

A
SYLLABI
For
M.A./M.Sc.
I, II, III, IV Semester
COURSE
IN
MATHEMATICS
Session 2019-20 Onwards

DR. H. S. GOUR VISHWAVIDYALAYA
(A CENTRAL UNIVERSITY)
SAGAR (M.P.)

Introduction

Mathematics Profession

Mathematics is the backbone of all sciences. Along with many other branches mathematics concerns with algebra, vector, calculus, differential, partial and integral equations, which are frequently used in all physical sciences and discrete mathematics in computer sciences, etc. Students possessing degrees Ph. D., M.Sc./M.A. in Mathematics and B.Sc./B.A. with Mathematics have a very large numbers of job opportunities in the fields of Banking, Teaching, Software Engineering, Actuaries. Defence and as operation Research Analyst, Computer System Analyst, etc. They can also get administrative jobs through UPSC and PSC. The course is so designed that the student can also take employment worldwide.

1. Name of the Programme : M.Sc./M.A.
2. Duration of Programme : The duration of programme is six semesters spread over a period of not less than 90 working days for each semester.
3. Structure of Programme: The course (elective and core) of study for M.Sc./M.A., includes the subject. number of hrs. per week devoted to each subject and credits for its theory practicals as per scheme attached.
4. Medium of instruction : English.
5. Each courses of M.Sc./M.A. is mark as a core/compulsory/elective/open elective course etc.
6. Credit allotted: Credit allotted followed through out of scheme of programme
(Total credit: 84)
 - (i) Core Course : 64
 - (ii) Elective Course : 16
 - (iii) Open Elective : 04
7. Scheme of Examination:

(a) Mid Semester Examination	:	20
(b) Internal Assessment	:	20
(c) End Semester Examination	:	60
Total :		100

DOCTOR HARISINGH GOUR VISHWAVIDYALAYA, SAGAR
(A Central University)

Department of Mathematics and Statistics
Academic Session 2019-2020 onwards

Summary of Post Graduate Courses in Mathematics

	Course Name	Paper Code	Title of Paper	Credit	Contact Hours
I S E M	M. Sc. Sem-I	MTS CC 121	Advanced Abstract Algebra-I	4	60
	M. Sc. Sem-I	MTS CC 122	Real Analysis	4	60
	M. Sc. Sem-I	MTS CC 123	Topology-I	4	60
	M. Sc. Sem-I	MTS CC 124	Complex Analysis-I	4	60
	Opt any one out of the following two elective courses				
	M. Sc. Sem-I	MTS EC 121	Probability Theory & Inference	4	60
	M. Sc. Sem-I	MTS EC 122	Advanced Numerical Methods-I	4	60
II S E M	M. Sc. Sem-II	MTS CC 221	Advanced Abstract Algebra-II	4	60
	M. Sc. Sem-II	MTS CC 222	Measure Theory	4	60
	M. Sc. Sem-II	MTS CC 223	Topology-II	4	60
	M. Sc. Sem-II	MTS CC 224	Complex Analysis -II	4	60
	Opt any one from the following two, which was opted in Sem-I				
	M. Sc. Sem-II	MTS EC 221	Mathematical Finance	4	60
	M. Sc. Sem-II	MTS EC 222	Advanced Numerical Methods-II	4	60
PG Mathematics Sem – II(OD)		MTS OE 221	Elementary Mathematics	2	30

	Course Name	Paper Code	Title of Paper	Credit	Contact Hours
III S E M	M. Sc. Sem-III	MTS CC 321	Functional Analysis	4	60
	M. Sc. Sem-III	MTS CC 322	Integral Equations and Boundary Value Problems-I	4	60
	M. Sc. Sem-III	MTS CC 323	Mathematical Biology - I	4	60
	M. Sc. Sem-III	MTS CC 324	Operations Research –I	4	60
	Opt any one out of the following two elective courses				
	M. Sc. Sem-III	MTS EC 321	Differential Geometry	4	60
	M. Sc. Sem-III	MTS EC 322	Analytic Number Theory-I	4	60
	M. Sc. Sem-III	MTS EC 323	Advanced Discrete Mathematics-I	4	60
	PG Mathematics Sem – III (OD)	MTS OE 321	Elementary Statistics	2	30
IV S E M	M. Sc. Sem-IV	MTS CC 421	Integration theory	4	60
	M. Sc. Sem-IV	MTS CC 422	Integral Equations and Boundary Value Problems-II	4	60
	M. Sc. Sem-IV	MTS CC 423	Mathematical Biology - II	4	60
	M. Sc. Sem-IV	MTS CC 424	Operations Research –II	4	60
	Opt only one from the following two, which was opted in III semester				
	M. Sc. Sem-IV	MTS EC 421	MATLAB & Dynamical Systems	4	60
	M. Sc. Sem-IV	MTS EC 422	Analytic Number Theory-II	4	60
	M. Sc. Sem-IV	MTS EC 423	Advanced Discrete Mathematics-II	4	60

DOCTOR HARISINGH GOUR VISHWAVIDYALAYA, SAGAR
(A Central University)
Department of Mathematics and Statistics
M.A. /M.Sc.- I-Semester (Mathematics)
Core Course -I: Advanced Abstract Algebra-I

MTS CC 121	Advanced Abstract Algebra-I	L	T	P	C
		4	0	0	4
		Max. Marks-100			

Mid Sem-20
Internal assessment-20
End Sem-60

Objectives: (1) To inculcate the basic features of Advanced Abstract algebra.
(2) To teach solvable and nilpotent groups.
(3) To acquainted with field extension and finite field theory.
(4) To introduce Galois Theory.
(5) To teach solvability of polynomial equation using the theory.

Unit-I: Normal series, subnormal series of group, composition series, Jordan- Holder theorem, solvable groups, nilpotent groups.	(12 hours)
Unit-II: Irreducible polynomial, Gauss lemma, Einstein criterion, adjunction of roots Algebraic extensions, algebraically closed fields.	(12 hours)
Unit-III: Splitting fields, uniqueness of splitting fields, normal extensions, multiple roots, finite fields, separable & inseparable polynomials, separable & inseparable extensions.	(12 hours)
Unit-IV: Perfect fields. Automorphism groups and fixed fields, Dedekind lemma, Fundamental theorem of Galois theory and example.	(12 hours)
Unit-V: Roots of unity and cyclotomic polynomials, cyclic extension, solution of polynomial by radicals. Insolvability of general equation of degree five by radicals.	(12 hours)

Learning Outcomes: After completion of this course the students will be able to understand the composition series, Jordan- Holder theorem, solvable groups, nilpotent groups. Further, they will understand field extension and Galois Theory and solvability of polynomial equation using the Galois theory.

Essential Readings:

1. N. Jacobson, Basic Algebra, Vol. I, II & III Hindustan Publishing Company.
2. S. Lang, Algebra, Addison-Wisley.
3. I.S. Luther & IBS Passi, Algebra Vol. I, II & III Narosha Pub. House, New Delhi.
4. M. Artin, Algebra, Prentice- Hall of India, 1991.

Suggested Readings and Link:

1. P.B. Bhattacharya, S.K. Jain and S.R. Nagpaul, Basic Abstract Algebra, Cambridge University press.
2. I.N. Herstein, Topic in Algebra, Wiley Eastern, New Delhi.

E-book links: National Digital Library

DOCTOR HARISINGH GOUR VISHWAVIDYALAYA, SAGAR**(A Central University)****Department of Mathematics and Statistics****M.A. /M.Sc.- I–Semester (Mathematics)****Core Course -II: Real Analysis**

MTS CC 122	Real Analysis	L	T	P	C
		4	0	0	4
		Max.Marks-100			

Mid Sem-20**Internal assessment-20****End Sem-60**

- Objectives:**
- 1) To teach fundamentals of Riemann & Riemann-Stieltjes integration.
 - 2) To introduce the Rearrangement of series, Riemann's, Dirichlet's theorem.
 - 3) To explain sequence, series sequence of functions, uniform convergence.
 - 4) To teach Inverse function, Implicit function theorem.
 - 5) To explain the concept of extremum in several variable

Unit - I: Definition and existence of Riemann-Stieltjes integral and its properties, integration and differentiation, the fundamental theorem of Calculus, integration of vector-valued functions, rectifiable curves.	(12 hours)
Unit - II: Rearrangements of terms of a series, Riemann's theorem, Sequences and series of functions, point wise and uniform convergence, Cauchy criterion for uniform convergence, Weierstrass M-test, Abel's and Dirichlet's tests for uniform convergence.	(12 hours)
Unit - III: Uniform convergence and continuity, uniform convergence and Riemann-Stieltjes integration, uniform convergence and differentiation, Power series, uniqueness theorem for power series.	(12 hours)
Unit - IV: Functions of several variables, linear transformations, derivatives in an open subset of $\mathbb{R}^n$, chain rule. Partial derivatives, interchange of the order of differentiation, derivatives of higher orders.	(12 hours)
Unit - V: Taylor's theorem, inverse function theorem, implicit function theorem, Jacobians, extremum problems with constraints, Lagrange's multiplier method, differentiation of integrals, partitions of unity.	(12 hours)

Learning Outcomes: After completion of this course, students will able to know the concept of integration, convergence of series and sequence of functions, point wise and uniform convergence. The students will able to know how to read and write the proofs in analysis. Another outcome includes that student able to the proof of several important theorems. They will know a variety of examples and counterexamples in Real analysis.

Essential Readings:

1. T.M. Apostol: Mathematical analysis, Narosa.
2. H.L. Royden: Real Analysis, Macmillan (Indian Edition).

Suggested Readings:

1. Walter Rudin: Principles of Mathematical Analysis, McGraw Hill.

E book links:

1. https://www.google.com/search?source=hp&ei=FnSLXOq4OZG-rQGEpLUY&q=principles+of+mathematical+analysis&oq=Principles+of+Mathematical+Analysis&gs_l=psy-ab.1.0.0l10.1467.1467..2452...0.0..0.175.340.0j2.....0....2j1..gws-wiz.....0.OFL94B6Dxo8.
2. https://ndl.iitkgp.ac.in/document/gsmLtL2IIYyUKY5xU5byr4vR5xSlxb3DEh5zL_zGOIvu-NQSK_YZqZNsCFI1Px-y-FpdJzjI0yyCXydGf0IXka

DOCTOR HARISINGH GOUR VISHWAVIDYALAYA, SAGAR
(A Central University)
Department of Mathematics and Statistics
M.A. /M.Sc.- I–Semester (Mathematics)
Core Course -III: Topology-I

MTS CC 123	Topology-I	L	T	P	C
		4	0	0	4
		Max.Marks-100			

Mid Sem-20
Internal assessment-20
End Sem-60

Objectives: 1) To teach fundamental of set theory.
2) To introduce Topology.
3) To explain the topological properties of topological spaces.
4) To teach Urysohn lemma & Tietz Extension Theorem.
5) To explain the characteristics of topological space

Unit - I: Countable and uncountable sets, infinite sets and the axiom of choice, cardinal numbers and its arithmetic, Schroeder-Bernstein theorem, Zorn's lemma.	(12 hours)
Unit - II: Well-ordering theorem, definition and examples of topological spaces, closed sets, closure, dense subsets, neighborhoods, interior, exterior and boundary, accumulation points and derived sets.	(12 hours)
Unit - III: Bases and sub-bases, subspaces and relative topology, alternate methods of defining a topology in terms of Kuratowski closure operator and neighborhood systems.	(12 hours)
Unit - IV: Continuous functions and homeomorphism, first and second countable spaces, Lindelof's theorems.	(12 hours)
Unit - V: Separable spaces, second countability and separability, separation axioms $T_0, T_1, T_2, T_3, T_{3\frac{1}{2}}$ & T_4 their characteristics and properties, Urysohn lemma, Tietze extension theorem.	(12 hours)

Learning Outcomes: After completion of this course, students will know the definitions of standard terms in topology. The students will be able to know how to read and write the proofs in topology. They will know a variety of examples and counterexamples in topology.

Essential Readings:

1. G.F. Simmons, Introduction to Topology and Modern Analysis, McGraw Hill.
2. K.D. Joshi, Introduction to general Topology, Wiley Eastern.
3. J.L. Kelley, General Topology, Van Nostrand .

Suggested Readings:

1. J.R. Munkres, Topology-A first course, Prentice-Hall of India, New Delhi.

E-book links: National Digital Library

DOCTOR HARISINGH GOUR VISHWAVIDYALAYA, SAGAR
(A Central University)
Department of Mathematics and Statistics
M.A. /M.Sc. - I Semester (Mathematics)
Core Course: IV - Complex Analysis I

MTS CC 124	Complex Analysis-I	L	T	P	C
		4	0	0	4
		Max.Marks-100			

Mid Sem-20
Internal assessment-20
End Sem-60

Objectives: (1) Importance of analytic functions in the complex integration.
(2) Series expansion of complex valued functions of a complex variable.
(3) To understand Singularities and learn to use Argument principle.
(4) Applications of complex integration for the evaluation of real integrals.
(5) To visualize the multi-valued complex functions.

Unit - I: Analytic functions, Contour integration, Cauchy-Goursat theorem, Cauchy's integral formula, Derivatives of analytic functions, Cauchy's inequality, Liouville's theorem, Morera's theorem, The fundamental theorem of algebra.	(12 hours)
Unit - II: Power series and its properties, Radius of convergence, Taylor's and Laurent's series, Zeros of analytic functions, Singularities and their classification, Isolated and non-isolated singularities.	(12 hours)
Unit - III: Identity theorem for analytic functions, Maximum modulus principle, Schwarz's lemma, Meromorphic functions, Argument principle, Rouché's theorem, Schwarz reflection principle, Weierstrass-Casorati's theorem.	(12 hours)
Unit - IV: Residue, Cauchy's residue theorem, Jordan's lemma, Evaluation of proper and improper integrals, Integration along a branch cut.	(12 hours)
Unit - V: Möbius transformations and its geometrical properties. Conformal mappings, Riemann mapping theorem and its applications, Branch point, Branch cut, Branches of multi-valued functions, analyticity of the branches of $\text{Arg } z$, $\text{Log } z$ and z^a .	(12 hours)

Learning Outcomes: In the end of the course, students will learn the fundamental concepts of complex integration, Contour integration to evaluate complicated real integrals using residue calculus and also know how to construct conformal mappings.

Essential Readings:

1. S. Ponnuswamy, Foundations of Complex Analysis, Narosa Publishing House
2. E.C. Titchmarsh, The Theory of Functions, Oxford University Press
3. H.A. Priestley, Introduction to Complex Analysis, Oxford University Press

Suggested Readings:

1. J.E. Brown, R.V. Churchill, Complex Variables and Applications, McGraw-Hill
2. L.V. Ahlfors, Complex Analysis, McGraw-Hill
3. J.B. Canvey, Function of one Complex Variable, Springer-Verlag, Narosa Publishing House

E-book links: National Digital Library

DOCTOR HARISINGH GOUR VISHWAVIDYALAYA, SAGAR
(A Central University)
Department of Mathematics and Statistics
M.A. /M.Sc.– I Semester (Mathematics)
Elective Course – I: Probability Theory & Inference

MTS EC 121	Probability Theory & Inference	L	T	P	C
		4	0	0	4
		Max. Marks -100			

Mid Sem-20
Internal assessment-20
End Sem-60

- Objectives:** (1) To study Bayes theorem & distribution functions.
(2) To understand Probability inequalities and models of convergence.
(3) To explain transition probabilities & Poisson and birth-and-death processes.
(4) To study standard errors and asymptotic distributions.
(5) To understand properties of estimators.

Unit I: Basic idea of probability measure, Sample space, various events, Bayes theorem. Random variables and distribution functions (univariate and multivariate); expectation and moments.	(12 hours)
Unit II: Independent random variables, marginal and conditional distributions. Characteristic functions. Probability inequalities (Tchebyshef, Markov, Jensen). Modes of convergence, weak and strong laws of large numbers, Central Limit theorems (i.i.d. case).	(12 hours)
Unit III: Markov chains with finite and countable state space, classification of states, limiting behavior of n-step transition probabilities, stationary distribution, Poisson and birth-and-death processes.	(12 hours)
Unit IV: Standard discrete and continuous univariate distributions, sampling distributions, standard errors and asymptotic distributions, distribution of order statistics and range.	(12 hours)
Unit V: Methods of estimation, properties of estimators, confidence intervals, Tests of hypotheses: most powerful and uniformly most powerful tests, likelihood ratio tests.	(12 hours)

Learning Outcomes: After completion of this course the students will be able to understand the Basic idea of probability and use in daily life, which is necessary to study any higher course in Probability Theory .

Essential Readings:

1. S.C. Gupta, V.K. Kapoor, Fundamentals of Mathematical Statistics: S.Chand& Sons , New Delhi
2. F. L. Coolidge, F. Lawrence, Statistics: A Gentle Introduction: A Gentle Introduction: Sage

Suggested Readings:

1. H. Cramér, Mathematical Methods of Statistics: Pricinton University Press.
2. S.C. Gupta &V.K. Kapoor: Fundamentals of Applied Statistics, Sultan Chand & Co.

E-book links: National Digital Library

DOCTOR HARISINGH GOUR VISHWAVIDYALAYA, SAGAR

(A Central University)

Department of Mathematics and Statistics**M.A. /M.Sc.- I–Semester (Mathematics)****Elective Course -II: Advanced Numerical Methods-I**

MTS EC 122	Advanced Numerical Methods-I	L	T	P	C
		4	0	0	4
		Max.Marks-100			

Mid Sem-20

Internal assessment-20

End Sem-60

Note: In this paper a non programmable scientific calculator is allowed in the examination.**Objectives:** 1) To teach the techniques of solution of algebraic and transcendental equations.

2) To introduce convergence criteria for various numerical method.

3) To explain the numerical solution of system of equations.

4) To explain the relaxation and iterative methods.

5) To explain the concept of interpolation, Lagrange, Newton's interpolation.

Unit - I: (12 hours)
Solution of algebraic and transcendental equations, Nonlinear Equations in One Variable, Fixed point iterative method, convergence criterion, Aitken's Δ_2 – process, Sturm sequence method to identify the number of real roots.

Unit - II : (12 hours)
Newton–Raphson's method, convergence criterion, order and rate of convergence, Ramanujan's Method, Bairstow's Method. Linear and Nonlinear system of Equations: Gauss Eliminations with Pivotal Strategy.

Unit - III: (12 hours)
Jacobi and Gauss Seidel Iterative methods with convergence criterion, LU - decomposition methods (Crout's, Choleky and DeLittle methods), consistency and ill conditioned system of equations, tri-diagonal system of equations, Thomas Algorithm.

Unit - IV: (12 hours)
Iterative methods for Nonlinear system of equations, Newton Raphson, Quasi Newton and Over Relaxation methods for Nonlinear system of Equations.

Unit - V: (12 hours)
Interpolation: Lagrange, Hermite interpolation, spline interpolation. Cubic-spline's (Natural, Not a Knot and Clamped)- with uniqueness and error term for polynomial interpolation, Cubic B-splines, Bivariate-interpolation.

Learning Outcomes: After completion of this course, students will learn the several numerical techniques for the numerical solution of equation (algebraic and transcendental). The students can also learn the rate and order of convergence of these methods. They will know a variety of numerical examples and derivation of several numerical methods.

Essential Readings:

1. M.K. Jain: Numerical solution of differential equations, Wiley Eastern, 2nd Ed. 1979.
2. S.C. Chapra and P.C. Raymond: Numerical Methods for Engineers, Tata McGraw Hill, New Delhi

Suggested Readings:

1. M. K. Jain, S. R. K. Iyengar and R.K. Jain: Numerical methods for scientific and engineering computation, Wiley Eastern Ltd. Third Edition, 1993.
2. S.S. Sastry: Introductory methods of Numerical analysis, Prentice - Hall of India, New Delhi, 1998
3. C.F. Gerald and P.O. Wheatley : Applied Numerical Methods, Low- priced edition, Pearson Education Asia, Sixth Edition, 2002

E book links:

1. https://ndl.iitkgp.ac.in/document/7a0yOeBMxyS3OylPsFkf9Of1-73MD_07QpPk0kthj-Oq0WmDzZ4VYmCOTLMHpGS
2. <https://ndl.iitkgp.ac.in/document/BrI6RXE1Y2VDVtRfjDDFsUw8louqqRG4Vyl33RSRmeLF-JegaVYqlluZVfCwQVq>

DOCTOR HARISINGH GOUR VISHWAVIDYALAYA, SAGAR
(A Central University)

Department of Mathematics and Statistics
M.A. /M.Sc.- II–Semester (Mathematics)
Core Course -I: Advanced Abstract Algebra-II

MTS CC 221	Advanced Abstract Algebra-II	L	T	P	C
		4	0	0	4
		Max. Marks-100			

Mid Sem-20

Internal assessment-20

End Sem-60

- Objectives:** (1) To inculcate the basic features of Advanced Abstract algebra.
(2) To teach canonical forms and primary decomposition theorem.
(3) To acquainted with Module theory.
(4) To introduce Noetherian and Artinian modules.
(5) To teach finitely generated modules over a PID.

Unit-I: Canonical forms-similarity of linear transformation, Invariant spaces, reduction to triangular forms, Nilpotent transformations, index of nilpotency, invariants of a nilpotent transformation, the primary decomposition theorem.	(12 hours)
Unit-II: Cyclic modules, sum of modules, internal and external direct sum, direct product, quotient modules, Exact sequences of modules, semi simple modules.	(12 hours)
Unit-III: Schur's lemma, free modules, Noetherian & Artinian modules and rings, the ring of triangular matrices which is right Noetherian but not left Noetherian, Hilbert basis theorem, Wedderburn-Artin theorem.	(12 hours)
Unit - IV: Uniform modules, primary module, Noether-Laskar theorem, Smith normal forms over a principle ideal domain and rank.	(12 hours)
Unit - V: Fundamental theorem of finitely generated modules over a principal ideal domain and its applications to finitely generated abelian groups, Rational canonical forms.	(12 hours)

Learning Outcomes : After completion of this course the students will be able to understand the canonical forms and primary decomposition theorem, Module theory, Noetherian and Artinian modules, finitely generated modules over a PID and rational canonical forms.

Essential Readings:

1. N. Jacobson, Basic Algebra, Vol. I, II & III Hindustan Publishing Company.
2. S. Lang, Algebra, Addison-Wisley.
3. I.S. Luther & IBS Passi, Algebra Vol. I, II & III Narosha Pub. House, New Delhi.
4. M. Artin, Algebra, Prentice- Hall of India, 1991.

Suggested Readings and Link :

1. P.B. Bhattacharya, S.K. Jain and S.R. Nagpaul, Basic Abstract Algebra, Cambridge University press.
2. I.N. Herstein, Topic in Algebra, Wiley Eastern, New Delhi.

E book links: National Digital Library

DOCTOR HARISINGH GOUR VISHWAVIDYALAYA, SAGAR
(A Central University)
Department of Mathematics and Statistics
M.A. /M.Sc.- II–Semester (Mathematics)
Core Course -II: Measure Theory

MTS CC 222	Measure Theory	L	T	P	C
		4	0	0	4
		Max.Marks-100			

Mid Sem-20
Internal assessment-20
End Sem-60

Objectives: (1) To inculcate the basic features of Lebesgue measures.
(2) To teach Lebesgue integration Theory.
(3) To acquainted with Lebesgue differentiation.
(4) To introduce The L_p -space and some inequalities.
(5) To teach Completeness of L_p -space and convergence in measure.

Unit-I: Lebesgue outer measure, measurable sets, regularity, measurable functions, Borel and Lebesgue measurability	(12 hours)
Unit - II: Non-measurable sets, integration of non-negative functions, the general integral, integration of series, Reimann and Lebesgue integrals.	(12 hours)
Unit - III: The four derivatives, functions of bounded variation, Lebesgue differentiation theorem, differentiation and integration.	(12 hours)
Unit - IV: The L_p -spaces, Convex functions, Jensen's inequality, Holder and Minkowski inequalities.	(12 hours)
Unit - V: Completeness of L_p -space and its duality, convergence in measure, uniform convergence and almost uniform convergence.	(12 hours)

Learning Outcomes : After completion of this course the students will be able to understand the basic concept of measure and integration, Lebesgue integration Theory, Lebesgue differentiation, L_p -space and some inequalities. Further, they will learn Completeness of L_p -space and convergence in measure and almost uniform convergence.

Essential Readings:

1. Walter Rudin, Principles of Mathematical Analysis, McGraw-Hill, New Delhi International student edition.
2. Inder K. Rana, An introduction to measure and integration, Macmillan, Narosa Publishing House, India.

Suggested Readings and Link :

- 1 G. de Barra. Measure Theory and Integration, Wiley Eastern (Indian Edition).
2. H.L. Royden, Real Analysis, Macmillan, Indian Edition New Delhi.

E book links: National Digital Library

DOCTOR HARISINGH GOUR VISHWAVIDYALAYA, SAGAR
(A Central University)
Department of Mathematics and Statistics
M.A. /M.Sc.- II–Semester (Mathematics)
Core Course -III: Topology-II

MTS CC 223	Topology-II	L	T	P	C
		4	0	0	4
		Max.Marks-100			

Mid Sem-20
Internal assessment-20
End Sem-60

- Objectives:** 1) To teach the concept of compactness and connectedness.
2) To introduce product space.
3) To explain the nets & filters and their convergence.
4) To teach Urysohn metrization Theorem & Tychonoff Embedding Theorem.
5) To explain the concept of the fundamental group.

Unit-I: Compactness. Continuous functions and compact sets. Basic properties of compactness, Compactness and finite intersection property. Sequentially and countably compact sets, Local compactness and one point compactification.	(12 hours)
Unit-II: Stone-Cech compactification, Compactness in metric spaces. Equivalence of compactness, countable compactness and one point compactification, Countable compactness and sequential compactness in metric spaces.	(12 hours)
Unit-III: Connected spaces. Connectedness on the line. Components. Locally connected spaces. Embedding and metrization. Embedding lemma and Tychonoff embedding theorem, The Urysohn metrization theorem. Tychonoff product topology in terms of standard sub-base and its characterizations.	(12 hours)
Unit-IV: Projection maps. Separation axioms and product spaces. Connectedness and product spaces. Compactness and product spaces (Tychonoff's theorem) Countability and product spaces. Net and filters. Topology and convergence of nets. Hausdorffness and nets. Compactness and nets.	(12 hours)
Unit - V: Filters and their convergence. Canonical way of converting nets to filters and vice-versa. Ultra filters and compactness. The fundamental group and covering spaces-Homotopy of paths. The fundamental group. Covering spaces. The fundamental group of the circle & the fundamental theorem of algebra.	(12 hours)

Learning Outcomes: After completion of this course, students will know the definitions of standard terms in topology. The students will be able to know how to read and write the proofs in topology. They will know a variety of examples and counterexamples in topology.

Essential Readings:

1. G.F. Simmons, Introduction to Topology and Modern Analysis, McGraw Hill.
2. K.D. Joshi, Introduction to general Topology, Wiley Eastern.
3. J.L. Kelley, General Topology, Van Nostrand .

Suggested Readings:

1. J.R. Munkres, Topology-A first course, Prentice-Hall of India, New Delhi.

E book links: National Digital Library

DOCTOR HARISINGH GOUR VISHWAVIDYALAYA, SAGAR
(A Central University)

Department of Mathematics and Statistics
M.A. / M.Sc.–II Semester (Mathematics)
Core Course: IV - Complex Analysis II

MTS CC 224	Complex Analysis-II	L	T	P	C
		4	0	0	4
		Max.Marks-100			

Mid Sem-20

Internal assessment-20

End Sem-60

Objectives: (1) Introduce infinite product of complex numbers.
(2) Importance of infinite product for defining Gamma and Zeta functions.
(3) To understand the principal of analytic continuation and its applications.
(4) Factorization theorems of entire functions having infinite zeros.
(5) Idea related to univalent functions and conjecture for complex valued functions.

Unit-I: (12 hours)
Infinite product of complex numbers, Weierstrass factorization theorem, Mittag-Leffer's theorem, Canonical products, Gamma function and its properties, Riemann Zeta function, Jensen's formula.

Unit-II: (12 hours)
Analytic continuation, Uniqueness of direct Analytic continuation, Uniqueness of Analytic continuation along a curve. Power series method of analytic continuation, Monodromy theorem and its consequences.

Unit - III: (12 hours)
Harmonic function on a disc, Harnack's inequality and theorem, Dirichlet problem, Green's function, Hadamard's three circles theorem, Riemann's functional equation, Runge's theorem.

Unit - IV: (12 hours)
Order of an entire function, Exponent of convergence, Borel's theorem, Hadamard's factorization theorem. The range of an analytic function, Bloch's theorem.

Unit - V: (12 hours)
The little Picard theorem, Schottky's theorem, Montel Caratheodary and great Picard theorem, Univalent function, Bieberbach conjecture and the $\frac{1}{4}$ -theorem.

Learning Outcomes: In the end of the course, students will be able to express entire function in the form of canonical products. Also, they knowing about theory related to convergence of infinite product and expression of some well known functions in the form of Infinite products.

Essential Readings:

1. S. Ponnuswamy, Foundations of Complex Analysis, Narosa Publishing House.
2. E.C. Titchmarsh, The Theory of Functions, Oxford University Press.
3. H.A. Priestley, Introduction to Complex Analysis, Oxford University Press

Suggested Readings:

1. L.V. Ahlfors, Complex Analysis, McGraw-Hill
2. J.B. Canvey, Function of one Complex Variable, Springer-Verlag, Narosa Publishing House

E book links: National Digital Library

DOCTOR HARISINGH GOUR VISHWAVIDYALAYA, SAGAR
(A Central University)
Department of Mathematics and Statistics
M.A. /M.Sc.- II–Semester (Mathematics)
Elective Course I- :Mathematical Finance

MTS EC 221	Mathematical Finance	L	T	P	C
		4	0	0	4
		Max.Marks-100			

Mid Sem-20

Internal assessment-20

End Sem-60

- Objectives:** (1) To study random variable and its properties.
(2) To understand Trinomial processes & Brownian motion.
(3) To explain transition Wiener processes & Forward contracts .
(4) To study standard pricing models in the term of Black-Scholes options.
(5) To understand Arbitrage relationship for American options.

Unit-I:	(12 hours)
Probability & conditional probability, Random variables, Expectation and conditional expectation, Variance & Covariance, correlation. Normal random variable and its properties. The central limit theorem.	
Unit-II:	(12 hours)
Stochastic processes in discrete time, Binomial processes, Trinomial processes, General random walks, Geometric random walks. Binomial models with state dependent increments. Brownian motion.	
Unit - III:	(12 hours)
Stochastic integration, Stochastic differential equations. The stock price as a stochastic process. Option pricing, Wiener processes. Derivatives, Forward contracts, spot price, forward price, future price, call & put options.	
Unit - IV:	(12 hours)
Ito's lemma, Black-Scholes options pricing model, Binomial model for European options, Cox-Ross Rubinstein approach.	
Unit - V:	(12 hours)
Pricing contract via arbitrage. The arbitrage theorem. Arbitrage relationship for American options.	

Learning Outcomes : After completion of this course the students will be able to understand the Basic concept of different models and use in daily life, which is necessary to study any higher course in Mathematical Finance.

Essential Readings:

1. Stanley L. S. (2012): A Course on Statistics for Finance, Chapman and Hall/CRC.

Suggested Readings:

1. Franke, J., Hardle, W.K. And Hafner, C.M. (2011): Statistics of Financial Markets: An Introduction, 3rd Edition, Springer Publications.

E book links: National Digital Library

DOCTOR HARISINGH GOUR VISHWAVIDYALAYA, SAGAR
(A Central University)
Department of Mathematics and Statistics
M.A. /M.Sc.- II–Semester (Mathematics)
Elective Course -II: Advanced Numerical Methods-II

MTS EC 222	Advanced Numerical Methods-II	L	T	P	C
		4	0	0	4
		Max.Marks-100			

Mid Sem-20

Internal assessment-20

End Sem-60

Note: In this paper a non programmable scientific calculator is allowed in the examination.

- Objectives:**
- 1) To teach least square approximation, Rational function (Pade) approximation.
 - 2) To introduce various method for numerical integration, Gaussian quadrature.
 - 3) To introduce the numerical techniques for initial value problems.
 - 4) To teach concept of stability, multistep methods.
 - 5) To explain the numerical solution of BVP, finite difference method.

Unit - I:	(12 hours)
Least squares approximation, orthogonal polynomials, Chebyshev polynomials and economization of power series, Rational function approximation, Gram Schmidt orthogonalization procedure and least square. Trigonometric polynomial approximation, Fast Fourier transforms.	
Unit - II:	(12 hours)
Numerical Integration, Newton-Cotes formulae, construction of Gaussian quadrature formulae, error estimates, Radau and Lobatto quadrature rules, Gauss-Legendre, Gauss-Chebyshev formulas, Gauss Legendre, Gauss Hermite and Spline integration – Integration over rectangular and general quadrilateral areas and multiple integration with variable limits. Extrapolation methods and their applications.	
Unit - III:	(12 hours)
Numerical solution of ordinary differential equations: Initial value problems- Picard's and Taylor series methods – Euler's Method- Higher order Taylor methods - Modified Euler's method – Runge-Kutta methods of second and fourth order.	
Unit - IV:	(12 hours)
Stability and convergence of single step method, absolute stability, A-stability, B-stability. Region of absolute stability of explicit and implicit Runge-Kutta methods. Multistep method, the Adams-Moulton method, stability (Convergence and Truncation error for the above methods).	
Unit - V:	(12 hours)
Boundary - Value problems, Second order finite difference and cubic spline methods. Numerical solution of partial differential equations, Basic concept of finite element method, weak formulation of BVP, Ritz Method.	

Learning Outcomes: After completion of this course, students will learn the several numerical techniques for the numerical integration, IVP and BVP. The students can use these techniques in his/her further studies. They will know a variety of numerical examples, stability analysis of numerical method.

Essential Readings:

1. M.K. Jain: Numerical solution of differential equations, Wiley Eastern, 2nd Ed. 1979.
2. S.C. Chapra and P.C. Raymond: Numerical Methods for Engineers, Tata McGraw Hill, New Delhi

Suggested Readings:

1. M. K. Jain, S. R. K. Iyengar and R.K. Jain: Numerical methods for scientific and engineering computation, Wiley Eastern Ltd. Third Edition, 1993.
2. S.S. Sastry: Introductory methods of Numerical analysis, Prentice - Hall of India, New Delhi, 1998
3. C.F. Gerald and P.O. Wheatley : Applied Numerical Methods, Low- priced edition, Pearson Education Asia, Sixth Edition, 2002

E book links:

1. https://ndl.iitkgp.ac.in/document/7a0yOeBMxyS3OyIpsFkf9Of1-73MD_O7QpPk0kthj-Oq0WmDzZ4VYmCOTLMHpGS
2. <https://ndl.iitkgp.ac.in/document/BrI6RXE1Y2VDVtRfjDDFsUw8IouqqRG4Vyl33RSRmeLF-JegaVYqlluZVfCwQVq>

DOCTOR HARISINGH GOUR VISHWAVIDYALAYA, SAGAR
(A Central University)
Department of Mathematics and Statistics
M.A. /M.Sc.- II–Semester (Mathematics)
Open Elective -I: Elementary Mathematics

MTS OE 221	Elementary Mathematics	L	T	P	C
		2	0	0	2
		Max. Marks-100			

Mid Sem-20

Internal assessment-20

End Sem-60

- Objectives:** 1) To teach the concept of differentiation & integration.
2) To introduce homogeneous and linear differential equations.
3) To explain the background of integral and differential calculus.
4) To teach the formulae based on differentiation & integration.
5) To explain the integration by parts & by substitution.

Unit I : Historical background of integral and differential calculus. Differential coefficients of algebraic, logarithmic, exponential and trigonometric functions.	(6 hours)
Unit II : Derivatives of sum, difference, product and quotient of functions and function of a function.	(6 hours)
Unit III: Ordinary differential equations. Homogeneous differential equations and equations reducible to homogeneous form.	(6 hours)
Unit IV: Differential equations of first order but not of first degree. Clairaut's differential equation. Linear differential equations and equations reducible to linear form.	(6 hours)
Unit V: Integration as the inverse of differentiation. Integration of functions by parts and by substitution methods.	(6 hours)

Learning Outcomes: After completion of this course, students will be able to know how to do the differentiation and integration of functions. They will know how to use and apply these formulae in their respective work.

Essential Readings:

1. M.D. Raishnghaniya, Ordinary and partial differential equations, S. Chand Publication.

Suggested Readings:

1. Gorakh Prasad, Differential Calculus, Pothishala Prakashan Pvt, Ltd., Allahabad.
2. Gorakh Prasad, Integral Calculus, Pothishala Prakashan Pvt, Ltd., Allahabad.

E book links: National Digital Library

DOCTOR HARISINGH GOUR VISHWAVIDYALAYA, SAGAR
(A Central University)
Department of Mathematics and Statistics
M.A. /M.Sc.- III–Semester (Mathematics)
Core Course: I- Functional Analysis

MTS CC 321	Functional Analysis	L	T	P	C
		4	0	0	4
		Max.Marks-100			

Mid Sem-20
Internal assessment-20
End Sem-60

- Objectives:** (1) To inculcate the basic features of normed spaces.
(2) To teach basic properties of finite dimensional spaces.
(3) To acquainted with four pillars of Functional Analysis.
(4) To study Hilbert space theory.
(5) To teach reflexivity of Hilbert space and various operators.

Unit-I: Normed linear spaces, Banach spaces and examples, Quotient space of normed linear space and its completeness, equivalent norms, Riesz Lemma, basic properties of finite dimensional normed linear spaces and compactness.	(12 hours)
Unit - II: Weak convergence and bounded linear transformations, normed linear spaces of bounded linear transformations, dual spaces with examples and reflexive spaces.	(12 hours)
Unit - III: Uniform boundedness theorem and some of its consequences, open mapping and closed graph theorems, Hahn-Banach theorem for real linear spaces and complex linear spaces.	(12 hours)
Unit - IV: Inner product spaces: Hilbert spaces, Orthonormal Sets, Bessel's inequality, complete orthonormal sets and Parseval's identity, structure of Hilbert spaces.	(12 hours)
Unit-V: Reflexivity of Hilbert spaces, Projection theorem, Riesz representation theorem, adjoint of an operator on a Hilbert space, self-Adjoint operators, positive, compact operators, normal and unitary operators.	(12 hours)

Learning Outcomes: After completion of this course the students will be able to understand the basic theory of normed linear spaces and properties of finite dimensional spaces. They will learn four pillars of the subject: uniform boundedness, open mapping theorem, closed graph theorems and Hahn-Banach theorem. They will also learn a detailed theory of Hilbert spaces and operators acting on it.

Essential Readings:

- 1.B. Choudhary and Sudarsan Nanda. Functional Analysis with applications, Wiley Eastern Ltd.
2. Walter Rudin, Functional analysis, TMH Edition, 1974
3. A.E Taylor, Introduction to Functional Analysis, John Wiley & sons, New York, 1978.
4. A.H. Siddiqui, Functional Analysis with applications, TMH Publication Company Ltd., New Delhi.
5. B.K. Lahiri, Elements of functional Analysis, The World Press, Calcutta, 1994

Suggested Readings:

1. G.F. Simmons, Introduction to Topology & Modern Analysis, Mc Graw Hill, New York, 1963.
2. E. Kreyszig, Introductory Functional Analysis with applications, John Wiley & Sons, New York, 1978 .

E book links: National Digital Library

DOCTOR HARISINGH GOUR VISHWAVIDYALAYA, SAGAR

(A Central University)

Department of Mathematics and Statistics

M.A. / M.Sc. (Mathematics)–III Semester

Core Course: II- Integral Equations and boundary value problems-I

MTS CC 322	Integral Equations and boundary value problems-I	L	T	P	C
		4	0	0	4
		Max. Marks-100			

Mid Sem-20

Internal assessment-20

End Sem-60

- Objectives:** (1) To study existence and uniqueness of the solution of the ODE.
(2) To understand Sturm Liouville BVP & Singular Sturm Liouville BVP.
(3) To explain converting Volterra Integral equation to an ODE.
(4) To study Abel's problem and classification of integral equations.
(5) To understand the Adomian Decomposition Method.

Unit - I: Initial value problem for ODEs, methods of existence and uniqueness of the solution of the ordinary differential equation of the first order and their examples.	(12 hours)
Unit-II: Two point Boundary Value Problems, Sturm Liouville BVP, Non-homogeneous BVP, Singular Sturm Liouville BVP.	(12 hours)
Unit-III: Classification of Linear integral Equations, solution of an integral equation, converting Volterra Integral equation to an ODE, converting IVP to Volterra Integral Equations.	(12 hours)
Unit - IV: Classification of non linear integral equations, Singular Integral equations, Abel's problem, the generalized Abel's Integral Equation.	(12 hours)
Unit - V: Fredholm Integral equations, the Adomian decomposition method, the Variational Iteration method, the direct computation method, the successive approximations method.	(12 hours)

Learning Outcomes : After completion of this course the students will be able to understand the basic ideas of Ordinary Differential Equations & Boundary Value Problems, which is necessary to study higher course to solve the models.

Essential Readings:

1. V. I. Smirnov A course of higher Mathematics, Vol.IV, (Translation), Pergamon Press, Oxford.
2. C. Corduneanu, Integral equations & Applications, Cambridge University Press, Cambridge.
3. B.P. Parashar, Differential & Integral Equations, CBS Publishers & Distribution, Delhi.

Suggested Readings:

1. A-M Wazwaz, A first course in Integral Equations, World Scientific Singapore.
2. S.G. Mikhlin, Integral equations, (Vol 4) (Translation), Pergamon Press, London.
3. L. G. chambers, Integral equations- A short course International Suggested Books company East Kilbridge, Scotland.

E book links: National Digital Library

DOCTOR HARISINGH GOUR VISHWAVIDYALAYA, SAGAR
(A Central University)
Department of Mathematics and Statistics
M.A. / M.Sc. (Mathematics)–III Semester
Core Course: III- Mathematical Biology - I

MTS CC 323	Mathematical Biology - I	L	T	P	C
		4	0	0	4
		Max. Marks-100			

Mid Sem-20

Internal assessment-20

End Sem-60

- Objectives:**
- (1) To learn about the concept of analytical theory of stability.
 - (2) To understand the mathematical modelling of single species population models.
 - (3) To study the interacting species models.
 - (4) To study the interacting species models with time delay and stage-structure.
 - (5) To deal with the discrete population model.

Unit-I:	(12 hours)
Mathematical Modelling, basics of Mathematical Biology, equilibrium point, phase plane methods and qualitative solutions, asymptotic stability, concept of limit cycle, non-existence of limit cycle, Origin of bifurcation, type of bifurcations.	
Unit-II: :	(12 hours)
Continuous population models for single species: Malthus growth model, logistic growth model, delay model, age-structure model, harvesting model.	
Unit-III:	(12 hours)
Continuous population model for interacting species: prey-predator, competition, mutualism models.	
Unit-IV:	(12 hours)
Three species food chain and food web models, interacting species models with response function, delay and stage structure.	
Unit -V:	(12 hours)
Discrete population models: density dependence single species populations, Delay model for single species, Fishery Management Model, Host-parasitoid system, Nicholson-Bailey model, plant-herbivore interaction model.	

Learning Outcomes: After completion of this course the students will be able develop a mathematical model for a realistic ecological problem and they will also be able to solve it analytically as well as numerically.

Essential Readings:

1. L.E. Keshet, Mathematical Models in Biology, SIAM, 1988.
2. H.I. Freedman, Deterministic Mathematical models in Population Ecology, Marcel Dekker Inc., New York, 1980.

Suggested Readings and Links:

1. D.K. Arrowosmith, Introduction to Dynamical Systems, Cambridge University Press, 1990.
2. J.D. Murray, Mathematical Biology: I. An Introduction, Springer-Verlag, 2002.

E Books : National Digital Library

DOCTOR HARISINGH GOUR VISHWAVIDYALAYA, SAGAR
(A Central University)
Department of Mathematics and Statistics
M.A. / M.Sc. (Mathematics)–III Semester
Core Course: IV- Operations Research –I

MTS CC 324	Operations Research –I	L	T	P	C
		4	0	0	4
		Max. Marks-100			

Mid Sem-20

Internal assessment-20

End Sem-60

- Objectives:**
- (1) To introduce the scope of operations research and formulation of LPP.
 - (2) To obtain the solution of LPP by Simplex method.
 - (3) To introduce Gomory's cutting plane method.
 - (4) To find the initial basic feasible solution of a transportation problem.
 - (5) To introduce the concept of shortest path in Network analysis.

Unit-I:	(12 hours)
Operations Research and its scope. Necessity of Operations Research in Industry, Linear Programming-Simplex method.	
Unit-II:	(12 hours)
Convex sets, theory of the Simplex method, revised simplex method, Two-Phase simplex method. Big-M method, duality and dual simplex method and sensitivity analysis.	
Unit-III:	(12 hours)
Integer linear programming: Pure and mixed, Gomory's cutting plane method, branch and bound method.	
Unit- IV:	(12 hours)
Transportation problem-initial basic feasible solution, Initial Basic Feasible Solution by North-West Corner Method, Matrix minima method and Vogel's approximation method. Optimal solution, degeneracy in transportation problems. Assignment Problems: Hungarian Method for solution. Crew based problems, Traveling-Salesman (Routing) problems.	
Unit- V:	(12 hours)
Network analysis. Shortest path problems, minimum spanning tree problems, Critical path method, Project evaluation and review technique.	

Learning Outcomes: After completion of this course/paper students will able to formulate and find solution of Linear Programming Problem, Transportation problem and project evaluations. Also, they may able to find the shortest path of any network related problem in their daily-life.

Essential Readings:

1. H.A. Taha, Operations Research-An Introduction, Macmillan Publishing INC., New- York.
2. F. S. Hillier & G.J. Lieberman, Introduction to Operations Research (sixth-edition), McGraw Hill International Edition.
3. Kanti Swarup, P.K. Gupta & Man Mohan, Operations Research., Sultan Chand & sons, New Delhi.
4. S.D. Sharma, Operations Research, Kedar Nath Ram Sons & co. Publisher Meerut (thirteenth-edition) 2001.
5. J.C. Pant, Operations Research and optimization, Jain publisher (7th edition).

Suggested Readings and Link:

1. Video lecture on Introduction of Operations Research | Models of Operations Research
https://www.youtube.com/watch?v=PSOW3_gX2OU
2. Video on Simplex method <https://www.youtube.com/watch?v=M8POtpPtQZc>

E Books : National Digital Library

DOCTOR HARISINGH GOUR VISHWAVIDYALAYA, SAGAR
(A Central University)
Department of Mathematics and Statistics
M.A. /M.Sc.–III Semester
Elective Course I: Differential Geometry

MTS EC 321	Differential Geometry	L	T	P	C
		4	0	0	4
		Max.Marks-100			

Mid Sem-20

Internal assessment-20

End Sem-60

- Objectives:** 1) To teach the concept of curves & surfaces.
2) To introduce the first & the second Fundamental Form and the Weingarten Map.
3) To explain the Gaussian and Mean curvatures and isometries of surfaces.
4) To teach famous Gauss's Theorem Egregium.
5) To explain the concept of the exponential map.

Unit-I	(12 hours)
Curves in R^2 and R^3 : Basic Definitions and Examples. Arc Length. Curvature and the Frenet-Serret Apparatus.	
Unit-II	(12 hours)
The Fundamental Existence and Uniqueness Theorem for Curves. Non-Unit Speed Curves. Surfaces in R^3 : Basic Definitions and Examples.	
Unit-III	(12 hours)
The First Fundamental Form. Arc length of curves on surfaces. Normal curvature. Geodesic curvature. Gauss and Weingarten Formulas. Geodesics, Parallel Vector Fields Along a Curve and Parallelism.	
Unit-IV	(12 hours)
The Second Fundamental Form and the Weingarten Map, Principal, Gaussian and Mean curvatures. Isometries of surfaces, Gauss's Theorem Egregium.	
Unit-V	(12 hours)
The Fundamental Theorem of Surfaces, Surfaces of Constant Gaussian Curvature. Exponential map, Gauss Lemma, Geodesic Coordinates. The Gauss-Bonnet Formula and the Gauss-Bonnet Theorem (description only).	

Learning Outcomes: After completion of this course, students will know the definitions of standard terms in differential geometry. The students will be able to know how to read and write the proofs in differential geometry. They will know a variety of examples and counterexamples in differential geometry with application.

Essential Readings:

1. M. P. Do Carmo, Differential geometry of curves and surfaces, Prentice Hall 1976.
2. A. Gray, Differential Geometry of Curves and Surfaces, CRC Press, 1998.
3. John A. Thorpe, Elementary Topics in Differential Geometry, Springer, 1979.

Suggested Readings:

1. B. O.'Neill, Elementary Differential Geometry, Elsevier 2006
2. A. Pressley, Elementary Differential Geometry, Springer 2010.

E book links: National Digital Library

DOCTOR HARISINGH GOUR VISHWAVIDYALAYA, SAGAR
(A Central University)
Department of Mathematics and Statistics
M.A. /M.Sc.- III–Semester (Mathematics)
Elective Course -II: Analytical Number Theory I

MTS EC 322	Analytical Number Theory I	L	T	P	C
		4	0	0	4
		Max.Marks-100			

Mid Sem-20

Internal assessment-20

End Sem-60

- Objectives:**
- 1) To explain the concept of primes, Fermat and Mersenne numbers .
 - 2) To introduce various arithmetic functions, Mobius inversion formula.
 - 3) To explain the Gaussian integers and its properties.
 - 4) To explain the arithmetic in Z_n , The group U_n
 - 5) To explain the solution of Diophantine equations, four square theorem

Unit-I:	(12 hours)
Distribution of primes, Fermat and Mersenne numbers, Farey series and some results concerning Farey series, Approximation of irrational numbers by rationals, Hurwitz theorem, Irrationality of e and π . The series of Fibonacci and Lucas. System of linear congruences, Chinese Remainder Theorem, congruence to prime power modulus.	
Unit-II:	(12 hours)
Arithmetic functions $\phi(n)$, $\tau(n)$, $\sigma(n)$ and $\sigma_k(n)$, $U(n)$, $N(n)$, $I(n)$, Definitions and examples and simple properties, Perfect numbers, Mobius inversion formula, The Mobius function μ_n , The order and average order of the function $\phi(n)$, $\tau(n)$ and $\sigma(n)$.	
Unit-III:	(12 hours)
Algebraic number and Integers : Gaussian integers and its properties. Primes and fundamental theorem in the ring of Gaussian integers. Integers and fundamental theorem in $Q(w)$ where $w^3 = 1$, algebraic fields. Primitive polynomials.	
Unit - IV:	(12 hours)
The arithmetic in Z_n , The group U_n , Primitive roots and their existence, the group U_{p^n} (p -odd) and U_{2^n} , The group of quadratic residues Q_n , Quadratic residues for prime power moduli and arbitrary moduli, The algebraic structure of U_n and Q_n .	
Unit-V:	(12 hours)
Diophantine equations $ax + by = c$, $x^2 + y^2 = z^2$ and $x^4 + y^4 = z^4$, The representation of number by two or four squares, Waring problem, Four square theorem, The numbers $g(k)$ & $G(k)$, Lower bounds for $g(k)$ & $G(k)$.	

Learning Outcomes: After completion of this course, students will learn tools of prime number theory. They will know the definitions of several arithmetic functions and also learn how to solve number theory problems through the use of arithmetic functions. They can also learn to solve the Diophantine equations. They can also deal the number theory problems through Mobius inversion formula and Mobius function μ_n .

Essential Readings:

1. G.H. Hardy and E.M. Wright, An Introduction to the Theory of Numbers.
2. D.M. Burton, Elementary Number Theory.
3. N.H. McCoy, The Theory of Number by McMillan.
4. A. Gareth Jones and J Mary Jones, Elementary Number Theory, Springer Ed. 1998.

Suggested Readings:

1. T.M. Apostol, Introduction to Analytic Number Theory, Narosa Publication House, 1980.
2. I. Niven, I. and H.S. Zuckermann, An Introduction to the Theory of Numbers.

E book links:

1. https://ndl.iitkgp.ac.in/document/-D1QeBZqWkFT4bJbpPDpQwQjPXW4wH4qIQzHIQla_oS5cYKclKOnuSbQKoNrubuU
2. https://ndl.iitkgp.ac.in/document/rTOPVQVfa3n_skskbCDCfSXkfNbpz0r9c-nLWs5Q10c9OI1-wDvsGjP2t34qFddE
3. [https://ndl.iitkgp.ac.in/result?q={%22t%22:%22search%22,%22k%22:%22Elementary%20Number%20Theory%22,%22s%22:\[\],%22b%22:%22filters%22:\[\]}}](https://ndl.iitkgp.ac.in/result?q={%22t%22:%22search%22,%22k%22:%22Elementary%20Number%20Theory%22,%22s%22:[],%22b%22:%22filters%22:[]}})

DOCTOR HARISINGH GOUR VISHWAVIDYALAYA, SAGAR
(A Central University)
Department of Mathematics and Statistics
M.A. / M.Sc.–III Semester
Elective Course III- : Advanced Discrete Mathematics-I

MTS EC 323	Advanced Discrete Mathematics-I	L	T	P	C
		4	0	0	4
		Max.Marks-100			

Mid Sem-20
Internal assessment-20
End Sem-60

Objectives: (1) To understand Semigroups and Monoids.
(2) To study Basic homomorphism theorem and Boolean algebra
(3) To explore Boolean forms and their equivalence.
(4) To apply Boolean algebra to switching theory.
(5) To study Graph theory and Matrix representation of graphs.

Unit - I: Semigroups & monoids, definition and examples of semi groups and monoids (including those pertaining to concatenation operation). Homomorphism of Semigroups and monoids. Congruence relation and quotient semigroups. Sub semi group and sub monoids.	(12 hours)
Unit - II: Direct products. Basic homomorphism theorem. Lattices-lattices as partially ordered sets. Their properties. Lattices as Algebraic systems. Sub lattices such as Complete, Complemented and Distributive Lattices. Boolean algebras- Boolean algebra as lattices. Various Boolean identities.	(12 hours)
Unit - III: The switching algebra examples, sub algebras, direct products and homomorphisms, join-irreducible elements, atoms and minterms. Boolean forms and their equivalence, minterms.	(12 hours)
Unit - IV: : Boolean forms, sum of products canonical forms, minimization of Boolean functions. Applications of Boolean algebra to switching theory (using AND, OR, NOT gates), The Karnaugh map method.	(12 hours)
Unit - V: : Graph theory-definition of graphs, paths, circuits, cycles, &sub graphs, induced subgraphs, degree of a vertex. Connectivity. Planer graphs and their properties. Trees, Euler's formula for connected planer graphs. Complete bipartite graphs. Kuratowski's theorem (statement only). Minimal spanning trees and Kruskal's algorithm. Matrix representation of graphs.	(12 hours)

Learning Outcomes: After studying the syllabus the student will be able to understand basics of Boolean algebra and Graph theory.

Essential Readings :

1. J.P.Tremblay & R.Manobar, Discrete Mathematical Structures, McGraw Hill, New Delhi.
- 2.Narsingh Deo, Graph Theory with applications, Prentice-Hall, New Delhi.

Suggested Readings :

1. C.L.Liu, Elements of Discrete Mathematics, McGraw Hill, New Delhi.
2. J.L.Gresting, Mathematical Structures for Computer Science, Computer Science Press, New York.

E book links: National Digital Library

DOCTOR HARISINGH GOUR VISHWAVIDYALAYA, SAGAR
(A Central University)
Department of Mathematics and Statistics
M.A. / M.Sc.–III Semester
Open Elective : Elementary Statistics

MTS OE 321	Elementary Statistics	L	T	P	C
		2	0	0	2
		Max. Marks-100			

Mid Sem-20

Internal assessment-20

End Sem-60

Objectives: (1) To study Correlation and Distributions.
(2) To explain the characteristics of various distributions.
(3) To learn testing of hypothesis.
(4) To study, type-I and type-II error.
(5) to perform analysis of variance.

Unit I :	(6 hours)
Karl Pearson's and Rank correlation coefficients, concept of probability distribution.	
Unit II :	(6 hours)
Binomial, Poisson's and normal distributions and their characteristics	
Unit III :	(6 hours)
Basics of testing of hypothesis- null and alternative hypothesis, level of significance	
Unit IV :	(6 hours)
Degrees of freedom, critical region, type-I and type-II error, χ^2 – test, t-test and F-test.	
Unit V :	(6 hours)
Regression, curve fitting. One way analysis of variance, Theory of index numbers.	

Learning Outcomes : After completion of this course the students will be able to understand basics of probability distributions, Curve fitting and testing of hypothesis.

Essential Readings:

1. S.C. Gupta & V.K. Kapoor: Fundamentals of Applied Statistics, Sultan Chand & Co.

Suggested Readings and Link :

1. S.C. Gupta & V.K. Kapoor: Fundamentals of Mathematical Statistics, Sultan Chand & Co.
2. Goon, Gupta & Das Gupta : Fundamentals of Statistics Vol. -1 & 2 , Worlds Press, Kolkata.

E book links: National Digital Library

DOCTOR HARISINGH GOUR VISHWAVIDYALAYA, SAGAR
(A Central University)
Department of Mathematics and Statistics
M.A. /M.Sc. - IV–Semester (Mathematics)
Core Course: I- Integration theory

MTS CC 421	Integration theory	L	T	P	C
		4	0	0	4
		Max. Marks-100			

Mid Sem-20

Internal assessment-20

End Sem-60

- Objectives:** (1) To inculcate the basic features of Abstract measures.
(2) To teach Abstract integration Theory.
(3) To acquainted with RNT and Riesz Representation Theorem.
(4) To introduce interplay between measure and Topology.
(5) To teach Regularity of measures on LCT, Riesz- Markov theorem.

Unit–I: General measures. Examples. Semifinite and σ -finite measures. Measurable functions. Signed measures, Hahn decomposition theorem. Mutually singular measures, Jordon decomposition theorem.	(12 hours)
Unit–II: Radon-Nikodym theorem. Lebesgue decomposition theorem. The L^p spaces and Riesz representation theorem.	(12 hours)
Unit–III: Outer measure and measurability. Caratheodory extension theorem. The Lebesgue-Stieltjes integral. Product measures. Fubini's theorem.	(12 hours)
Unit–IV: Baire sets and Borel sets, Baire measure and Borel measure, the regularity of Baire and Borel Measure.	(12 hours)
Unit–V: The construction of Borel Measure. Regularity of measures on locally compact spaces. Riesz-Markov theorem.	(12 hours)

Learning Outcomes: After completion of this course the students will be able to understand the abstract concept of measure and integration, the famous Radon –Nikodym Theorem, Riesz representation theorem, The Lebesgue-Stieltjes integral. Fubini's theorem. Further, they will learn advanced topics of measure theoretic integration in topological spaces.

Essential Readings:

1. P.R. Halmos, Measure theory, Von-Nostrand.
2. I.K. Rana, Introduction to measure and integration, Narosa Publishing House, New Delhi.

Suggested Readings and Link:

1. H.L. Royden, Real Analysis, Macmillan Publishing House

E book links: National Digital Library

DOCTOR HARISINGH GOUR VISHWAVIDYALAYA, SAGAR
(A Central University)
Department of Mathematics and Statistics
M.A. /M.Sc. - IV–Semester (Mathematics)
Core Course: II -Integral Equations and Its Applications

MTS CC 422	Integral Equations and Boundary value problems-II	L	T	P	C
		4	0	0	4
		Max. Marks-100			

Mid Sem-20
Internal assessment-20
End Sem-60

Objectives: (1) To inculcate the basic features of Integral equations.
(2) To teach Fredholm alternative theorem.
(3) To explain use of Gauss and Legendre differential equations.
(4) To introduce Hilbert-Schmidt theory.
(5) To introduce properties of Green's function and its construction .

Unit-I:	(12 hours)
Eigen values and Eigen functions. Fredholm Integral equations of second kind with Separable Kernels. Iterated kernels, Resolvent kernels.	
Unit-II:	(12 hours)
Volterra integral equation of the second kind, Fredholm alternative theorem, Fredholm integral equation of first kind. Volterra integral equation of first kind.	
Unit-III:	(12 hours)
Gauss differential equations, Legendre differential equations, Bessel's differential equations.	
Unit-IV:	(12 hours)
Hilbert-Schmidt theory, Orthogonality and orthonormality of Eigen-functions, Bessel's inequality, Hilbert Schmidt's expansion theorem.	
Unit-V:	(12 hours)
Green's function, properties of Green's function and its construction. Application of Green's function to Solving BVP involving ODE .	

Learning Outcomes: After completion of this course, students will able to classify the Integral equations. Also, they will comprehend Hilbert Schmidt's expansion theorem, Hilbert-Schmidt theory and Green's function with applications.

Essential Readings:

1. Integral equations; (Vol. 4) (Translation), S.G. Mikhlin, Pergamon Press London.
2. Integral equations- A short course, L. G. chambers International Suggested Books Compan East kilbridge, Scotland.
3. A course of higher Mathematics, Vol.IV, (Translation); V. I. Smirnov, Pergmon Press, Oxford,(chapter I: .Integral equations, chapter IV: Boundary value Problems).
4. Integral equations & Applications, C. Corduneanu, Cambridge University Press, Cambridge.
5. Differential & Integral Equations; BP Parashar, CBS Publishers & Distribution, Sahdara, Delhi.

Suggested Readings:

1. Lectures on Differential & Integral equations; Vol. X, Kosaku Yosida, Innterscience Publishers London1960.
2. Integral Equations and Boundary Value Problems:, M.D. Raisinghanian, S.Chand Publications, New Delhi.

E book links: National Digital Library

DOCTOR HARISINGH GOUR VISHWAVIDYALAYA, SAGAR
(A Central University)
Department of Mathematics and Statistics
M.A. / M.Sc. – IV Semester
Core Course – III : Mathematical Biology – II

MTS CC 423	Mathematical Biology – II	L	T	P	C
		3	0	1	4
		Max. Marks-100			

Mid Sem-20
Internal assessment-20
End Sem-60

- Objectives:**
- (1) To understand the concept of modeling of viral infection.
 - (2) To study the basic epidemic model with latent period and time delay.
 - (3) To find the dynamics of vector-borne disease model.
 - (4) To understand the optimal control strategies.
 - (5) To learn about impulsive differential equations and their applications in epidemics.

Unit-I:	(12 hours)
Historical aspect of epidemics. Model without demography: SI, SIS and Kermack-Mckendrick SIR epidemic models. Basic Reproduction Number, SIR model with demography. Eco-epidemic models.	
Unit-II:	(12 hours)
SIS, SIR epidemic models with saturating incidence and treatment, epidemic models with latent period, time delay. vector-borne disease models.	
Unit-III:	(12 hours)
Delay differential equation model of vector-borne disease, vector-borne disease model with temporal immunity, global stability of epidemic models using Liapunov functions.	
Unit-IV:	(12 hours)
Modeling for control strategies, basic theory of optimal control strategies, Pontryagin's maximum principle.	
Unit-V:	(12 hours)
Basic theory of impulsive differential equations, SIR, SIS, SIRS epidemic models with pulse vaccination, eco-epidemic pest control models with impulse.	

Learning Outcomes: After completion of this course the students will be able to find the dynamics of infection disease model using mathematical techniques and understand the transmission of the disease.

Essential Readings:

1. V. Lakshmikanthan, D.D. Bainov and P.S. Simeonov, Theory of Impulsive differential equations, World Scientific Press, 1989.
2. Z. Ma and J. Li, Dynamical Modeling and Analysis of Epidemics, World Scientific, 2009.

Suggested Readings :

1. J.D. Murray, Mathematical Biology: I. An Introduction, Springer-Verlag, 2002.
2. Maia Martcheva, An Introduction to Mathematical Epidemiology, Springer, 2015.
3. L.E. Keshet, Mathematical Models in Biology, SIAM, 1988.

E book links: National Digital Library

DOCTOR HARISINGH GOUR VISHWAVIDYALAYA, SAGAR
(A Central University)
Department of Mathematics and Statistics
M.A. /M.Sc.- IV–Semester (Mathematics)
Core Course –IV: Operations Research –II

MTS CC 424	Operations Research –II	L	T	P	C
		4	0	0	4
		Max. Marks-100			

Mid Sem-20

Internal assessment-20

End Sem-60

Objectives:

- (1) To understand the concept of game theory and finding graphical solution of LPP.
- (2) To obtain the Steady-state solutions of Markovian queuing models.
- (3) To understand the EOQ Models with constant demand rate.
- (4) Evaluate the computational performance unconstrained and constrained problems, optimization and learning algorithms.
- (5) Evaluate Minimum path problems on single additive constraints and multiplicative constraints and learning algorithms to real world problems.

Unit-I:	(12 hours)
Games Theory, Two person zero-sum game, game with mixed Strategies. Principle of dominance, rectangular game. Graphical solution by linear programming.	
Unit-II:	(12 hours)
Elementary queuing models. Steady-state solutions of Markovian queuing models: M/M/1, M/M/1 with limited waiting space, Queuing models M/M/C.	
Unit-III:	(12 hours)
Inventory models, Economic order quantity models with constant rate of demand. Production lot size model with shortage. Buffer stock. Production planning and inventory control.	
Unit-IV:	(12 hours)
Classical Optimization: Unconstrained problem of maxima and minima (necessary & sufficient condition). Kuhn-Tucker conditions for constrained problem, Wolfe method for quadratic programming problem.	
Unit-V:	(12 hours)
Dynamic programming: Minimum path problems, problems on single additive constraints, additive separable return, single multiplicative constraints and additive separable return.	

Learning Outcomes: Queuing theory has broad applications in computer operating and to find business strategies. Thus, after completion of the course, students able to solve problems based on Queuing theory. Also, they may be aware problems occurring in inventory management.

Essential Readings:

1. H.A. Taha, Operations Research- An Introduction, Macmillan publishing INC., New- York.
2. F. S. Hillier & G.J. Lieberman, Introduction to Operations Research, (sixth- edition). McGraw Hill International Edition
3. S.D. Sharma, Operations Research, Kedar Nath Ram Sons co. Publisher Meeru thirteenth- edition) 2001.
4. Kanti Swarup, P.K. Gupta & Man Mohan, Operations Research, Sultan Chand & sons, New Delhi.

Suggested Readings and Link:

1. Video on Game Theory in Operation research USING mini max principle, odds method, dominance method <https://www.youtube.com/watch?v=LV7TLjIFBYy>

E book links: National Digital Library

DOCTOR HARISINGH GOUR VISHWAVIDYALAYA, SAGAR
(A Central University)
Department of Mathematics and Statistics
M.A. / M.Sc. (Mathematics)–IV Semester
Elective Course I: MATLAB and Dynamical Systems

MTS EC 421	MATLAB and Dynamical Systems	L	T	P	C
		3	0	1	4
		Max. Marks-100			

Mid Sem-20

Internal assessment-20

End Sem-60

- Objectives:**
- (1) To understand the concept of basics of MATLAB.
 - (2) To learn about operator and decision-making construct.
 - (3) To develop the user defined function.
 - (4) To learn about input/output through file.
 - (5) To discuss the application of MATLAB in Dynamical Systems.

Unit-I:	(12 hours)
Introduction to MATLAB, MATLAB environment, variables and arrays, scalar and array operations, displaying output data, introduction to plotting, additional features of plotting, two and three dimensional plots.	
Unit-II:	(12 hours)
Arithmetic operators, relational operators, logical operators, branching statements, if construct, if else construct, switch construct.	
Unit-III:	(12 hours)
While loop, for loop, nesting loops, User defined functions, string functions, cell arrays, structure arrays, function handles.	
Unit-IV:	(12 hours)
Input/output functions, file opening and closing, binary I/O functions, formatted I/O functions.	
Unit-V:	(12 hours)
Dynamical systems with MATLAB: Differential equations, planner systems, interacting species, limit cycles, Hamiltonian systems, Liapunov functions, stability, bifurcation theory.	

Learning Outcomes: After completion of this course the students will be able to use Mathematical software MATLAB to develop their own user defined functions for any problems. They can also use MATLAB to solve the complex dynamical systems.

Essential Books:

1. D.K. Arrowosmith, Introduction to Dynamical Systems, Cambridge University Press, 1990.
2. Stephen Lynch, Dynamical Systems with applications using MATLAB, Springer, 2004.

Suggested Readings and Links:

1. Stephen J. Chapman, MATLAB Programming for Engineers, 4th edition, Thomson Learning, 2007.
2. Rudra Pratap, Getting started with MATLAB 7, oxford university Press, 2009.

E book links: National Digital Library

DOCTOR HARISINGH GOUR VISHWAVIDYALAYA, SAGAR
(A Central University)
Department of Mathematics and Statistics
M.A. /M.Sc.- IV–Semester (Mathematics)
Elective Course -II: Analytical Number Theory II

MTS EC 422	Analytical Number Theory II	L	T	P	C
		4	0	0	4
		Max.Marks-100			

Mid Sem-20

Internal assessment-20

End Sem-60

- Objectives:**
- 1) To explain the Riemann Zeta Function and convergence.
 - 2) To introduce Dirichlet series, L-series as analytic function and its derivative.
 - 3) To explain the Gaussian integers and its properties.
 - 4) To introduce basics of Modular forms , Congruences Residue classes.
 - 5) To explain the solution of Diophantine equations, four square theorem.

Unit - I:	(12 hours)
Riemann Zeta Function $\zeta(s)$ and its convergence, Application to prime numbers, $\zeta(s)$ as Euler product, Evaluation of $\zeta(2)$ and $\zeta(2k)$, Functional equation for Zeta function.	
Unit - II:	(12 hours)
Dirichlet series with simple properties, arithmetic functions, Dirichlet characters and Dirichlet L-series as analytic function and its derivative. Nonvanishing of L- series on the real line, $\text{Re}(S)=0$, Eulers products.	
Unit-III:	(12 hours)
Functional equations for Dirichlet's L – functions, Error bounds in the prime number theorem; the Riemann hypothesis, Zeroes of zeta in the critical strip; a zero-free region, A zero-free region; von Mangoldt's formula.	
Unit-IV:	(12 hours)
Introduction to Modular forms: Congruences Residue classes and complete residue system. Linear congruences. Reduced residue system and the Euler-Fermat theorem. Polynomials congruences modulo p, lagrange's theorem. Simultaneous linear congruences, The Chinese remainder theorem, Application of Chinese remainder theorem. Polynomial congruences with prime power modulli.	
Unit-V:	(12 hours)
The Bell series of arithmetical functions. Bell series and Dirichlev multiplication. Derivative of arithmetical functions. Euler's summation formula, Estimates for sums of Divisors, Estimate for the Number of Divisors, Highly composite Numbers. The average order of $d(n)$ The average order of the divisor functions (n) . the average order of Euler's totient. The partial sums of a Dirichlet product. Multiplicatively perfect number numbers and super Perfect numbers.	

Learning Outcomes: After completion of this course, students will learn the important applications of Riemann Zeta functions towards number theory. The students can also learn use of L-series in numbers theory. The key outcome is to make capable students to teach the tools of number theory. They will know a variety of examples in number theory and derivation of several theorems in number theory.

Essential Readings:

1. G.H. Hardy and E.M. Wright, An Introduction to the Theory of Numbers.
2. D.M. Burton, Elementary Number Theory.
3. N.H. McCoy, The Theory of Number by McMillan.
4. A. Gareth Jones and J Mary Jones, Elementary Number Theory, Springer Ed. 1998.

Suggested Readings:

1. T.M. Apostol, Introduction to Analytic Number Theory, Narosa Publication House, 1980.
2. I. Niven, I. and H.S. Zuckermann, An Introduction to the Theory of Numbers.

E book links:

1. https://ndl.iitkgp.ac.in/document/-D1QeBZqWkFT4bJbpPDpQwQjPXW4wH4qlQzHIQIa_oS5cYKcIkOnuSbQKoNruboU
2. https://ndl.iitkgp.ac.in/document/rTOPVQVfa3n_skskbCDCfSXkfNbpbz0r9c-nLWs5Q10c9O11-wDvsGjP2t34qFddE

DOCTOR HARISINGH GOUR VISHWAVIDYALAYA, SAGAR
(A Central University)
Department of Mathematics and Statistics
M.A. / M.Sc.–IV Semester

Elective Course III - : Advanced Discrete Mathematics-II

MTS EC 423	Advanced Discrete Mathematics-II	L	T	P	C
		4	0	0	4
		Max.Marks-100			

Mid Sem-20

Internal assessment-20

End Sem-60

- Objectives:** (1) To understand the basics of Directed and Weighted Graphs.
(2) To be able to comprehend Equivalence of finite state machines.
(3) To learn Grammers and Languages.
(4) To study Language generated by a grammer.
(5) To learn The reverse polish notation.

Unit - I: Directed graphs, indegree and outdegree of a vertex. Weighted undirected graphs. Dijkstra's algorithm, strong connectivity and Warshall's algorithm directed trees, search trees, tree traversals.	(12 hours)
Unit - II: Introductory computability theory-finite state machines and their transition table diagrams. Equivalence of finite state machines. Reduced machines. Homomorphism. Finite automata. Acceptors.	(12 hours)
Unit - III: Non-deterministic finite automata and equivalence of its power to that of deterministic finite automata. Moore and Mealy machines. Turing machine and partial recursive functions. Grammers and Languages-phrase-structure grammars.	(12 hours)
Unit - IV: Rewriting rules. Derivations. Sentential forms. Language generated by a grammer. Regular, Context-Free and context sensitive grammars and languages. Regular sets.	(12 hours)
Unit - V: Regular expressions and the Pumping lemma. Kleene's theorem. Notions of syntax analysis. Polish notations. Conversion of infix expressions to polish notations. The reverse polish notation.	(12 hours)

Learning Outcomes : After completion of this course the students will be able to understand the Warshall's algorithm Turing machine, grammars and languages

Essential Readings

- 1 C.L.Liu, Elements of Discrete Mathematics, McGraw Hill, New Delhi.
- 2 J.L. Gresting, Mathematical Structures for Computer Science, Computer Science Press, New York.

Suggested Readings and Link :

1. J.P. Tremblay & R. Manobar, Discrete Mathematical Structures, McGraw Hill, New Delhi.
2. Narsingh Deo, Graph Theory with applications, Prentice-Hall, New Delhi.

E book links: National Digital Library