Deccan Education Society's
FERGUSSON COLLEGE (AUTONOMOUS), PUNE

Department of Mathematics

Syllabus
for
T. Y. B. Sc. (Mathematics)

To be implemented
From Academic Year
2021-22

Deccan Education Society's

Fergusson College (Autonomous), Pune
Syllabus under Autonomy for T. Y. B. Sc. (Mathematics)
Under CBCS pattern (2019) *effective from June 2021*

Sem.	**Paper No.**	**Course code**	**Title**	**Credits**	**CE maximum Marks**	**ESE maximum Marks**	**Total makimum Marks**
V	DSE-1A	MTS3501	Real Analysis-I	2	50	50	100
	DSE-1B	MTS 3502	Complex Analysis-I	2	50	50	100
	DSE-2A	MTS 3503	Group Theory	2	50	50	100
	DSE-2B	MTS 3504	Advanced Linear Algebra	2	50	50	100
	DSE-3A	MTS 3505	Metric Spaces-I	2	50	50	100
	DSE-3B	MTS 3506	Number Theory	2	50	50	100
	DSE-1	MTS 3507	Mathematics Practical –I based on MTS3501 & MTS3502	2	50	50	100
	DSE-2	MTS 3508	Mathematics Practical –II based on MTS3503 & MTS3504	2	50	50	100
	DSE-3	MTS 3509	Mathematics Practical –III based on Paper SEC	2	50	50	100
	SEC-1*	MTS 3511	Operations Research	2	50	50	100
	SEC-2*	MTS 3512	Financial Mathematics-I	2	50	50	100
	SEC-3*	MTS 3513	Python Programming	2	50	50	100
	SEC-4*	MTS 3514	Partial Differential Equations	2	50	50	100
	SEC-5*	MTS 3515	Combinatorics	2	50	50	100
			Total Credits	**25/31**			**1100/1400**

Sem.	Paper No.	Course code	Title	Credits	CE maximum Marks	ESE maximum Marks	Total makimum Marks
VI	DSE-4A	MTS 3601	Real Analysis-II	2	50	50	100
	DSE-4B	MTS 3602	Complex Analysis-II	2	50	50	100
	DSE-5A	MTS 3603	Ring Theory	2	50	50	100
	DSE-5B	MTS 3604	Dynamical Systems	2	50	50	100
	DSE-6A	MTS 3605	Metric Spaces-II	2	50	50	100
	DSE-6B	MTS 3606	Differential Geometry	2	50	50	100
	DSE-4	MTS 3607	Mathematics Practical –IV based on MTS3601 & MTS3602	2	50	50	100
	DSE-5	MTS 3608	Mathematics Practical –V based on MTS3603 & MTS3604	2	50	50	100
	DSE-6	MTS 3609	Mathematics Practical –VI based on Paper SEC	2	50	50	100
	SEC-6*	MTS 3611	Optimization Techniques	2	50	50	100
	SEC-7*	MTS 3612	Financial Mathematics-II	2	50	50	100
	SEC-8*	MTS 3613	Graph Theory	2	50	50	100
	SEC-9*	MTS 3614	Lebesgue Integration	2	50	50	100
	SEC-10*	MTS 3615	Mathematical Models in Population Biology	2	50	50	100
			Total Credits	**25/31**			**1100/1400**

** For SEC courses – CE and ESE exam will be conducted by the department. It will not be conducted centrally*.

Note:

1. **DSE (Department Specific Elective)** - 12 Courses selected by the department. The list provided by UGC CBCS pattern for T. Y. B. Sc. is suggestive in nature and each department has a complete freedom to suggest their own papers under this category based on expertise, specialization, requirements, scope and need.
2. **SEC (Skill Enhancement courses)** - Minimum 4 for T. Y. B. Sc. These courses may be chosen from pool of courses designed to provide value-based and/or Skill-based knowledge and should contain both theory and lab/hands-on-training/field work. The main purpose of these courses is to provide students life-skills in hands on mode so as to increase their employability. The list provided by UGC is suggestive in nature and each department has freedom to suggest their own papers under this category based on expertise, specialization, requirements, scope and need.

T. Y. B.Sc. Semester V		
Title of the Course and Course Code	**Real Analysis-I** **MTS3501**	**Number of Credits :2**
Course Outcomes (COs) **On completion of the course, the students will be able to:**		
CO1	Retrieve the structure of system of real numbers. State lub axiom. Define countability of subsets of real numbers, convergence of sequences and series, integrability of functions.	
CO2	Classify, distinguish countable and uncountable sets, convergent and divergent sequences and series.	
CO3	Apply, use, examine countability theorems to test the countability of sets, convergence tests/statements to discuss the convergence of sequences and series.	
CO4	Analyse and demonstrate the statements with diagrams. Arrange, explain the sets according to their cardinalities, sequences and series to test the convergence.	
CO5	Determine supremum, infimum of a set, maps between two sets, equivalent sets and justify. Evaluate limit of sequences and sums of series, integrals.	
CO6	Produce bijective maps between equivalent sets. Create counter examples to the statements about sequences, series and integrable functions.	

Unit. No.	**Title of Unit and Contents**	**No. of Lectures**
I	**Real Numbers:** Revision of Algebraic Structure of R, Ordered Field, Supremum and Infimum, Archimedean property, LUB Axiom, Density of rational and irrational numbers, Countable and uncountable subsets of R, Cantor's Theorem, Schroeder-Bernstein theorem(Statement only)	**5**
II	**Sequences of Real Numbers:** Convergence of sequences, Algebra of limits of sequences, Bounded sequences, Monotonic sequences, Monotone convergence Theorem, Nested interval property, Sandwich principle, Ratio test for sequence of positive numbers.	**11**

	Subsequences: Monotone subsequence theorem, Bolzano-Weierstrass Theorem, Cauchy sequences, Cauchy criteria for convergent sequences, Contracting sequences.	
III	**Series of Real Numbers:** Convergence of Infinite Series, Convergence criteria, Cauchy’s Convergence criteria, Tests for Convergence: Absolute and conditional convergence, Comparison test, Cauchy’s n-th root test, D'Alembert's ratio test, Integral Test, Alternating Series Alternating Series, Leibnitz test, Abel’s test and Dirichlet Test, rearrangement of terms	**10**
IV	**Integration:** Riemann Integrable functions, Necessary and sufficient conditions for Riemann Integrability, Uniform Continuity, Integral as a limit of Riemann sum, Properties of Riemann integrable functions, Fundamental Theorem of Calculus, Mean value theorems for integrals and their applications.	**10**

Textbooks:

1. Richard R. Goldberg, Methods of Real Analysis, Oxford and IBH Publishing Co. Pvt. Ltd., (1970).
2. Ajitkumar and S. Kumaresan, A Basic Course in Real Analysis, CRC Press, 2010.

Reference Books:

1. Tom Apostol, Mathematical Analysis, 2 nd Edition, Prentice Hall of India, 1994.
2. D. Somasundaram and B. Choudhari, a first course in Mathematical Analysis, Narosa Publishing House, 1997.
3. R. G. Bartle and D. R. Sherbert, Introduction to Real Analysis, 4 th Edition, John Wiley, 2012.
4. S. Ponnusamy, Foundations of Mathematical Analysis, Birkauser, (2010)
5. W. Rudin, Principles of Mathematical Analysis.

T. Y. B.Sc. Semester V

Title of the Course and Course Code	Complex Analysis-I MTS3502	Number of Credits :2
Course Outcomes (COs) On completion of the course, the students will be able to:		
CO1	Articulate and retrieve basic concepts of complex numbers. Recall, remember and list all basic properties of complex numbers. Discuss the geometrical interpretation of algebraic properties of complex numbers.	
CO2	Discuss calculus related properties in complex, carry out and outline different maps, illustrate theorems on limit, continuity and differentiation.	
CO3	Discriminate, check, evaluate and create different types of complex functions on calculus related properties.	
CO4	Define, classify, illustrate, verify and invent different types of elementary functions on field complex numbers.	
CO5	Define, classify, illustrate, verify and invent different types of integration on functions of complex numbers.	
CO6	Define, classify, illustrate, verify and invent different types of series on field complex numbers.	

Unit. No.	Title of Unit and Contents	No. of Lectures
I	**Complex Numbers:** Revision, Algebra of complex numbers, Exponential Form, Products and powers in exponential form, Arguments of products and quotients, Roots of complex numbers, Roots of unity, Examples, regions in the complex plane	**4**
II	**Analytic functions** of Complex Variables, mappings, mappings by exponential functions, Limits, Theorems on limits, Limits involving the point at infinity, Continuity, Derivatives, Differentiation formulas, Cauchy – Riemann Equations, Sufficient Conditions for differentiability, Polar coordinates, analytical functions, examples, Harmonic functions, uniquely determined analytic functions, reflection principle	**10**
III	**Elementary Functions:** The Exponential functions, The Logarithmic function, Branches and derivatives of logarithms, Some identities involving logarithms, Complex exponents, Trigonometric functions, Hyperbolic functions, Inverse trigonometric and hyperbolic functions	**8**
IV	**Integrals:** Derivatives of functions, Definite integrals of functions, Contours, Contour integral, Examples, Upper bounds for moduli of contour integrals, Anti-derivatives, Examples, Cauchy-Goursat's Theorem (without proof), Simply and multiply Collected domains. Cauchy integral formula. Derivatives of analytic functions. Liouville's Theorem and Fundamental Theorem of Algebra, Maximum modulus principle.	**10**
V	**Series:** Convergence of sequences, Convergence of series, Taylor	**4**

	Series, examples, Laurent Series, region of convergence, examples, absolute and uniform convergence of power series, continuity of sums of power series, integration and differentiation of power series, uniqueness of series representations, multiplication and division of power series.	

Text Book:
J. W. Brown and R. V. Churchill, Complex Variables and Applications, International Student Edition, 2009. (Eighth Edition). Chapter 1, Chapter 2, Chapter 3, Chapter 4, Chapter 5.

Reference Books:
1. S. Ponnusamy, Complex Analysis, Second Edition (Narosa).
2. J. M. Howie, Complex Analysis, (Springer, 2003).
3. S. Lang, Complex Analysis, (Springer, Verlag).
4. A. R. Shastri, An Introduction to Complex Analysis, (MacMillan).

T. Y. B.Sc. Semester V		
Title of the Course and Course Code	**Group Theory** **MTS3503**	**Number of Credits :2**
Course Outcomes (COs) **On completion of the course, the students will be able to:**		
CO1	Define and retrieve basic concepts of algebra such as integers and functions. Recall, remember and list all basic algebraic properties of number systems.	
CO2	Discuss groups and its basic terminology. Categorize, compare different types of groups, outline and illustrate basic properties and theorems of groups.	
CO3	Illustrate, homomorphism on groups, quotient groups and normal subgroups. Carryout, outline and illustrate theorems on these concepts.	
CO4	Classify homomorphism on groups and to study quotient groups and normal subgroups.	
CO5	Discriminate, check, evaluate different subgroups of a group. Validate simple groups, alternating groups, permutation groups and illustrate theorems on these concepts and composition of series of groups.	
CO6	Formulate group actions and related concepts. Create different subgroups of a group.	

Unit. No.	**Title of Unit and Contents**	**No. of Lectures**
I	**Introduction to Groups** Basic Axioms: Uniqueness of identity and inverse, cancellation laws, order of an element, abelian groups, Examples: R, R*, Q, Q*, C, C*,Z, nZ, Z_n, Z_n^*, direct product, Matrix group under addition and multiplication, Dihedral Groups: order of Z_n , generators and relations Symmetric Groups: Order of S_n, Cycle decomposition algorithm, disjoint cycles, commute, permutations, order of	**10**

	an element in S_n Matrix Groups: $GL_n(F)$, order of $GL_n(F)$ The Quaternion Group Homomorphisms and Isomorphisms.	
II	**Subgroups** Definition, subgroup criterion, Examples of subgroups of various groups, Centralizers and Normalizers, Stabilizers and Kernels: Definitions and examples, Cyclic Groups and Cyclic Subgroups: Definition, Fundamental theorem of cyclic groups, order of subgroups in cyclic groups, The lattice of Subgroups of a group.	**10**
III	**Quotient Groups and Homomorphisms** Definitions, fibers, kernels, cosets, normal subgroups, characterization of normal subgroups, relation between kernel of a homomorphism and normal subgroup, Examples More on Cosets and Lagrange's Theorem, index of a subgroup, order of an element divides order of the group, converse of Lagrange's Theorem, The Isomorphism Theorems: 1st Isomorphism Theorem, 2nd Isomorphism Theorem, 3rd Isomorphism Theorem, 4th Isomorphism Theorem, Composition Series and the Holder program: Simple group, composition series, solvable series Transpositions and Alternating groups: Definitions, order of An, An is simple for n >=5.	**10**
IV	**Group Actions:** Definition and examples, Cayley's Theorem (Without proof), the class equation (Without proof), Applications of the class equation, Conjugacy in Sn, Sylow's theorems (Without proof), Applications of Sylow's theorems	**6**

Textbook: D. S. Dummit and R. M. Foote, Abstract Algebra, 2nd Edition, Wiley 1999.
Sections: 1.1 to 1.7, 2.1 to 2.3, and 3.1 to 3.3.

Reference Books:

1. M. Artin, Algebra, Prentice Hall of India, New Delhi, 1994.
2. N. Herstein, Topics in Algebra, Wiley, 1990. § 2.1 to § 2.10
3. P. B. Bhattacharya, S. K. Jain and S. R. Nagpal, Basic Abstract Algebra, Second Ed., Foundation Books, New Delhi, 1995.
4. J. B. Fraleigh, A First Course in Abstract Algebra, Third Ed., Narosa, New Delhi,
5. N. S. Gopalakrishnan, University Algebra, Second Ed., New Age International, New Delhi, 1986.
6. D. A. R. Wallace, Groups, Rings and Fields, Springer-Verlag, London, 1998.
7. I. N. Herstein, Abstract Algebra.

T. Y. B.Sc. Semester V

Title of the Course and Course Code	**Advanced Linear Algebra** **MTS3504**	**Number of Credits :2**
Course Outcomes (COs) **On completion of the course, the students will be able to:**		
CO1	Describe rank of matrix, determinants, eigenvalues and eigenvectors, canonical forms. Identify eigenvectors, Jordan canonical forms.	
CO2	Classify canonical forms of matrices, compare nature of matrices, Associate linear transformation with a matrix. Differentiate matrices/linear transformations according to rank, eigenvalues and eigenvectors, canonical forms.	
CO3	Apply elementary operations to solve system of equations, determinant of matrices. Compute solutions of system, eigenvalues and eigenvectors, canonical forms of matrices. Interpret properties of linear transformation using determinant, eigenvalues, eigenvectors and canonical forms.	
CO4	Analyse type of matrix to perform elementary operations. Classify and distinguish the matrices according to their eigenvalues, eigenvectors, determinant, and canonical forms. Identify nature of matrix from characteristic polynomial, minimal polynomial.	
CO5	Test the consistency of system of equations by using echelon form to get rank of a matrix. Evaluate solutions of system of equations and canonical forms. Determine invertible matrix to diagonalize a matrix.	
CO6	Hypothesize the conditions for invertibility of matrix, solve the system of equations to get specific canonical forms. Produce the examples and counter examples in support to the theory.	

Unit. No.	Title of Unit and Contents	No. of Lectures
I	**Elementary Matrix Operations and System of Linear Equations:** Elementary matrix operations and elementary matrices, The Rank of matrix and matrix inverses, System of linear equations: Theoretical Aspects, System of linear equations: Computational Aspects	7
II	**Determinants:** Determinants of Order 2 Determinants of Order n, Properties of Determinants, Characterization of determinant	7
III	**Diagonalization:** Eigenvalues and eigenvectors, Diagonalizability, Direct Sums, Invariant subspaces and the Cayley-Hamilton theorem	12
IV	**Canonical Forms:** The Jordan Canonical forms-I, The Jordan Canonical forms-II, The minimal polynomial	10

Textbook: Stephen H. Friedberg, Arnold J. Insel, Lawrence G. Spence, *Linear Algebra*, Pearson, Fifth Edition

Reference Books:

1. Howard Anton, Chris Rorres, *Elementary Linear Algebra: Applications Version*, Wiley (11^{th} Edition)

2. Steven J. Leon, *Linear Algebra with Applications*, Pearson
3. Titu Andreescu, *Essential Linear Algebra with Applications-A Problem Solving Approach*, Birkhauser.
4. Gene H. Golub, Charles F. Van Loan, *Matrix Computations*, The Johns Hopkins University Press, Baltimore (Fourth Edition)
5. Theodore Shifrin, Malcolm R. Adams, *Linear Algebra-A Geometric Approach*, W. H. Freeman and Company, New York.

T. Y. B.Sc. Semester V		
Title of the Course and Course Code	**Metric Spaces** **MTS3505**	**Number of Credits :2**
Course Outcomes (COs) **On completion of the course, the students will be able to:**		
CO1	Recall and state basic concepts of real numbers. Define metric spaces.	
CO2	Explain the open and closed intervals in R. Classify the intervals and sets into open and closed sets.	
CO3	Examine continuous functions, compact sets, the structure of open sets in R. Apply sequences and their properties to check and classify compact, connected, dense sets. Solve different metrics on general metric space. Illustrate different inequalities and apply them to check metrics.	
CO4	Discriminate, check different types of functions in R.	
CO5	Evaluate different types of functions in R. Test and verify different metrics on general metric space.	
CO6	Create different types of functions and compact sets in R.	

Unit. No.	Title of Unit and Contents	No. of Lectures
I	**Topology on R** Open and closed sets in R, Compact sets in R, Continuous functions on R	**6**
II	**Introduction of Metric Spaces** Definition and examples of metric spaces, Young's inequality, Holder's inequality, Minkowski inequality, Cauchy-Schwartz inequality, Open balls and open sets, Hausdorff property, Structure of open sets in R, Equivalent metrics, necessary and sufficient conditions for equivalence of metrics	**10**
III	**Convergence in Metric Spaces** Convergent sequences, Limit points and cluster points, closure of a set, Bolzano-Weierstrass Theorem, Cauchy sequences, Completeness, Completeness of R; R^n, Bounded sets, Dense sets, dense subsets of R, Boundary of a set, Basis for metric space	**10**
IV	**Continuous functions on metric space** Continuous functions, composition of continuous functions, space of continuous functions, Characterisations of continuity, Urysohn's lemma for metric spaces, Gluing	**10**

	lemma for metric spaces, Tietze extension theorem for metric spaces (statement only) ,Uniform continuity, limit of a function, open and closed maps	

Text Book:

1. Introduction to real analysis by Robert Bartle and Donald Sherbert, Wiley-India, 2007.Sections 11.1,11.2,11.3
2. Topology of Metric Spaces by S. Kumaresan, Narosa Publishing House, 2005. Sections 1.1,1.2 (except the Sections 1.2.51 to 1.2.65), 2.1, 2.2, 2.3, 2.4, 2.5 and 2.7,3.1,3.2 (upto 3.2.32 only), 3.3, 3.4, 3.5.

Reference:

1. Satish Shirali, Harkrishan L. Vasudeva, Metric Spaces, Springer International Edition, First Indian Reprint, 2009.
2. Richard R. Goldberg, Methods of Real Analysis, Oxford and IBH Publishing Co. Pvt. Ltd., 1970.
3. Micheal O. Searcoid, Metric Spaces, Springer International Edition, Fourth Indian Reprint,2014.
4. G. F. Simmons, Topology of Metric Spaces.

T. Y. B.Sc. Semester V		
Title of the Course and Course Code	**Number Theory** **MTS3506**	**Number of Credits :2**
Course Outcomes (COs) **On completion of the course, the students will be able to:**		
CO1	Recall, define basic concepts of set of integers and divisibility.	
CO2	Discuss congruence relation. Illustrate theorems on divisibility, theorems on congruences.	
CO3	Solve and verify problems in divisibility, congruences. Examine different techniques of numerical calculations.	
CO4	Classify different types of congruence equations.	
CO5	Test and verify different number theoretic functions, congruences laws and, Legendre's symbol.	
CO6	Create different types of congruence equations.	

Unit. No.	**Title of Unit and Contents**	**No. of Lectures**
I	**Divisibility** Divisibility in Integers, Division Algorithm, GCD, LCM, Fundamental Theorem of Arithmetic, Infinitude of Primes, Mersenne Numbers and Fermat Numbers	8
II	**Congruences** Definition, Properties of Congruences, Residue classes, complete and reduced residue system, their properties, Fermat's theorem. Euler's theorem, Wilsons theorem, $x^2 \equiv 1 \pmod{p}$ has a solution if and only if $p = 2$ or $1 \pmod{4}$; where p is a prime. Linear congruences of degree 1 and	8

	Chinese remainder theorem.	
III	**Diophantine Equations** $ax + by = c, x^2 + y^2 = z^2$	4
IV	**Greatest integer function** Arithmetic functions Euler's function, the number of divisors d(n), sum of divisors σ(n); Ω(n), Multiplicative functions, Mobius function, Mobius inversion formula	8
V	**Quadratic Reciprocity:** Quadratic residues, Legendre's symbol and its properties, Law of quadratic reciprocity	8

Text Book:

I. Niven, H. Zuckerman and H. L. Montgomery, An Introduction to Theory of Numbers, 5^{th} Edition, John Wiley and Sons. (§1.1- §1.3, §2.1 - §2.5, §3.1 - §3.3, §4.1 -§4.3.)

Reference:

David M. Burton, Elementary Number Theory (Second Ed.), Universal Book Stall, New Delhi, 1991

T. Y. B.Sc. Semester V		
Title of the Course and Course Code	**Mathematics Practical -I based on MTS3501 & MTS3502** **MTS3507**	**Number of Credits :2**
Course Outcomes (COs) **On completion of the course, the students will be able to:**		
CO1	Articulate and retrieve basic concepts and basic properties of complex numbers. Discuss the geometrical interpretation of algebraic properties of complex numbers.	
CO2	Define calculus related properties in complex. Carryout and outline different maps, illustrate theorems on limit, continuity and differentiation.	
CO3	Discriminate, check, evaluate and create different types of complex functions on calculus related properties.	
CO4	Define, classify, illustrate, verify invent different types of elementary functions on field complex numbers.	
CO5	Define, classify, illustrate, verify invent different types of integration on functions of complex numbers.	
CO6	Define, classify, illustrate, verify invent different types of series on field complex numbers.	

Sr. No.	Topic	No. of Practicals
	Topic 1: Real Analysis-I	8
I	System of Real Numbers	8

II	Countability	4
III	Sequences of Real numbers	8
IV	Series of Real Numbers	8
V	Riemann Integral and properties	
VI	Mean Value Theorems for Integral	
	Topic 2 : Complex Analysis-I	
I	Complex numbers and maps	
II	Analytic functions	
III	Elementary functions and their proteries	
IV	Complex Integrals	
V	Applications of complex integrals	
VI	Series of complex numbers	

T. Y. B.Sc. Semester V		
Title of the Course and Course Code	**Mathematics Practical -II based on MTS3503 & MTS3504 MTS3508**	**Number of Credits :2**
Course Outcomes (COs) On completion of the course, the students will be able to:		
CO1	Articulate and retrieve basic concepts of algebra such as integers and functions. Recall, remember and list all basic algebraic properties of number systems.	
CO2	Define groups and its basic terminology. Categorize, compare verify, examine, create different types of groups. List, carryout, outline and illustrate basic properties and theorems of groups.	
CO3	Discriminate, check, evaluate and create different subgroups of a group.	
CO4	Define, classify, illustrate, verify, invent homomorphism on groups and to study quotient groups and normal subgroups. List, carryout, outline and illustrate theorems on these concepts.	
CO5	Define, classify, illustrate, verify, invent simple groups, alternating groups and to study permutation groups. List, carryout, outline and illustrate theorems on these concepts and composition of series of groups.	
CO6	Define, classify, illustrate, verify, invent group actions and related concepts. List, carryout, outline and illustrate theorems on these concepts.	

Sr. No.	**Topic**	**No. of Practicals**
	Topic 1: Group Theory	8
I	Groups Examples	8
II	Subgroups	4

III	Quotient Groups	8
IV	Homomorphisms	8
V	Group Actions	
VI	Miscellaneous	
	Topic 2: Advanced Linear Algebra	
I	Linear transformations and matrices	
II	Inner product spaces	
III	Elementary Matrix operations and System of equations	
IV	Determinants, Diagonalization	
V	Canonical forms	
VI	Matrix Limits and Markov Chains, Rational Canonical forms	

T. Y. B.Sc. Semester V		
Title of the Course and Course Code	**Mathematics Practical -III based on SEC MTS3509**	**Number of Credits :2**
Course Outcomes (COs) On completion of the course, the students will be able to:		
CO1	Recall and articulate basic concepts of simple Interest, Calculate and illustrate interest with discrete and continuous compounding. Discuss, execute, explain, illustrate, use time value of money.	
CO2	Construct deterministic cash flows, translate, formulate Internal rate of return, NPV.	
CO3	Define, explain random cash flows.	
CO4	Define, explain, solve Markowitz model. Use, execute various methods to solve it.	
CO5	Define, explain, solve CAPM, Use of Portfolio diagrams	
CO6	Formulate CAPM, Calculate and illustrate CAPM formula and Discuss, execute, explain, illustrate, use it.	

(Any Two of the Following)

Sr. No.	Topic 1: Operations Research	No of Practicals
I	Modelling with Linear Programming	
II	The Simplex Method	
III	Duality	

IV	Transportation Model	
V	The Assignment Model	
VI	Miscellaneous	
	Topic 2: Financial Mathematics-I	
I	Simple Interest	
II	Compound Interest	
III	Net Present Value	
IV	Duration and Convexity	
V	Markowitz Model and CAPM	
VI	Miscellaneous	
	Topic 3: Partial Differential Equation	
I	Pfaffian Differential Equation	
II	First Order Partial Differential Equation	
III	Charit's Method	
IV	Jacobi's Method	
V	Second Order Partial Differential Equation	
VI	Miscellaneous	
	Topic 4: Combinatorics	
I	Permutations and Combinations	
II	Distribution Problem	
III	Inclusion-Exclusion Principle	
IV	Pigeonhole Principle	
V	Recurrence Relations-I	
VI	Recurrence Relations-II	
	Topic 5: Python	
I	Variables, Keywords, Identifiers, Literals, Operators, Comments	
II	Control Statements	
III	Strings	
IV	List and Tuples	
V	Functions	
VI	Modules	

T. Y. B.Sc. Semester V		
Title of the Course and Course Code	**Operations Research MTS3511**	**Number of Credits :2**
Course Outcomes (COs) On completion of the course, the students will be able to:		
CO1	Recall and describe the basic concepts of LPP.	
CO2	Illustrate Linear Programming Problems using different methods.	
CO3	Execute various methods to solve transportation and assignment problems.	
CO4	Explain and solve dual LPP. Relate and compare primal and dual LPP.	
CO5	Test, verify optimal solutions of various Linear Programming, Transportation and Assignment Problems.	
CO6	Construct and solve LPP in equation form, translate, formulate graphical to algebraic solution.	

Unit. No.	Title of Unit and Contents	No. of Lectures
I	**Modelling with Linear Programming** Two variable LP Model,, Graphical LP solution, Selected LP Applications, Graphical Sensitivity analysis	**6**
II	**The Simplex Method** LP Model in equation form, Transition from graphical to algebraic solutions, the simplex method, Artificial starting solutions	**12**
III	**Duality** Definition of the dual problem, primal dual relationship	**6**
IV	**Transportation Model** Definition of the Transportation model, the Transportation Algorithm	**6**
V	**The Assignment Model** The Hungarian method, Simplex explanation of the Hungarian method	**6**

Text Book:
Hamdy A. Taha, Operation Research (Eighth Edition, 2009), Prentice Hall of India Pvt. Ltd, New Delhi.**Ch. 2:**2.1, 2.2, 2.3(2.3.4, 2.3.5, 2.3.6) **Ch. 3:**3.1, 3.2, 3.3, 3.4, 3.5, 3.6 (3.6.1)**Ch. 4:**4.1, 4.2**Ch. 5:**5.1, 5.3 (5.3.1, 5.3.2, 5.3.3), 5.4 (5.4.1, 5.4.2)

Reference:

1. Frederick S. Hillier, Gerald J. Lieberman, Introduction to Operations Research (Eighth Edition), Tata McGraw-Hill.
2. J. K. Sharma, Operations Research (Theory and Applications, second edition, 2006), Macmillan India Ltd.
3. Hira and Gupta, Operations Research.

T. Y. B.Sc. Semester V		
Title of the Course and Course Code	**Financial Mathematics-I** **MTS3512**	**Number of Credits :2**
Course Outcomes (COs) **On completion of the course, the students will be able to:**		
CO1	Recall and articulate basic concepts of simple Interest, Calculate and illustrate interest with discrete and continuous compounding. Discuss, execute, explain, illustrate, use time value of money.	
CO2	Construct deterministic cash flows, translate, formulate Internal rate of return, NPV.	
CO3	Define, explain random cash flows.	
CO4	Define, explain, solve Markowitz model. Use, execute various methods to solve it.	
CO5	Define, explain, solve CAPM, Use of Portfolio diagrams	
CO6	Formulate CAPM, Calculate and illustrate CAPM formula and Discuss, execute, explain, illustrate, use it.	

Unit. No.	Title of Unit and Contents	No. of Lectures
I	**Basic Concepts** Arbitrage, return and interest, time value of money, bonds, shares and indices, Models and assumptions.	**12**
II	**Deterministic cash flows** Net present value, internal rate of return, a comparison of IRR and NPV, bonds: price and yield, clean and dirty price, price yield curves, duration, term structure of interest rates, immunization, convexity.	**12**
III	**Random cash flows** Random returns, Portfolio diagrams and efficiency, feasible set, Markowitz model, capital asset pricing model, diversification, CAMP as a pricing formula.	**12**

Reference Books:

1. Amber Habib, The Calculus of Finance, Universities Press.
2. D. Lemberger, Investment Science, Cambridge University Press
3. John Hull, Option Futures and other derivatives, Prentice Hall.

T. Y. B.Sc. Semester V		
Title of the Course and Course Code	**Python Programming** **MTS3513**	**Number of Credits :2**
Course Outcomes (COs) **On completion of the course, the students will be able to:**		
CO1	Describe various constructs of python programming.	
CO2	Illustrate file handling operations in Python.	
CO3	Apply conditional and looping constructs to solve different problems.	

	Demonstrate the use of built-in data structures.
CO4	Explain different programming concepts in python.
CO5	Test and validate Python applications
CO6	Write interactive applications using Database, GUI and multithreading. Write, compile, run, and test python programs.

Unit. No.	Title of Unit and Contents	No. of Lectures
I	Python Introduction What is Python? , Features, History, Version, Applications, Install Python, Python Path, Python Example, Execute Python, Variables, Keywords, Identifiers, Literals, Operators, Comments	4
II	Control Statement if, if-else if, nested if, for loop, while loop, do-while, break, continue, pass.	4
III	Python Strings Accessing Strings, Basic Operators, Membership Operators, Relational Operators, Slice Notation, String functions and Methods	6
IV	Python Data Structures Python List - Accessing Lists, List Operations, Functions and Methods of Lists Python Tuple-Accessing Tuple, Tuple Operations, Functions of Tuples, Why use Tuple?Python Dictionary- Accessing Values, Functions & Methods.	8
V	Python Functions Built-in Functions, User defined Functions, Invoking a Function, return Statement, Argument and Parameter, Positional Argument (Required Argument), Default Argument, Keyword Argument, Anonymous Function, Difference between Normal Functions and Anonymous Function, Scope of a Variable	4
VI	Python Files I/O Input from Keyboard, File Handling, Attributes of File, Modes of File, File Handling Methods	6
VII	Python Modules What is a Module? , Importing a Module, Built in Modules in Python, Package.	4

Text Book: Reema Thareja, Python Programming using problem solving approach, Oxford university press.

Reference:

1. Magnus Lie Hetland, Beginning-Python, Second Edition
2. Martin C. Brown, The Complete Reference Python
3. Patrick Barry, Head First Python
4. Mark Lutz, O'Reilly Learning Python
5. Alex Martelli Python in a Nutshell, O'Reilly

T. Y. B.Sc. Semester V		
Title of the Course and Course Code	**Partial Differential Equations MTS3514**	**Number of Credits :2**
Course Outcomes (COs) **On completion of the course, the students will be able to:**		

CO1	Recall cartesian and parametric equations of curves and surfaces in the space. Name the type of differential equations and Remember the methods to solve them.
CO2	Categorize the first order and second order partial differential equations. Clarify the existence of solutions of partial differential equations. Differentiate the differential equations according to the methods of solutions. Interpret solutions geometrically.
CO3	Apply and demonstrate the method to solve the partial differential equations. Examine the solvability of the differential equations and modify the initial conditions in order to solve them. Manipulate the parameter and observe the dynamics of the differential equations.
CO4	Analyse the differential equation in order to apply proper method of solution. Compare differential equations in order to study stability, solvability, method of solutions. Explain the solution of differential equation analytically, geometrically.
CO5	Evaluate general, complete, particular, singular solutions of first order and second order partial differential equations. Compare two or more differential equations analytically, geometrically. Criticize the solvability of the differential equations.
CO6	Create counter examples for which method of solution fails. Assemble various techniques to solve the differential equation completely. Develop method of solution by changing constraints/data. Formulate a practical problem as a differential equation or system of differential equations. Modify the differential equations and interpret the change in solution.

Unit. No.	**Title of Unit and Contents**	**No. of Lectures**
I	**First Order Partial Differential Equations** Curves and surfaces, Genesis of First Order Partial Differential Equations, Classification of Integrals, Linear Equations of the First Order, Pfaffian Differential Equations, Compatible Systems, Charpit's Method, Jacobi's Method, Integral Surfaces through a given curve	**30**
II	**Second Order Partial Differential Equations** Genesis of Second order Partial Differential Equations, Classification of Second Order Partial Differential Equations by using Discriminant (Problems Only)	**8**
III	Applications of Partial Differential Equations	**10**

Text Books:

T. Amaranath, An Elementary Course in Partial Differential Equations, Narosa Publishing, House, 2nd Edition, 2003 (Reprint, 2006).

Topics: Chapter 1 - Sec. - 1.1 to 1.11, Chapter 2 - Sec. 2.1 to 2.2

References:

1. Ian Sneddon, Element of Partial Differential Equations, McGraw-Hill Book Company, McGraw-Hill Book Company.
2. Frank Ayres Jr., Differential Equations, McGraw-Hill Book Company, SI Edition, International Edition, 1972.
3. Ravi P. Agarwal and Donal O'Regan, Ordinary and Partial Differential Equations, Springer, First Edition 2009.
4. W. E. Williams, Partial Differential Equations, Clarendon Press, Oxford, 1980.

T. Y. B.Sc. Semester V		
Title of the Course and Course Code	**Combinatorics** **MTS3511**	**Number of Credits :2**
Course Outcomes (COs) **On completion of the course, the students will be able to:**		
CO1	Recall and define basic concepts of counting principles.	
CO2	Illustrate formulae for Permutation of combinations. Explain the use of Pigeonhole principle	
CO3	Apply Inclusion-Exclusion Principle to solve combinatorial problems.	
CO4	Explain various counting principles and Binomial Identities to solve different problems.	
CO6	Test and validate Binomial identities, distribution problems and Multinomial theorem.	
CO6	Construct and formulate Recurrence relations.	

Unit. No.	Title of Unit and Contents	No. of Lectures
I	**Two basic Counting Principles:** Addition Principle and Multiplication Principle, Simple, Arrangements and Selections, Arrangements and Selections with repetition, Distributions, Number of distributions of r distinct objects into n distinct boxes, Number of distributions of r identical objects into n distinct boxes, Binomial identities and Multinomial theorem	12
II	Inclusion-Exclusion Principle, Counting with Venn, diagrams, Inclusion Exclusion formula, Derangements, Simple Examples.	10
III	Pigeonhole principle	6
IV	Recurrence Relations: Recurrence relation models, Solution of Linear Homogeneous and non-homogeneous recurrence relations (methods without proof)	8

Text Book:

Alan Tucker, Applied Combinatorics, Wiley, 1995.

Reference Books:

1. Richard A. Brualdi, Introductory Combinatorics, Elsevier, North-Holland, New York,

1977.
2. V. K. Balkrishnan, Combinatorics, Schuam Series, 1995.
3. S. S. Sane, Combinatorial Thechniques, TRIM Series, Vol. 64.

T. Y. B.Sc. Semester VI		
Title of the Course and Course Code	**Real Analysis-II** **MTS3601**	**Number of Credits :2**
Course Outcomes (COs) **On completion of the course, the students will be able to:**		
CO1	Recall the convergence of sequences and series of functions, Riemann integrability of functions. Identify the function to which sequences and series of functions converge, type of improper integrals, properties of elementary functions. Show the pointwise or uniform convergence, properties of elementary functions, convergence of improper integrals, identity using DUIS.	
CO2	Clarify the pointwise or uniform convergence of sequences and series of functions, properties/identities about elementary functions, convergence/divergence of improper integrals, applicability of DUIS. Compare the sequences and series of functions, improper integrals for convergence, elementary functions. Illustrate the validity of statements by suitable examples.	
CO3	Apply tests of convergence for sequences and series of functions, improper integrals, properties of elementary functions to prove identities, DUIS to prove improper integrals, identities such as Fubini's theorem, Schwarz theorem, Euler's formula etc. Compute limit of sequences and series of functions, improper integrals, integrals using DUIS. Interpret the theorems/statements geometrically.	
CO4	Analyse the sequence and series of functions to test the pointwise or uniform convergence, properties of elementary functions to prove the identities. Compare function to test the convergence of improper integrals. Detect the properties of integrand to apply DUIS.	
CO5	Evaluate limit of sequence/series of functions, combinations of elementary functions, improper integrals and write the conclusion. Decide the suitable method/test to check the convergence of sequence and series of functions, improper integrals. Criticise the properties of elementary functions analytically and geometrically.	
CO6	Produce counter examples for false statements, non-validity of converse of the statement. Combine statements and predict the result. Design the statement from examples. Formulate the new statement from given data.	

Unit. No.	Title of Unit and Contents	No. of Lectures
I	**Sequences of Functions:** Sequences of functions, Point-wise Convergence, Uniform Convergence, Cauchy criteria for uniform convergence, Interchange of limit and integration, Interchange of limit and derivative	**8**

II	**Series of functions:** Series of functions, Point-wise Convergence, Uniform Convergence, Weirestrass M-test, Term by term Integration, Term by term differentiation, Power series, radius of convergence	**10**
III	**Elementary Functions:** Exponential function, Logarithmic function, Trigonometric Functions, Inverse Trigonometric functions, Hyperbolic functions	**8**
IV	**Improper Integrals:** Improper integrals of first and second kind, Integral test	**6**
V	**Differentiation under the integral sign:** Differentiation under integral sign with constant limits, Differentiation under integral sign with variable limits	**4**

Text Book:

1. Richard R. Goldberg, Methods of Real Analysis, Oxford and IBH Publishing Co. Pvt. Ltd.,(1970).
2. Ajitkumar and S. Kumaresan, A Basic Course in Real Analysis, CRC Press, 2010.

Reference:

1. S. Ponnusamy, Foundations of Mathematical Analysis, Birkauser, (2010)
2. Serge Lang, Undergraduate Analysis, Springer International Edition, (2010)
3. R. G. Bartle and D. R. Scherbert, Introduction to Real Analysis, 4 th Edition, John Wiley, 2012.
4. Apostol, Advanced Calculus, 2 nd Edition, Prentice Hall of India, 1994.
5. D. Somasundaram and B. Choudhari, a first course in Mathematical Analysis, Narosa Publishing House, 1997.

T. Y. B.Sc. Semester VI		
Title of the Course and Course Code	**Complex Analysis-II** **MTS3602**	**Number of Credits :2**
Course Outcomes (COs) **On completion of the course, the students will be able to:**		
CO1	Articulate and retrieve basic concepts of first semester complex analysis.	
CO2	Define residues and poles and its basic terminology. Categorize, compare verify, examine, create different types of residues and poles.	
CO3	List, carryout, outline and illustrate basic properties and theorems of residues and poles.	
CO4	Apply residues and poles to evaluate improper integrals. List, carryout, outline and illustrate theorems on complex integration.	
CO5	Define, classify, illustrate, verify, invent mappings by elementary functions. List, carryout, outline and illustrate theorems on these concepts.	
CO6	Define, classify, illustrate, verify, invent conformal mappings. List, carryout, outline and illustrate theorems on these concepts.	

Unit. No.	Title of Unit and Contents	No. of Lectures
I	**Residues and Poles:** Cauchy residue theorem, using a single residue, Three types of isolated singular points, Residues at poles, Zeros of analytic functions, Zeros and poles, Applications to real integrals, Behaviour off near isolated singular points.	**10**
II	**Applications of Residues**: Evaluation of improper integrals, examples, improper integrals from Fourier Analysis, Jordan's lemma, indented paths, an indentation around a branch point, integration along a branch cut, definite integrals involving sines and cosines, argument principle, Rouche's theorem, inverse Laplace transforms, examples.	**10**
III	**Mapping by elementary functions**: Linear transformations, the transformation w=1/z, mappings by 1/z, linear fractional transformation/ Mobius transformation, an implicit form, mappings of the upper half plane, the transformation w=sin z, mappings by z^2 and branches of z^1/2, square roots of polynomials, Riemann surfaces, surfaces for related functions	**10**
IV	**Conformal mapping**: Preservation of angles, scale factors, local inverses, Harmonic conjugates, transformations of harmonic functions, transformation of boundary conditions.	**6**

Text Book:

J. W. Brown and R. V. Churchill, Complex Variables and Applications, International Student Edition, 2009. (Eighth Edition).
Chapter 6, Chapter 7, Chapter 8, Chapter 9.

Reference:

1. S. Ponnusamy, Complex Analysis, Second Edition Narosa.
2. J. M. Howie, Complex Analysis, Springer, 2003.
3. S. Lang, Complex Analysis, (Springer, Verlag).
4. R. Shastri, An Introduction to Complex Analysis, (MacMillan)

T. Y. B.Sc. Semester VI		
Title of the Course and Course Code	**Ring Theory** **MTS3603**	**Number of Credits :2**
Course Outcomes (COs) **On completion of the course, the students will be able to:**		
CO1	Define integers, polynomials, matrices, functions and group theory, ring and its basic terminology,.	
CO2	Categorize, compare different examples of rings.	
CO3	Carryout, outline and illustrate basic properties and theorems of rings.	
CO4	Explain ideals, subrings of a ring with examples.	

CO5	Validate different types of domains and illustrate theorems on these concepts.
CO6	Formulate polynomial rings, irreducible polynomials and use these concepts to prove theorems.

Unit. No.	Title of Unit and Contents	No. of Lectures
I	**Introduction to Rings:** Basic Definitions and Examples, Examples: Polynomial Rings, Matrix Rings and Group, Ring Homomorphisms an Quotient Rings Properties of Ideals Rings of Fractions, The Chinese Remainder Theorem, Finite fields	**12**
II	**Euclidean Domains, Principal Ideal Domains and Unique Factorization Domains** Euclidean Domains, Principal Ideal Domains (P.I.D.s),Unique Factorization Domains (U.F.D.s)	**12**
III	**Polynomial Rings** Definitions and Basic Properties, Polynomial Rings over Fields I, Polynomial Rings that are Unique Factorization Domains, Irreducibility Criteria, Polynomial Rings over Fields II	**12**

Textbook: D. S. Dummit and R. M. Foote, Abstract Algebra, 2nd Edition,Wiley 1999.
Sections: 7.1 to 7.6, 8.1 to 8.3, and 9.1 to 9.5.

Reference:

1. M. Artin, Algebra, Prentice Hall of India, New Delhi, 1994.
2. N. Herstein, Topics in Algebra, Wiley, 1990. § 2.1 to § 2.10
3. P. B. Bhattacharya, S. K. Jain and S. R. Nagpal, Basic Abstract Algebra, Second Ed., Foundation Books, New Delhi, 1995.
4. J. B. Fraleigh, A First Course in Abstract Algebra, Third Ed., Narosa, New Delhi, 1990.
5. N. S. Gopalakrishnan, University Algebra, Second Ed., New Age International, New Delhi, 1986.
6. D. A. R. Wallace, Groups, Rings and Fields, Springer-Verlag, London, 1998.
7. I. N. Herstein, Abstract Algebra.

T. Y. B.Sc. Semester VI		
Title of the Course and Course Code	**Dynamical Systems** **MTS3604**	**Number of Credits :2**
Course Outcomes (COs) **On completion of the course, the students will be able to:**		
CO1	Recall differentiable functions, eigenvalues, eigenvectors, canonical forms of matrices. Identify the nature of the solution of system of equations, describe the solutions, stability of equilibrium points.	
CO2	Classify the linear systems form eigenvalues and eigenvectors of coefficient matrices, discuss the nature of equilibrium points, compare nonlinear system with its linearization, interpret solutions geometrically, produce examples of linear systems conjugate to the linearization of nonlinear system. Draw the phase portrait diagrams of continuous and discrete dynamical systems.	

CO3	Calculate eigenvalues and eigenvectors of coefficient matrix of linear systems and classify the systems. Apply basic calculus to understand solutions of differential equations. Examine the nature of the solutions of system from properties of coefficient matrix and coefficient functions.
CO4	Analyse the nature of solution by the differential equations. Discriminate the systems according to the stability, type of critical points, type of bifurcations. Sketch the phase portrait diagrams locally, globally for linear, non-linear systems and discrete systems.
CO5	Evaluate the Poincare map for a first order equation, critical points, eigenvalues and eigenvectors for linear systems, exponential of a matrix, variational equation for nonlinear systems. Determine the nature of critical point of continuous and discrete dynamical systems.
CO6	Produce examples of systems for the given phase portrait. Create a system conjugate to the given system. Formulate the system for simple problems such as population model, harmonic oscillator, Hamiltonian, Gradient etc. Invent the conditions for bifurcation of continuous and discrete dynamical systems.

Unit. No.	Title of Unit and Contents	No. of Lectures
I	**Dynamics of First Order Equations:** The Simple Examples, The Logistic Population Model, Constant Harvesting Bifurcations, Periodic Harvesting and periodic solutions, Computing the Poincare map A two parameter family	**6**
II	**Planar Linear Systems:** Second order Differential equations, Planar systems and planar linear systems, Eigenvalues, eigenvectors and Solution of planar linear systems, The Linearity principle Phase Portrait for planar system with real distinct eigenvalues, complex eigenvalues, repeated eigenvalues, Change of coordinates, Trace-determinant plane, Dynamical classification	**8**
III	**Higher Dimensional linear systems:** Distinct eigenvalues, Repeated eigenvalues, The exponential of a matrix, Non-autonomous linear systems	**8**
IV	**Non-linear Systems:** Dynamical systems, The Existence and uniqueness theorem Continuous dependence of solutions, The Variational equation, Equilibria in nonlinear systems: Sink Source, Saddles, Stability, Bifurcations: Saddle node Bifurcation, Pitchfork bifurcation, Hopf bifurcation	**8**
V	**Discrete Dynamical system:** Introduction, Bifurcations, The Discrete Logistic model Chaos	**6**

Text Book:

Morris W. Hirsch, Stephen Smale., Robert L. Devaney, Differential Equations, Dynamical Systems and an Introduction to Chaos (Third Edition), Academic Press, ELSEVIER.

Reference:
1. Stephen Lynch, Dynamical Systems with Applications using Python, Birkhauser.
2. Lawrence Perko, Differential Equations and Dynamical Systems, Springer, Third Edition
3. J D Meiss, Differential Dynamical Systems, SIAMS

T. Y. B.Sc. Semester VI		
Title of the Course and Course Code	**Metric Spaces-II** **MTS3605**	**Number of Credits :2**
Course Outcomes (COs) **On completion of the course, the students will be able to:**		
CO1	Recall and state basic concepts of metric spaces. Define compact metric spaces.	
CO2	Discuss continuous functions and their properties. Classify connected subsets of R, different compact metric spaces.	
CO3	Examine connected spaces and solve problems based on them.	
CO4	Discriminate and check different types of connected spaces, sets.	
CO5	Test and evaluate different compact metric spaces.	
CO6	Create different complete metric spaces.	

Unit. No.	**Title of Unit and Contents**	**No. of Lectures**
I	**Connectedness** Connected spaces, Continuous image of connected space is connected, Connected subsets of R, Intermediate value theorem, Cartesian product of connected spaces	**12**
II	**Compactness** Compact spaces and their properties, Heine-Borel Theorem for R, closed rectangle in R^2 is compact, Continuous functions on compact metric spaces, Characterizations of compact metric spaces, Arzela-Ascoli theorem (statement only), Finite intersection property and compactness	**12**
III	**Complete metric spaces** Definition and examples of complete metric spaces, Nested interval theorem, Cantors intersection property, Completion of metric space (statement only), Baire category theorem (statement only) , Banach's contraction principle	**12**

Text Book:

Topology of Metric Spaces by S. Kumaresan, Narosa Publishing House, 2005.
Sections 4.1, 4.2, (Proposition 4.2.13 without proof) and 4.3 (Theorem 4.3.24 withoutproof), 5.1 and 6.1 (Theorems 6.1.1, 6.1.3, 6.1.11, without proofs).

References:

1. Satish Shirali, Harkrishan L. Vasudeva, Metric Spaces, Springer International Edition, First Indian Reprint, 2009.
2. Richard R. Goldberg, Methods of Real Analysis, Oxford and IBH Publishing Co. Pvt. Ltd., 1970.
3. Micheal O. Searcoid, Metric Spaces, Springer International Edition, Fourth Indian Reprint, 2014.
4. G. F. Simmons, Topology of Metric Spaces.

T. Y. B.Sc. Semester VI		
Title of the Course and Course Code	**Differential Geometry** **MTS3606**	**Number of Credits :2**

Course Outcomes (COs) **On completion of the course, the students will be able to:**	
CO1	Recall and articulate basic concepts such as Parametric and Cartesian curves, surfaces. Discuss their properties. Classify curves as planar curves and space curves using torsion
CO2	Examine plane curves. Evaluate their signed curvature and classify the curves
CO3	Define the first fundamental form and evaluate them. Define normal on a surface and regular surfaces.
CO4	Discuss diffeomorphisms between surfaces. Classify, illustrate, verify, invent different diffeomorphisms as conformal maps ,isometry and equiareal maps
CO5	Define and evaluate surface area. Discuss the relation between the area and the first fundamental form. Create different equiareal diffeomorphisms
CO6	Define the second fundamental form and evaluate them for different surface patches of the same surface.

Unit. No.	**Title of Unit and Contents**	**No. of Lectures**
I	**Curves in the plane and in space** What is a curve? Arc-length, Reparameterization, Level curves vs. Parametrized curves	**6**
II	**How much does a curve curve?** Curvature, Plane curves, Space curves	**6**
III	**Global Properties of curves** Simple closed curves, The Isoperimetric Inequality, The Four Vertex Theorem	**8**
IV	**Surfaces in three dimensions** What is a Surface? Smooth Surfaces, Tangents, Normals and Orientability, Examples of Surfaces	**8**
V	**The first and second fundamental form** Lengths of curves on surfaces, Isometries of Surfaces, Conformal mappings of surfaces, Surface area, Equiareal maps and a Theorem of Archimedes, The Second Fundamental Form	**8**

Text Book:

Andrew Pressley: Elementary Differential Geometry, Springer International Edition, Indian Reprint 2004. Chapters: 1, 2, 3, 4.1 - 4.4, 5 and 6. 1.

Reference:

John A. Thorpe: Differential Geometry, Springer International Edition, Indian Reprint 2004.

T. Y. B.Sc. Semester VI		
Title of the Course and Course Code	**Mathematics Practical -IV based on MTS3601 & MTS3602** **MTS3607**	**Number of Credits :2**
Course Outcomes (COs) **On completion of the course, the students will be able to:**		
CO1	Articulate and retrieve basic concepts of first semester complex analysis.	
CO2	Define residues and poles and its basic terminology. Categorize, compare verify, examine, create different types of residues and poles.	
CO3	List, carryout, outline and illustrate basic properties and theorems of residues and poles.	
CO4	Apply residues and poles to evaluate improper integrals. List, carryout, outline and illustrate theorems on complex integration.	
CO5	Define, classify, illustrate, verify, invent mappings by elementary functions. List, carryout, outline and illustrate theorems on these concepts.	
CO6	Define, classify, illustrate, verify, invent conformal mappings. List, carryout, outline and illustrate theorems on these concepts.	

Sr. No.	**Topic**	**No. of Practicals**
	Topic 1: Real Analysis-II	8
I	Sequence of functions I: Convergence	8
II	Sequences of Functions II : Integration and differentiation	4
III	Series of Functions	8
IV	Elementary Functions	8
V	Improper Integrals	
VI	Differentiation Under the Integral Sign and its applications	
	Topic 2: Complex Analysis-II	
I	Residue and poles	
II	Evaluation of improper integrals	
III	Applications of Residue and poles	
IV	Mappings by elementary functions	
V	Conformal mappings	
VI	Applications of Conformal mappings	

T. Y. B.Sc. Semester VI		
Title of the Course and Course Code	**Mathematics Practical -V based on MTS3603 & MTS3604 MTS3608**	**Number of Credits :2**
Course Outcomes (COs) On completion of the course, the students will be able to:		
CO1	Articulate and retrieve basic concepts of integers, polynomials, matrices, functions and group theory.	
CO2	Define ring and its basic terminology. Categorize, compare verify, examine, create different examples of rings.	
CO3	List, carryout, outline and illustrate basic properties and theorems of rings.	
CO4	Define, classify, illustrate, verify, invent ideals, subrings of a ring. List, carryout, outline and illustrate theorems on these concepts.	
CO5	Define, classify, illustrate, verify, invent different types of domains. List, carryout, outline and illustrate theorems on these concepts.	
CO6	Define, classify, illustrate, verify, invent polynomial rings and so learn concepts of irreducible polynomials. List, carryout, outline and illustrate theorems on these concepts.	

Sr. No.	Topic	No. of Practicals
	Topic 1: Ring Theory	8
I	Polynomial rings and matrix rings	8
II	Rings of Fractions, The Chinese Remainder Theorem	4
III	Euclidean Domains	8
IV	Principal Ideal Domains	8
V	Unique Factorization Domains	
VI	Miscellaneous	
	Topic 2: Dynamical Systems	
I	Dynamics of First Order Equations	
II	Planar Linear Systems	
III	Higher Dimensional linear systems	
IV	Non-linear Systems	
V	Discrete Dynamical system	
VI	Miscellaneous	

T. Y. B.Sc. Semester VI		
Title of the Course and Course Code	**Mathematics Practical -VI based on SEC MTS3609**	**Number of Credits :2**
Course Outcomes (COs) On completion of the course, the students will be able to:		
CO1	Recall and articulate basic concepts of forwards and futures Calculate and illustrate the value of a future contract discrete and continuous compounding Discuss, execute, explain, illustrate, use of replicating portfolios	
CO2	Construct hedging, translate, formulate currency future and stock index	

	futures
CO3	Define, explain call and put options and their types, Evaluate them
CO4	Define and explain put-call parity and solve various problems model. Use, execute and explain various factors which affect the stock options
CO5	Define, explain, Black Scholes model and use of the formula. Define, Explain and use Greeks.
CO6	Formulate BOPM, Calculate and illustrate BOPM formula and Discuss, execute, explain, illustrate, use it.

(Any Two of the Following)

Sr. No.	**Topic 1: Optimization Techniques**	**No of Practicals**
I	Network Models	
II	Decision Analysis and Games	
III	Replacement and Maintenance Models	
IV	Sequencing Problems	
V	Classical Optimization Theory	
VI	Miscellaneous	
	Topic 2: Financial Mathematics-I	
I	Forwards and Future	
II	Call and Put Options	
III	Binomial Option pricing Model	
IV	Greeks	
V	Black-Scholes Formula	
VI	Miscellaneous	
	Topic 3: Graph Theory	
I	Properties of Graph	
II	Paths and cyclyes-I	
III	Paths and cyclyes-II	
IV	Trees	
V	Planarity	
VI	Miscellaneous	
	Topic 4: Lebesgue Integration	
I	Measurable Sets	
II	Measurable Functions	
III	Lebesgue Integrals-I	
IV	Lebesgue Integrals-II	

V	Fourier Series	
VI	Miscellaneous	
	Topic 5: Mathematical Models in Population Biology	
I	Continuous Population Model-I	
II	Continuous Population Model-II	
III	Discrete Population Model-I	
IV	Discrete Population Model-II	
V	Population Model with delays	
VI	Miscellaneous	

T. Y. B.Sc. Semester VI		
Title of the Course and Course Code	**Optimization Techniques MTS3611**	**Number of Credits :2**
Course Outcomes (COs) On completion of the course, the students will be able to:		
CO1	Describe and list the activities, CPM and PERT.	
CO2	Explain, classify, compare different decision criterion. Discuss properties of game.	
CO3	Execute types of failure and replacement policy of items.	
CO4	Explain sequencing problem of job by verifying optimal sequence.	
CO5	Assess and execute unconstrained problems, solve and construct optimal solution using various methods.	
CO6	Construct, create, design, test critical path, time schedule. Formulate LPP of game, CPM and PERT.	

Unit. No.	Title of Unit and Contents	No. of Lectures
I	**Network Models** CPM and PERT, Network representation, Critical Path Computations, Constru ction of the time schedule, Linear programming formulation of CPM, PERT calculations	**8**
II	**Decision Analysis and Games** Decision under uncertainty, Game theory, some basic terminologies, optimal solution of two person zero sum game, Solution of mixed strategy games, graphical solution of games, linear programming solution of games	**8**
III	**Replacement and Maintenance Models** Introduction, Types of failure, Replacement of items whose efficiency deteriorates with time	**6**
IV	**Sequencing Problems** Introduction, Notation, terminology and assumptions, processing n jobs through two machines, processing jobs	**6**

	through three machines	
V	**Classical Optimization Theory** Unconstrained problems, Necessary and sufficient conditions, Newton Raphson method, Constrained problems, Equality constraints(Lagrangian)	8

Text Books:

1. Hamdy A. Taha, Operation Research (Eighth Edition, 2009), Prentice Hall of India Pvt. Ltd., New Delhi.
   Ch.6: 6.5 (6.5.1 to 6.5.5).**Ch.13:** 13.3, 13.4 (13.4.1, 13.4.2, 13.4.3).
   Ch.18: 18.1 (18.1.1, 18.1.2), 18.2 (18.2.1).
2. J. K. Sharma, Operations Research (Theory and Applications, Second Edition, 2006), Macmillan India Ltd. **Ch.17:** 17.1, 17.2, 17.3. **Ch.20:** 20.1, 20.2, 20.3, 20.4.

Reference Books:

1 Frederick S. Hillier, Gerald J. Lieberman, Introduction to Operations Research (Eighth Edition), Tata McGraw-Hill.

2 Hira and Gupta, Operations Research.

T. Y. B.Sc. Semester VI		
Title of the Course and Course Code	**Financial Mathematics-II** **MTS3612**	**Number of Credits :2**
Course Outcomes (COs) **On completion of the course, the students will be able to:**		
CO1	Recall and articulate basic concepts of forwards and futures Calculate and illustrate the value of a future contract discrete and continuous compounding Discuss, execute, explain, illustrate, use of replicating portfolios	
CO2	Construct hedging, translate, formulate currency future and stock index futures	
CO3	Define, explain call and put options and their types, Evaluate them	
CO4	Define and explain put-call parity and solve various problems model. Use, execute and explain various factors which affect the stock options	
CO5	Define, explain, Black Scholes model and use of the formula. Define, Explain and use Greeks.	
CO6	Formulate BOPM, Calculate and illustrate BOPM formula and Discuss, execute, explain, illustrate, use it.	

Unit. No.	Title of Unit and Contents	No. of Lectures
I	**Forward and futures** Forward and futures, Forward and futures price, value of a future contract, method of replicating portfolios, hedging with futures, currency futures, stock index futures.	**12**
II	**Options** Call options, put options, put-call parity, binomial options pricing model, pricing American options, factor influencing option premiums, options on assets with dividends, dynamic hedging, risk-neutral valuation	**12**

III	**The black-scholes model** Risk-neutral valuation, the Black-Scholes formula, options on futures, options on assets with dividends, black-scholes and BOPM, implied volatility, dynamic hedging, the greeks, speculating with options	**12**

Reference:

1. Amber Habib, The Calculus of Finance, Universities Press.
2. Luenberger, Investment Science, Cambridge University Press
3. John Hull, Option Futures and other derivatives, Prentice Hall.

T. Y. B.Sc. Semester VI		
Title of the Course and Course Code	**Graph Theory** **MTS3613**	**Number of Credits :2**
Course Outcomes (COs) **On completion of the course, the students will be able to:**		
CO1	Define graph and its basic terminology, trees, planar graphs, paths and cycles with different examples.	
CO2	Articulate, categorize, compare and retrieve basic concepts of induction, logic and methods of proofs for studying trees, planar graphs, paths and cycles.	
CO3	Illustrate basic terminology, trees, planar graphs, paths and cycles. Carryout, outline theorems on these concepts.	
CO4	Classify, basic terminology, trees, planar graphs, paths and cycles.	
CO5	Verify, invent trees, planar graphs, paths and cycles.	
CO6	Create different types of graphs and counter examples on trees, planar graphs, paths and cycles.	

Unit. No.	**Title of Unit and Contents**	**No. of Lectures**
I	**Introduction** Definitions, examples of various types of graphs, degree of a graph, connected graph, sub graphs, isomorphism of graphs, matrix representation of a graph, three puzzles: the eight circles problem, six people at a party, the four cubes problem	**8**
II	**Paths and cycles** Definitions, walk, trail, path, cycle, bounds on number of edges in a simple graph, disconnecting set, edge connectivity, separating set, vertex connectivity, girth, distance, independent edges, connected graph, edge connectivity, Eulerian trail, Eulerian graphs, semi Eulerian graphs, non Eulerian graphs, characterizations of Eulerian graphs, Fleury's algorithm, Hamiltonian cycle, Hamiltonian	**10**

	graphs, semi Hamiltonian graphs, non-Hamiltonian graphs, Ore's theorem, Dirac's theorem, the shortest path problem, weighted graph, the Chinese postman problem, the travelling salesman problem.	
III	**Trees** Forest, tree, characterizations of trees, Properties of trees, spanning trees, spanning forest, cycle rank, cut-set rank, complement, fundamental set of cycles, fundamental set of cut-sets, center, counting trees, Cayley's theorem, matrix-tree theorem (without proof), Counting trees, applications - The minimum connector problem, greedy algorithm, enumeration of chemical molecules, electrical networks, searching trees, depth first search algorithm, breadth first search algorithm	**10**
IV	**Planarity** Planar graph, characterization of Planar graph (Kuratowski's theorem), crossing number, Euler's formula, corollaries of Euler's formula, thickness, dual graphs, abstract dual, infinite graph	**8**

Text Book:

R. J. Wilson, Introduction to Graph Theory, 4th Edition, Pearson Education, 2003.
Sections: 2 to 13, 17 to 21.

Reference:

1. A First Look at Graph Theory, John Clark and Derek Allan Holton, Allied Publishers Ltd., 1991.
2. Graph Theory, Hararay, Narosa Publishers, New Delhi (1989).
3. Graph Theory, Narsing Deo, Prentice Hall of India Pvt. Ltd. (1987).
4. Basic Graph Theory, K. R. Parthsarathy, Tata McGraw-Hill Publisher Co. Ltd.

T. Y. B.Sc. Semester VI		
Title of the Course and Course Code	**Lebesgue Integration** **MTS3614**	**Number of Credits :2**
Course Outcomes (COs) **On completion of the course, the students will be able to:**		
CO1	Recall sets of measure zero, Riemann integrable functions, open sets, closed sets, sequences of functions, inner product, norm linear space. Identify the integrable functions, even, odd functions, periodic functions. State the properties of functions, lub axiom, opens sets, closed sets.	
CO2	Categorize the Riemann integrable functions and Lebesgue integrable functions. Compare measurable functions, integrable functions. Extrapolate	

	the limit of sequence of measurable functions, integrable functions. Give example of non-integrable functions, non-measurable functions, non-measurable set. Illustrate statements with a particular example. Compute sequence of integrable functions that converges to an unbounded function. Compute integral of a function. Compute Fourier series of a function.
CO3	Apply properties of measurable sets to evaluate measure of a set. Apply properties of measurable functions to check the measurability and integrability of a function. Examine a set for measurability. Examine a function for measurability, integrability. Apply dominated convergence theorem to check the integrability of a function. Apply Fatou's lemma to evaluate limit of integrals of a sequence of functions. Use Fourier series to evaluate infinite sums. Use Dirichlet's conditions to check the convergence of Fourier series.
CO4	Classify sets according to measurability. Classify functions according to measurability, integrability. Compare limit of integrals of sequence of functions and integral of limit. Compare sets according to their measure, integrals of functions. Explain applicability of theorems in a particular situation.
CO5	Evaluate measure of a set, integral of a function. Compare functions and their integrals on different sets. Criticize the measurability of sets, functions, integrability of functions. Convince the applicability of theorems. Determine Fourier series of a function. Discriminate the properties of Riemann integrable and Lebesgue integrable functions.
CO6	Create example of non-measurable function. Generate counter examples for the theorems. Hypothesize the conditions for integrability of a function, interchange of limit and integration of a sequence of functions, convergence of Fourier series. Formulate the problems in support of the statements. Modify the statements so as to get the desired result. Modify the statements and propose the conclusion.

Unit. No.	**Title of Unit and Contents**	**No. of Lectures**
I	**Measurable Sets** Length of open sets and closed sets, Inner and outer measure, Measurable sets, Properties of measurable sets	**6**
II	Measurable Functions	**10**
III	**The Lebesgue Integrals** Definition and example of the Lebesgue integrals for bounded functions, Properties of Lebesgue integrals for bounded measurable functions, The Lebesgue integral for unbonded functions, Some fundamental theorems	**10**
IV	**Fourier Series** Definition and examples of Fourier Series, Formulation of convergence problems, Parseval's theorem	**10**

Text Book:

Richard R. Goldberg, Methods of Real Analysis, Oxford and IBH Publishing Co. Pvt. Ltd., (1970). (Chapter No. 11, 11.1 to 11.8, 12.1, 12.2. Theorem No. 11.1B and 11.1C, 11.8D).

Reference:

Apostol, Advanced Calculus, 2nd Edition, Prentice Hall of India, 1994.
D. Somasundaram and B. Choudhari, a first course in Mathematical Analysis, Narosa Publishing House, 1997.
R. G. Bartle and D. R. Scherbert, Introduction to Real Analysis, 4th Edition, John Wiley, 2012.

T. Y. B.Sc. Semester VI		
Title of the Course and Course Code	**Mathematical Models in Population Biology MTS3615**	**Number of Credits :2**
Course Outcomes (COs) **On completion of the course, the students will be able to:**		
CO1	Recall ordinary differential equations. Reproduce the differential equation from the discrete data. Formulate the differential equations and name it. Name the tyle of equilibria, type of differential equations, type of model.	
CO2	Arrange data to formulate the model. Compare model with actual data. Categorize discrete data, model, solutions. Differentiate the model according to the geometry and accuracy. Sketch the solutions of and compare with the given data. Explain the validity of solution up to certain accuracy.	
CO3	Calculate solution of difference equations, solutions of differential equations. Demonstrate the model for a given data. Examine the feasibility of model, Chaotic behaviour of a model. Generalize the statements from a model. Modify the model to get the desired accuracy. Predict future of the system from the model. Manipulate the constraints and interpret change in the behaviour.	
CO4	Analyse the constraints to formulate the model. Compare the model with the standard equations. Sketch the diagrams for the model, nature of solutions. Explain the behaviour nature of equilibrium points, Chaotic behaviour, validity of models. Relate the model with the standard equations.	
CO5	Evaluate the solutions from the model. Compare the solutions for various data sets. Criticize the nature of solution in the context of parameters. Justify the feasibility of model. Convince the applicability of a model with supporting examples.	
CO6	Create a data to model a system of equations. Combine a data to formulate the model. Hypothesize the conditions on data set for better modelling. Generate solutions form the given data. Invent a model for a specific case study. Generate a model for specific expectations. Propose the solutions form model or a given data.	

Unit. No.	Title of Unit and Contents	No. of Lectures
I	**Continuous Population Models:** Exponential Growth, The Logistic Population Model, The Logistic Equation in Epidemiology, Qualitative Analysis, Harvesting in Population Models, Constant-Yield Harvesting, Constant-Effort Harvesting, Eutrophication of a Lake: A Case Study	**12**
II	**Discrete Population Models:** Introduction: Linear Models, Graphical Solution of Difference Equations, Equilibrium Analysis, Period-Doubling and Chaotic Behaviour, Discrete–	**12**

	Time Metered Models, A Two-Age Group Model and Delayed Recruitment, Systems of Two Difference Equations. Oscillation in Flour Beetle Populations: A Case Study	
III	**Continuous Single-Species Population Models with Delays:** Introduction, Models with Delay in Per Capita Growth Rates, Delayed-Recruitment Models, Models with Distributed Delay, Harvesting in Delayed Recruitment Models,Constant-Effort Harvesting, Constant-Yield Harvesting, Nicholson's Blowflies: A Case Study	**12**

Textbook:
Fred Brauer , Carlos Castillo-Chavez, Mathematical Models in Population Biology and Epidemiology, Second Edition, Springer Verlag

Reference Books:

1 J. D. Murray, Mathematical Biology I. An Introduction, Third Edition

2 Elizabeth S. Allman, John A. Rhodes, Mathematical Models In Biology An Introduction, Cambridge University Press.

3 Mazen Shahin, Exploration of Mathematical Models in Biology with MATLAB, Wiley

4 Alessandra Rogato,Valeria Zazzu, Mario Guarracino, Dynamics of Mathematical Models in Biology-Bringing Mathematics to Life, Springer