else statement
3.3. switch-case statement
3.4. While Loop
3.5. Do-while loop
3.6. For Loop

Unit 4 : Array & Function

4.1. One Dimensional Array
4.2. Two Dimensional Array
4.3. Introduction to Function
4.4. Types of Function (Recursive & Non-Recursive).

Unit 5 : Pointer and User Defined Data Types

5.1. Introduction to pointer
5.2. Pointer & Arrays
5.3. Pointer & Function
5.4. Structure
5.5. Union

Reference Books:

1. K.R. Venugopal – Mastering C, Tata McGraw Hill
2. Yashwant Kanetkar – Let us C, BPB Publication
3. E.Balagurusamy – Programming in ANSI C, Tata McGraw Hill

Semester IV

Advanced Functional Analysis

Full Marks – 70 **Time – 3 Hours**

The content of this paper has been divided into five units. The pattern of questions to be set and the details of the units are as mentioned below:

Question 1 is compulsory and consists of ten objective questions, with two chosen from each unit and each objective question carries 2 marks.

10 x 2 = 20

Question 2 consists of five short answer type questions, one selected from each unit and each question carries 5 marks. An examinee is required to answer any four out of them.

4 x 5 = 20

Question 3 consists of five long answer type questions, one selected from each unit and each question carries 10 marks. An examinee is required to answer any three out of them.

3 x 10 = 30

Unit : (1) Definition and examples of topological Vector Spaces. Convex, balanced and absorbing sets and their properties. Minkowski's functional, Subspace, product spaces and quotient spaces of a topological vector space.

Unit : (2) Locally convex topological Vector spaces, Normable and metrizable topological vector spaces. Complete topological vector spaces and Frechet space.

Unit : (3) Linear transformation and linear functionals and their continuity. Finite - dimensional topological vector spaces. Linear Verieties and Hyperplanes. Geometric form of Hahn- Banach theorem.

Unit : (4) Uniform- boundedness principles. Open mapping theorem and closed graph theorem for Frehet spaces. Banach – Alaoglu theorem. Extreme points and External sets. Krein- milman's theorem. Duality, Polar, Bipolar theorem. Baralled and Bornological Spaces.

Unit : (5) Macekey Spaces, Semi- reflexive and Reeflexive topological vector spaces. Montel spaces and Schwarz spaces. Quasi – completeness, inverse limit and inductive limit of locally convex spaces Distributions.

References :

1. John Horvath, Topological Vector Space and Distributions. Addison - Wesley Publishing Company, 1966.
2. J. L. Kelley and Issac Namioka. Linear Topology Spaces. D. Van Nostand Company, Inc., 1963.
3. You - Chuen Wong, Introductory Theory of Topology Vector Spaces, Marcel Dekker, Inc., 1992
4. Laurent Schwarz, Functional Analysis, Courant Institute of Mathematical Sciences, New York University, 1964.
5. F. Treves, Topological Vector Spaces, Distributions, and Kernel, Academic Press, Inc., New York, 1967.
6. G. Kotlle, Topological Vector Spaces, Vol. I, Springer, New York, 1969.

7. R. Larse, Functional Analysis, Marcel Dekker, Inc. N. Y, 1973.
8. Walter Rudin, Functional Analysis, TMH Edition, 1974.
9. L. V. Kantorovich and G. P. Akilov, Functional Analysis, Pergamon Press, 1982.
10. Edward W. Packel, Functional Analysis, Intext, Inc., 1974.
11. H. H. Scheefer, Topological Vector Spaces, McMillan, N.Y. 1966, Reprinted, Springer, NY 1971.

SEMESTER - IV
Theory of Differential Equations

Full Marks – 70 **Time – 3 Hours**

The content of this paper has been divided into five units. The pattern of questions to be set and the details of the units are as mentioned below:

Question 1 is compulsory and consists of ten objective questions, with two chosen from each unit and each objective question carries 2 marks.

10 x 2 = 20

Question 2 consists of five short answer type questions, one selected from each unit and each question carries 5 marks. An examinee is required to answer any four out of them.

4 x 5 = 20

Question 3 consists of five long answer type questions, one selected from each unit and each question carries 10 marks. An examinee is required to answer any three out of them.

3 x 10 = 30

Unit: (1) Initial value problem and the equivalent integral equation. m^{th} order equation in d-dimensions as a first order system.

Unit: (2) Concept of local existence, existence and uniqueness theorem with examples.

Unit: (3) Ascoli-Arzela theorem. A theorem on convergence of solutions of a family of initial value problems.

Unit: (4) Picard- Lindel theorem. Peano's existence theorem. Maximal intervals of existence. Extension theorem. Kamke's convergence theorem.

Unit: (5) Gronwall's inequality. Maximal and minimal solutions. Differential inequalities. A theorem of Winter. Uniqueness theorems.

Books Recommended :

1. P. Hartman – Ordinary differential equations, John Willey, 1964.

References :

1. W.I. Reid – ordinary differential equations. John Wiley and sons.
2. E.A. Coddington – Theory of ordinary differential equations and N. Levinson, McGraw Hill, New York, 1957.

SEMESTER - IV

Space Dynamics

Full Marks – 70 **Time – 3 Hours**

The content of this paper has been divided into five units. The pattern of questions to be set and the details of the units are as mentioned below:

Question 1 is compulsory and consists of ten objective questions, with two chosen from each unit and each objective question carries 2 marks.

10 x 2 = 20

Question 2 consists of five short answer type questions, one selected from each unit and each question carries 5 marks. An examinee is required to answer any four out of them.

4 x 5 = 20

Question 3 consists of five long answer type questions, one selected from each unit and each question carries 10 marks. An examinee is required to answer any three out of them.

3 x 10 = 30

Unit : (1) Basic Formulae of Spherical triangle - The two-body Problem: The Motion of the Center of Mass. The relative motion, Kepler's equation. Solution by Hamilton Jacobi theory.

Unit : (2) The Determination of Orbits - Laplace's Gauss Methods. The Three Body Problem, General Three Body Problem. Restricted Three Body Problem. Jacobi integral. Curves of Zero Velocity. Stationary Solution and their stability.

Unit : (3) The n-Body Problem- The motion of the Centre of Mass Classical Integrals. Perturbation - Osculating orbit. Perturbing forces. Secular and Periodic perturbation. Lagrange's Planetory Equations in terms of pertaining forces and in terms of a perturbed Hamiltonian.

Unit : (4) Motion of the moon- The perturbing forces. Perturbations of Keplerian elements of the Moon by the Sun. Flight Mechanics – Rocket performance in Vaccum. Vertically ascending paths. Gravity Trajectories. Multi stages rocket in a vacuum. Definitions pertinent to single stage rocket.

Unit : (5) Performance limitations of single stage rocket. Definitions pertinent to multi stage rockets. Analysis of multi stage rocket neglecting gravity. Analysis of multi stage rockets including gravity. Rocket performance with Aerodynamic forces. Short range non – lifting missiles. Ascent of a sounding rocket. Some approximate performance of rocket-pored air–craft.

References:

1. M.A. Danby, Fundamentals of Celestia Mechanics, The Macmillan Company, 1962
2. E. Finlay, Freundlich, Celestial Mechanics, The Macmillan Company, 1958.
3. Theodore E. Steme, An Introduction of Celestial Mechanics, Intersciences Publishing Company Inc., 1962
4. Arigelo Miele, Flight Mechanics - Vol. I - Theory of Flig.l1t paths, Addison - Wesley Publishing Company Inc., 1962.

SEMESTER-IV

Information Theory

Full Marks – 70 **Time – 3 Hours**

The content of this paper has been divided into five units. The pattern of questions to be set and the details of the units are as mentioned below:

Question 1 is compulsory and consists of ten objective questions, with two chosen from each unit and each objective question carries 2 marks.

10 x 2 = 20

Question 2 consists of five short answer type questions, one selected from each unit and each question carries 5 marks. An examinee is required to answer any four out of them.

4 x 5 = 20

Question 3 consists of five long answer type questions, one selected from each unit and each question carries 10 marks. An examinee is required to answer any three out of them.

3 x 10 = 30

Unit : (1) Measure of Information - Axioms for a measure of uncertainity. The Shannon entropy and its properties. Joint and conditional entropies, Transformation and its properties. Noiseless coding-Ingredients of noiseless coding problem. Uniquely decipherable codes. Necessary and sufficient condition for the existence of instantaneous codes. Constructions of optional code.

Unit : (2) Discrete Memoryless Channel - Classification of channels. Information processed by a channel. Calculation of channel capacity. Decoding Schemes. The ideal observer. The fundamental theorem of information theory and its strong and weak converses.

Unit : (3) Continuous Channels. The time discrete Gaussian Channel Uncertainty of an absolutely continuous random variable . The converse to the coding theorem for time discrete Gaussian channel. The time - continuous Gaussian Channel. Band -limited channels.

Unit : (4) Some imutitive properties of a measure of entropy- Symmetry, normalization, expansibility, boundedness, recursivity maximality, stability, additivity, subadditivity, nonegativity, continuity, branching etc. and interconnections among them. Axiomatic characterization of the Shannon entropy due to Shannon and Fadeev.

Unit : (5) Information function, the fundamental equation of information, information functions continuous at the origin, nonnegative bounded information functions, measurable information functions and entropy. Axiomatic characterization of the Shannon entropy due to Tverberg and Leo. The general solution of the fundamental equation of information. Derivations and their role in the study of information functions.

References:

1. R. Ash, Information Theory, Interscience Publishers, N,Y. 1965
2. F. M. Reza, An introduction to information Theory, McGraw Hill Book Company Inc., 1961.
3. J. Aczel and Z. Daroczy, On measurs of information and their characterization, Academic Press, New York.

SEMESTER-IV

Algebraic Topology

Full Marks – 70 **Time – 3 Hours**

The content of this paper has been divided into five units. The pattern of questions to be set and the details of the units are as mentioned below:

Question 1 is compulsory and consists of ten objective questions, with two chosen from each unit and each objective question carries 2 marks.

10 x 2 = 20

Question 2 consists of five short answer type questions, one selected from each unit and each question carries 5 marks. An examinee is required to answer any four out of them.

4 x 5 = 20

Question 3 consists of five long answer type questions, one selected from each unit and each question carries 10 marks. An examinee is required to answer any three out of them.

3 x 10 = 30

Unit : (1) Fundamental group functo, homotopology of maps between topological spaces, homotopy equivalence, contractible and simply connected spaces, fundamental groups of S^1, S^1 x S^1 etc Calculation of fundamental group of S^n, n> 1 using Van Kampe's theorem, fundamental groups of a topological group, Brouwer's fixed point theorem, fundamental theorem of algebra, vector fields on planer sets, Frobenius theorem for 3 x 3 matrices.

Unit : (2) Covering spaces, unique path lifting theorem, covering homotopy theorems, group of covering transformations, criteria of lifting of maps in terms of fundamental groups, universal covering its existence, special cases of manifolds and topological groups.

Unit : (3) Singular homology, reduced homology, Eilenberg Steenrod axioms of homology, reduced homology, Eilenberg Steenrod axioms of homology (no proof for monotopy invariance axioms, excision axiom and exact sequence axiom) and their application, relation between fundamental groups and first homology.

Unit : (4) Calculation of homology of S^n. Brouwer's fixed point theorem for f: $E^n \rightarrow E^n$ application spheres, vector fields, Mayer – Vietoris sequence (without proof) and its applications. Mayor Vietorsis sequence (with proof) and its application to calculation of homology of graphs, torus and compact surface of genus g, collard pairs, construction of spaces by attaching of cells, spherical complexes with examples of S^n r – leaves rose, torus, RP^n, CP^n etc.

Unit : (5) Computation of homology of CP^n, RP^n, torus suspension spaces, XVY, compact surface of genus g and non-orientable surface of genus h using Mayer Vietoris sequence, Betti numbers and Euler characteristics and their calculation for S^n, r-leaved rose, RP^n, CP^n, S^2 x S^2, X+Y etc.

References:

1. James, R. Munkres, Topology - A first Course, Prentice Hall of India, Pvt. Ltd., New Delhi, 1978.
2. Marwin J. Greenberg and J.R. Harper Algebraic Topology - A first Course, Addision - Wesly Publishing Co., 1981.
3. W.S. Massey, Algebraic Topology - An Introduction, Harcourt Brace and World Inc., 1967. Sv., 1977.

List of Elective Paper – XIV

Paper Code- MAT 542 **Credit : 6(6+0)**

(i) Object oriented Programming (C++)
(ii) Theory of ordinary differential equations
(iii) Non- linear programming
(iv) Banach algebras
(v) Fuzzy sets & their applications
(vi) Category theory

Semester – IV

Object Oriented Programming (C++)

Full Marks – 70 **Time – 3 Hours**

The content of this paper has been divided into five units. The pattern of questions to be set and the details of the units are as mentioned below:

Question 1 is compulsory and consists of ten objective questions, with two chosen from each unit and each objective question carries 2 marks.

10 x 2 = 20

Question 2 consists of five short answer type questions, one selected from each unit and each question carries 5 marks. An examinee is required to answer any four out of them.

4 x 5 = 20

Question 3 consists of five long answer type questions, one selected from each unit and each question carries 10 marks. An examinee is required to answer any three out of them.

3 x 10 = 30

Unit 1

1.1. Overview of procedural oriented programming
1.2. Introduction to Object oriented programming
1.3. Basic Concepts of Object Oriented Programming
1.4. Benefits of Object Oriented Programming
1.5. Object Oriented Language

Unit 2

2.1. Introduction to C++
2.2. Constants, Variables & Data Types
2.3. Operators in C++
2.4. Expression and their evaluation
2.5. Control Statement in C++

Unit 3 : Class and Object

3.1. Introduction to Class
3.2. Defining Object of a class
3.3. Members of Class
3.4. Constructor and their type
3.5. Destructor

Unit 4 : Inheritance

4.1. Introduction to inheritance
4.2. Types of inheritance
4.3. Single Inheritance
4.4. Multi level Inheritance
4.5. Multiple Inheritance

Unit 5 : Function & Operator overloading

5.1. Function overloading
5.2. Operator Overloading
5.3. Uniary Operator Overloading
5.4. Binary Operator Overloading
5.5. Type Conversion

Reference Books:

1. E. Balagurusamy – Object Oriented Programming with C++, Tata McGraw Hill.
2. Rajesh K. Shukla - Data Structure using C & C++, Willey India Pvt. Ltd.
3. Ashok Kamthane - Object Oriented Programming with ANSI & Turbo C++, Pearson Education.

SEMESTER- IV

Theory of Ordinary Differential Equations

Full Marks – 70 **Time – 3 Hours**

The content of this paper has been divided into five units. The pattern of questions to be set and the details of the units are as mentioned below:

Question 1 is compulsory and consists of ten objective questions, with two chosen from each unit and each objective question carries 2 marks.

10 x 2 = 20

Question 2 consists of five short answer type questions, one selected from each unit and each question carries 5 marks. An examinee is required to answer any four out of them.

4 x 5 = 20

Question 3 consists of five long answer type questions, one selected from each unit and each question carries 10 marks. An examinee is required to answer any three out of them.

3 x 10 = 30

Unit : (1) Existence theorems for differential equations - Introduction. Auxiliary results. Existence theorems of Cauchy - Peano type. Extreme solutions of real Scalar Differential Equations. Uniqueness Theorems. Existence theorem by the method of iterations. Applications of the contraction mapping theorem to existence theorems. Differential equations of higher order. Linear vector differential equations. Differenriability of Solutions of real differential systems. Differential equations in the Complex plane.

Unit : (2) Linear differential systems – Introduction. Adjoint Vector differential equations. Adjoint nth order differential equations. Homogeneous differential system involving two-point boundary conditions. Nonhomogenous differential system involving two-Point boundary conditions. Adjoint differential systems. Green’s matrix. Differential Systems involving a single nth order linear differential equations.

Unit : (3) Differential Systems involving nth order linear vector differential equations, generalized Green’s matrix. Equivalent differential systems involving linearly a parameter- formulation of the problem. Elementary properties of boundary value problems. Properties of the Green's matrix. Boundary problems involving an nth order linear Vector differential equation. Self-adjoint boundary problems, Definite boundary problems.

Unit : (4) Second order linear differential equations - Introduction preliminary properties of solutions. An associated functional. The associated Riccati differential equation. Oscillation criteria. Comparison theorems. Differential Systems involving a real parameter. Fundamental quadratic forms for conjugate and focal points.

Unit : (5) Self-adjoint boundary problems associated with second order linear differential equations- Canonical forms for self - adjoint boundary problems. Extermum properties for Self - adjoint Systems. Existence of proper values, Comparison theorems. Expansion theorems.

Recommended Text

1. W. T. Reld, Ordinary Differential Equations, John Wiley and Sons., N.Y., 1971

References:

1. Philip Hartman, Ordinary Differential Equations, John Wiley and Sons., NY (1964)
2. E. A. Coddington and N. Levinson, Theory of Ordinary Differential Equations. McGraw Hill, N.Y. (1965)

SEMESTER - IV

Non - Linear Programming

Full Marks – 70 **Time – 3 Hours**

The content of this paper has been divided into five units. The pattern of questions to be set and the details of the units are as mentioned below:

Question 1 is compulsory and consists of ten objective questions, with two chosen from each unit and each objective question carries 2 marks.

10 x 2 = 20

Question 2 consists of five short answer type questions, one selected from each unit and each question carries 5 marks. An examinee is required to answer any four out of them.

4 x 5 = 20

Question 3 consists of five long answer type questions, one selected from each unit and each question carries 10 marks. An examinee is required to answer any three out of them.

3 x 10 = 30

Unit : (1) The nonlinear programming problem and its fundamental ingredients. Linear inequalities and theorem of the alternative – Kas Theorem. The Optimality Criteria of linear programming. Tuker's lemma and existence theorems. Theorems of the alternative. Covex sets – Separation theorems.

Unit : (2) Convex and Concave functions – Basic properties and some fundamental theorems for convex functions. Generalised Gordan theorem, Bohnenblust – Karlin – Shapley theorem. Saddlepoint Optimality criteria without differentiability – The minimization and the local minimization problems and some basic results. Sufficient Optmality theorem. Fritz John Saddlepoint necessary Optimallity theorem. Slaster's and Karlin's Constraint qualifications and their equivalence. The strict constraint qualification. Kuhn-Tucker Saddlepoint necessary optimality theorems.

Unit : (3) Differentiable Convex and Concave functions - Some basic properties. Twice - differentiable convex and concave functions. Theorems in cases of strict convexity and concavity of functions.

Unit : (4) Optimality criteria with differentiability-Sufficient Optimality theorems. Fritz John Stationary-Point necessary Optimality theorem. The Arrow-Huurwicz-Uzawa Constraints qualification. Kuhn Tucker stationary-point necessary Optimality theorem.

Unit : (5) Duality in non - linear programming - Weak duality theorem. Wolfe's duality theorem. Srtict Converse duality theorem. the Hanson - Huard Strict Converse duality theorem. Unbounded dual theorem. Duality in quadrate and linear programmings.

Recommended Text:

1. O.L. Mangasarian, Non linear Programming, McGraw Hill, New York.

References :

1. Mokthar S. Bazaraa and C.M. Shetty, Non-linear Programming, Theory and Algorithm, Wiley, New York.
2. Mordecai Avriel, Nonlinear programming, Analysis and Methods, Prentice Hall, Inc., Englewood Cliffs, New Jersey.

SEMESTER - IV

Banach Algebras

Full Marks – 70 **Time – 3 Hours**

The content of this paper has been divided into five units. The pattern of questions to be set and the details of the units are as mentioned below:

Question 1 is compulsory and consists of ten objective questions, with two chosen from each unit and each objective question carries 2 marks.

10 x 2 = 20

Question 2 consists of five short answer type questions, one selected from each unit and each question carries 5 marks. An examinee is required to answer any four out of them.

4 x 5 = 20

Question 3 consists of five long answer type questions, one selected from each unit and each question carries 10 marks. An examinee is required to answer any three out of them.

3 x 10 = 30

Unit : (1) Definition of Banach Algebra and examples. Singular and Non - Singular elements. The abstract index. The spectrum of element. The spectral radius. Gelfand formula. Multiplicative Linear functional and the Maximal ideal space. Gleason - Kahane Zelazko theorem.

Unit : (2) The Gelfand Transforms. The Spectral Mapping Theorem Isometric Gelfand Transform. Maximal ideal spaces for Disc Algebra.

Unit : (3) C" - algebras - Definition and examples. Self adjoint, unitary, normal positive and projection elements in c* algebras. Commutative c*-algebras. C*-Homomorphisms. Respresentation of Commutative C* - algebra. Subalgebras and the spectrum. The spectral theorem. The continuous functional calculus. Positive linear functionals and states in C* - algebras. The GNS construction.

Unit : (4) Strong and weak operators topologies. Von Neumamm Algebras. Monotone Sequence of Operators. Range Projections. The Commutant. The Double Commutant Theorem. The Kaplansky Density Theorem.

Unit : (5) L^{∞} as von Nueumann Algebras. Maximal Abelian Algebras. Abelian Von Neumann Algebras. Cyclic and separating vectors. Representation of abelian von Neumann Algebras.

References :

1. Kehe Zhu, An Introduction to Operator Algebras - CRC Press Inc., 1993.
2. W. Arveson, Introduction to C* algebras, Springer-Verlag, 1976
3. F. F. Bonsall and J. Duncan, Complete normed algebras. Springer - Verlag, 1973
4. J. Dixmier, C* algebras, North Holland, Amsterdam, 1977
5. R. F. Kadison and J. R. Ringrose, Fundamentals of Operators Theory, VoL I and II. Academic Press, (1983 and 1986)
6. M. A. Naimark, Normed Algebras, Translated from the Second Russian Edition by Leo. F. Boron. Wolters Noordhoff, Groningen. The Netherlands, 1972.
7. T. W. Palmer, Banach Algebra Vol. I, Cambridge University Press, 1994.
8. C. E. Rickart, General Theory of Banach Algebras, Von. Nostrand, 1960.
9. M. Takesaki, Theory of Operators Algebras I, Springer Verlag, New York, 1979.

SEMESTER - IV

Fuzzv Sets and Their Applications

Full Marks – 70 **Time – 3 Hours**

The content of this paper has been divided into five units. The pattern of questions to be set and the details of the units are as mentioned below:

Question 1 is compulsory and consists of ten objective questions, with two chosen from each unit and each objective question carries 2 marks.

10 x 2 = 20

Question 2 consists of five short answer type questions, one selected from each unit and each question carries 5 marks. An examinee is required to answer any four out of them.

4 x 5 = 20

Question 3 consists of five long answer type questions, one selected from each unit and each question carries 10 marks. An examinee is required to answer any three out of them.

3 x 10 = 30

Unit: (1) Fuzzy Sets - Basic Definition, α - Level sets. Covex fuzzy sets. Basic operations on fuzzy sets. Types of fuzzy sets. Cartesian products. Algebraic products, Bounded sum and difference. t norms and t- conorms.

Unit: (2) The Extension Principle - The Zadeh's extension principle. Image and inverse image of fuzzy relations. Min-Max composition and its properties. Fuzzy equivalence relations. Fuzzy compatibility relations. Fuzzy relation equations. Fuzzy graphs. Similarity relation.

Unit: (3) Posibility Theory – Fuzzy measures. Evidence theory. Necessity measure. Possibility measure. Possibility distribution. Possibility theory of fuzzy sets. Possibility theory versus probability theory. Fuzzy Logic – An overview of classical logic. Multivalued logics. Fuzzy propositions.

Unit: (4) Fuzzy quantifiers. Linguistic variables and hedges. Interference from conditional fuzzy propositions, the compositional rule of inference. Approximate Reasoning - An overview of fuzzy expert system. Fuzzy implications and their selection. Multiconditional approximate reasoning. The role of fuzzy relation equation.

Unit: (5) An introduction to fuzzy Control - Fuzzy controllers. Fuzzy rule base. Fuzzy interface engine. Fuzzification. Defuzzification and the various defuzzification methods (the center of area, the centre of maxima, and the mean of maxima methods.

References:

1. H. J. Zimmermann, Fuzzy Set theory ·and its Applications, Allied publishers Ltd., New Delhi, 1991.
2. G. J. Klir and B. Yuan - Fuzzy sets and fuzzy logic, Prentice Hall of India, New Delhi, 1995.

SEMESTER - IV

Category Theory

Full Marks – 70 **Time – 3 Hours**

The content of this paper has been divided into five units. The pattern of questions to be set and the details of the units are as mentioned below:

Question 1 is compulsory and consists of ten objective questions, with two chosen from each unit and each objective question carries 2 marks.

10 x 2 = 20

Question 2 consists of five short answer type questions, one selected from each unit and each question carries 5 marks. An examinee is required to answer any four out of them.

4 x 5 = 20

Question 3 consists of five long answer type questions, one selected from each unit and each question carries 10 marks. An examinee is required to answer any three out of them.

3 x 10 = 30

Unit: (1) Categories, Functors and Natural Transformations. Axioms for Categories, Categories. Functors. Natural Transformations. Monics, Epis and Zeros. Foundations. Large Categories. Hom - sets.

Unit: (2) Construction on Categories – Duality, Contravariance and Opposites. Products of Categories - Duality Contravariance and Opposites. Products of Categories. Functor Categories. The Category of All Categories. Comma Categories. The Category of all Categories. Comma Categoris Graphs and Free Categories. Quotient Categories.

Unit: (3) Universal and Limits - Universal Arrows. The Yoneda Lemma. Coproducts and Colimits. Products and Limits. Categories with Finite Products. Groups in Categories. Adjoints - Adjunctions. Examples of Adjoints. Reflexive Subcategories. Equivalence of Categories. Adjoints for Preorders. Cartesian Closed Categories Transformations of Adjoints Compositions of Adjoints.

Unit: (4) Limits- Creation of Limits. Limits by Products and Equailizers. Limits with parameters. Preservation of Limits. Adjoints on Limits. Freyd's Adjoints Functor Theorem. Subobjects and Gererators. The Special Adjoint Functor Theorem. Adjoints in Topology.

Unit: (5) Monads and Algebras – Monads in a category. Algebras for a monad. The Comparison with Algebras. Words and Free Simigroups. Free Algebras for a Monad. Split Coequalizers. Beck's Theorem. Algebras are T- algebras. Compact Hausdorff Spaces. Monoidal Categories. Coherence. Monoids. Closed categories. Compactly Generated Spaces. Loops and Suspecsions.

References:

1. S. Maclane, Categories for the Working Mathematician Springer, 1971.
2. M.A. Arbib and E.G. Manes, Arrows, Structures and Functors The Categorical Imperative, Academic Press, 1975.
3. H. Herrlich and G.E. Strecker, Category Theory, Allyn and Bacon, 1973
4. M. Barr and C. Wells, Category Theory for Computer Science, Prentice Hall, 1990.

List of Elective Paper - XV

Paper Code- MAT 543 **Credit : 4(4+0)**

(i) Computer Science Practical

(ii) Theory of Linear Operations

(iii) Advanced Theory of Partial Differential Equations

(iv) Fundamental of Applied Functional Analysis

(v) Computation Biology

(vi) Non-Linear Optimization in Banach Spaces

SEMESTER - IV
Computer Science Practical

Full Marks – (50+50) **Time – 3 Hours**

Programming in C & C++

Books Recommended

1. Mastering in C++, K.R. Venugopal, Raj Kumar
2. Computer C++, K.R. – Sumit Arora

SEMESTER - IV

Theory of Linear Operators

Full Marks – 70 **Time – 3 Hours**

The content of this paper has been divided into five units. The pattern of questions to be set and the details of the units are as mentioned below:

Question 1 is compulsory and consists of ten objective questions, with two chosen from each unit and each objective question carries 2 marks.

10 x 2 = 20

Question 2 consists of five short answer type questions, one selected from each unit and each question carries 5 marks. An examinee is required to answer any four out of them.

4 x 5 = 20

Question 3 consists of five long answer type questions, one selected from each unit and each question carries 10 marks. An examinee is required to answer any three out of them.

3 x 10 = 30

Unit: (1) Spectral Theory in normed linear spaces, resolvent set and spectrum, spectral properties of bounded linear operators. Properties of resolvent and spectrum. Spectral mapping theorem for Polynomials. Spectral radius of a bounded linear operator on a complex Banach space. Elementary theory of Banach algebras.

Unit: (2) General Properties of compact linear operators. Spectral properties of compact linear operators on normed spaces. Behaviours of Compact linear operators with respect to solvability of operators equations. Fredholm type theorems. Fredhol alternative theorem. Fredhol alternative for integral equations.

Unit: (3) Spectral properties of bounded self – adjoint linear operators on a complex Hilber space. Positive operators on a complex Hilbert space. Square roots of a positive operators. Projection operators. Spectral family of a bounded self – adjoint linear operator and its properties. Spectral representation of bounded self - adjoint linear operators. Spectral theorem.

Unit: (4) Spectral measures. Spectral Integrals. Regular Spectral Measures. Real and Complex Spectral measures. Complex Spectral integrals. Description of the Spectral Subspaces. Characterization of the Spectral Subspaces. The Spectral Theorem for bounded Normal Operator.

Unit: (5) Unbounded linear operators in Hilbert space. Hellinger Toeplitz theorem. Hilbert adjoint operators. Symmetric and Selfadjoint linear operators. Closed linear operators and closures. Spectrum of an unbounded self-adjoint linear operator. Spectral theorem for unitary and self - adjoint linear operators. Multiplication operator and Differentiation Operator.

References:

1. E. Kreyszig. Introductory Functional Analysis with application, John - Wiley and Sons, New York, 1978.
2. P. R. Halmos, Introduction to Hilbert Space and the Theory of Spectral. Multiplicity, Second - Edition, Chelsea Publishing Co., NY 1957.

3. N. Dunford and J. T. Schwartz, Linear Operators - 3 Parts, Interscience I Wiley, New York, 1958 - 71.
4. G. Bachman and 1. Narici, Functional Analysis, Academic Press, New York, 1966.
5. Akhiezer, N.I. and I.M. Glazman, Theory of Linear operators in Hilbert Space, Frederick Ungar Pub. Co., N.Y. Vol. II (l961), Vol. II (1963)
6, P. R. Halmos, A h,Jbert Space Problem Book, D. Van Nostrand Company Inc., 1967.

SEMESTER - IV
Advanced Theory of Partial Differential Equations

Full Marks – 70 **Time – 3 Hours**

The content of this paper has been divided into five units. The pattern of questions to be set and the details of the units are as mentioned below:
Question 1 is compulsory and consists of ten objective questions, with two chosen from each unit and each objective question carries 2 marks.

10 x 2 = 20

Question 2 consists of five short answer type questions, one selected from each unit and each question carries 5 marks. An examinee is required to answer any four out of them.

4 x 5 = 20

Question 3 consists of five long answer type questions, one selected from each unit and each question carries 10 marks. An examinee is required to answer any three out of them.

3 x 10 = 30

Unit : (1) Distribution - Test Functions and Distributions. Examples, Operations on Distributions. Supports and Singular Supports. Convolution, Fundamental Solutions, Fourier Transform, Schwartz Spaces. Tempered Distributions.

Unit : (2) Sobolev Spaces - Basic Properties. Approximation by Smooth Functions, Extension Theorems, Compactness Theorems, Dual Spaces, Functional Order Spaces, Trace Spaces. Trace Theory, Inclusion Theorem.

Unit : (3) Weak Solutions of Elliptic Boundary Value Problems – Variational problems, Weak formulation of Elliptic PDE, Regularity Galerkin Method, Maximum Principles, Eigen Value problems, Introduction to the Finite Element Method.

Unit : (4) Evolution Equation – Unbounded Linear Operators, Co-Semigroups, Hille – Yosida Theorem, Contraction Semigroup on Hilbert Spaces. Heat Equation, Wave Equation, Schrodinger Equation, Inhomogeneous Equation.

Unit : (5) Calculus of Variations – Euler – Lagrange Equation, Second Variation Existence of Minimizers (Coereivity, Lower Semicontinuity, Convexity). Regularity, Constraints (Nonlinear Eigenvalue Problems. Variational Inequalities. Harmonic Maps, Incompressibility). Critical Points (Mountain Pass Theorem and applications to Elliptic PDE.

References:

1. S. Kesavan, Topic in Functional Analysis and Applications. Wilsey - Eastern, New Age International, 1989.
2. L. C. Evans, Partial Differential Equations, Graduate Studies in Mathematics, Volume 19, AMS, 1998.

SEMESTER - IV

Fundamental of Applied Functional Analysis

Full Marks – 70 **Time – 3 Hours**

The content of this paper has been divided into five units. The pattern of questions to be set and the details of the units are as mentioned below:

Question 1 is compulsory and consists of ten objective questions, with two chosen from each unit and each objective question carries 2 marks.

10 x 2 = 20

Question 2 consists of five short answer type questions, one selected from each unit and each question carries 5 marks. An examinee is required to answer any four out of them.

4 x 5 = 20

Question 3 consists of five long answer type questions, one selected from each unit and each question carries 10 marks. An examinee is required to answer any three out of them.

3 x 10 = 30

Unit: (1) Convex Programming - Support functional of a convex set. Minilowaski functional. Separation theorem. Kuhn - Tucker theorem. Minimax theorem. Farkas theorem.

Unit: (2) Spectral theory of operators. Spectral theory of compact Operators. Operators on a separable Hilbert space. Krein factorization theorem for continuous kernels and its consequences.

Unit: (3) L_2 Spaces over Hilbert Spaces. Multilinear forms. Analyticity theorem. Non linear Volterra Operators. Semigroup of linear operators – General properties of Semigroups. Generation of Semigroups. Dissipative semigroups. Compact semigroups. Holomorphic semigroups.

Unit: (4) Elementary examples of semigroups. Cauchy Problem. Controlability. State reduction. Observability. Stabilizability. Evolution equation.

Unit: (5) Optimal Control theory - Linear quadratic regulator problem. the same problem with infinite time interval. Hard Constraints. Final Value Control. Time Optimal Control problems.

Recommended Text:

1. A.V. Baladrishnall, Applied Functional Analysis, Springer Verlag, New York, Inc.

References:

2. N. Dunford and J. T. Schwartz, Linear Operators. Vols. I and II, Interscience, 1958, 1963.
3. S.G. Krein, Linear Differential Equations in a Banach Space, American Mathematical Society, Translation, 1970.
4. K. Yosida, Functional Analysis, Springer- Verlag, 1974.

SEMESTER - IV

Computation Biology

Full Marks – 70 **Time – 3 Hours**

The content of this paper has been divided into five units. The pattern of questions to be set and the details of the units are as mentioned below:

Question 1 is compulsory and consists of ten objective questions, with two chosen from each unit and each objective question carries 2 marks.

10 x 2 = 20

Question 2 consists of five short answer type questions, one selected from each unit and each question carries 5 marks. An examinee is required to answer any four out of them.

4 x 5 = 20

Question 3 consists of five long answer type questions, one selected from each unit and each question carries 10 marks. An examinee is required to answer any three out of them.

3 x 10 = 30

Unit : (1) Basic Concepts of molecular biology. DNA and Proteins. The Central Dogma. Gene and Genome Sequences. Restriction Maps - Graphs, Interval graphs. Measuring Fragment sizes.

Unit : (2) Algorithms for double digest problem (DDP) - Algorithms and complexity, approaches to DDP, Integer Programming. Pzrtition Problems. Traveling Salesman Problem (TSP) Simulated annealing.

Unit : (3) Sequence Assembly - Sequencing Strategies. Assembly in practices, fragment overlap statistics, fragment alignment. Sequence accuracy.

Unit : (4) Sequence comparison Methods - Local and global alignment. Dynamic Programming method. Multiple sequence alignment.

Unit : (5) Probability and Statistics for sequence alignment and sequence patterns - Hidden Markov model for biological sequence.

References:

1. M. S. Waterman, Introduction to Computational Biology, Chapman and Hall, 1995.
2. A. Baxevanis and B. Ouelette, Bioinformatics, A Practical Guide to the analysis of Genes and Proteins, Wiley Interscience (1998.)

SEMESTER - IV

Non - Linear Optimization in Banach Spaces

Full Marks – 70 **Time – 3 Hours**

The content of this paper has been divided into five units. The pattern of questions to be set and the details of the units are as mentioned below:

Question 1 is compulsory and consists of ten objective questions, with two chosen from each unit and each objective question carries 2 marks.

10 x 2 = 20

Question 2 consists of five short answer type questions, one selected from each unit and each question carries 5 marks. An examinee is required to answer any four out of them.

4 x 5 = 20

Question 3 consists of five long answer type questions, one selected from each unit and each question carries 10 marks. An examinee is required to answer any three out of them.

3 x 10 = 30

Unit : (1) Review of Weak Convergence in normed spaces, reflexivity of Banach spaces. Hahn - Banach theorem and partially ordered linear spaces. Existence Theorems for Minimal Points, Problem formulation, Existence theorems. Set of Minimal points.

Unit : (2) Applications to approximations and optimal control problems. Generalised Derivatives – Directional derivative, Gateaux and Frechet derivatives. Subdifferntial, Quasidifferential, Clarke derivative.

Unit : (3) Tangent Cones – Definition and properties. Optimality conditions, Lyusternik theorem. Generalized Lagrange Multipular Rule – Problem formulation. Necessary and Sufficient optimality conditions. Applications to optimal control problems.

Unit : (4) Duality – problem formulation. Duality theorem. Saddle point theorems. Linear problems. Applications to approximation problems. Some special optimization problems – Linear quadratic optimal control problems. Time minimal control problems.

Recommended Text:

1. Johannes John, Introduction to the theory of Nonlinear Optimization, Springer - Verlag, 1994.

References:

2. V. Barbu and T. Precupanu, Convexity and Optimization in Banach Spaces (Editure ACad. Buvaresti, 1986).
3. A. V. Balakrishnan, Applied Functional Analysis, Springer - Verlag, New York Inc.

SEMESTER – IV
Paper – XVI
Graph Theory

Full Marks – 70 **Time – 3 Hours**
Paper Code- MAT 544 **Credit : 5(5+0)**

The content of this paper has been divided into five units. The pattern of questions to be set and the details of the units are as mentioned below:
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10 x 2 = 20

Question 2 consists of five short answer type questions, one selected from each unit and each question carries 5 marks. An examinee is required to answer any four out of them.

4 x 5 = 20

Question 3 consists of five long answer type questions, one selected from each unit and each question carries 10 marks. An examinee is required to answer any three out of them.

3 x 10 = 30

Unit : (1) Definition and examples of graphs, and their basic properties, paths, circuits, subgraphs, operation on graphs, degree of vertex, out degree and indegree.

Unit : (2) Walks, paths, circuits, connected graphs, disconnected graphs and components, Eulerian and Hamiltonian graphs.

Unit : (3) Trees and their properties, Pendant vertices in a tree, distance and centers in a tree.

Unit : (4) Planar graphs, Kuratowskis two graphs, Euler's formula.

Unit : (5) Vector space and matrix representation of graphs.

Books Recommended :

1. N. Deo- Graph Theory with application to engineering and Computer Science.