Deccan Education Society's

Fergusson College (Autonomous), Pune

Department of Mathematics

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

To be implemented from academic year 2021-22

Deccan Education Society's
Fergusson College (Autonomous), Pune
Syllabus under Autonomy for T.Y.B.A. (Mathematics)
Under CBCS pattern (2019) *effective from June 2021*

Sem.	**Paper No.**	**Course code**	**Title**	**Credits**	**CE maximum Marks**	**ESE maximum Marks**	**Total maximum Marks**
V	SEC-1C	MTA3501	Real Analysis-I	3	50	50	100
	SEC-1D	MTA 3502	Group Theory	3	50	50	100
	SEC-1E	MTA 3503	Financial Mathematics-I	3	50	50	100
	DSE-1C	MTA 3504	Advanced Linear Algebra	4	50	50	100
	DSE-2C	MTA 3505	Complex Analysis-I	4	50	50	100
	SEC-1F	MTA 3506	Metric Spaces-I	2	50	50	100
			Total Credits	**19**			**600**
VI	SEC-1F	MTA 3601	Real Analysis-II	3	50	50	100
	SEC-1G	MTA 3602	Ring Theory	3	50	50	100
	SEC-1H	MTA 3503	Financial Mathematics-II	3	50	50	100
	DSE-1D	MTS 3604	Dynamical Systems	4	50	50	100
	DSE-2D	MTS 3605	Complex Analysis-II	4	50	50	100
	SEC-1H	MTA 3606	Metric Spaces-II	2	50	50	100
			Total Credits	**19**			**600**

T. Y. B.A. Semester V		
Title of the Course and Course Code	**Real Analysis-I** **MTA3501**	**Number of Credits : 03**
Course Outcomes (COs) **On completion of the course, the students will be able to:**		
CO1	Retrive the structure of system of real numbers. Define lub axiom, countability of subsets of real numbers, convergence of sequences and series, integrability of functions. Show the convergence of sequences and sequences, integrability of functions. State the conditions for lub, convergence of sequences and series, properties of integrable functions, conditions for integrability.	
CO2	Classify countable and uncountable sets. Compare the sets and their subsets in the context of countability. Distinguish convergent and divergent sequences and series. Estimate limit of sequence, series, integral of a function. Give examples to counter the statements/theorems on countability, convergence of sequences and series, integrability of functions. Explain the tests for convergence of sequences and series and illustrate with examples. Interpret properties of integrals, Fundamental theorem of calculus, Mean value theorems geometrically.	
CO3	Apply countability theorems to test the countability of sets. Use convergence tests/statements to discuss the convergence of sequences and series. Examine the set for its countability, sequences and series for convergence, functions for integrability. Illustrate the statements with supporting examples. Apply calculus to examine the integrability of functions and properties of integrable functions.	
CO4	Demonstrate the statements with diagrams. Arrange the sets according to their cardinalities. Analyse the sequences and series to apply proper test/technique to discuss the convergence. Invent examples in support of statements and their converses, in counter to the statements. Organise the statements in order to generalise the concepts. Identify the properties of functions to predict their integrability.	
CO5	Determine supremum, infimum of a set and justify. Determine maps between two sets, equivalent sets and justify. Evaluate limit of sequences and sums of series, integrals. Criticize the statements by arguments and/or counter examples. Discriminate the countable and uncountable set, convergent and divergent sequences and series, integrable and non-integrable functions. Justify the statements by arguments and/or suitable examples.	
CO6	Produce bijective maps between equivalent sets. Create counter examples to the statements about sequences, series and integrable functions. Modify/rewrite the statements in order to make it valid. State the hypothesis in order to get the desired outcome/result. Rearrange the statements so as to make the valid statement. Generate new statements for the expected outcome.	

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, Subsequences: Monotone subsequence theorem, Bolzano-Weierstrass Theorem, Cauchy sequences, Cauchy criteria for convergent sequences, Contracting sequences.	**11**
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.

References:

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.

Title of the Course and Course Code	**Group Theory** **MTA3502**	**Number of Credits : 03**
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.	

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, Zn, Zn*, direct product, Matrix group under addition and multiplication, Dihedral Groups: order of Dn, generators and relations Symmetric Groups: Order of Sn, Cycle decomposition algorithm, disjoint cycles, commute, permutations, order of an element in Sn Matrix Groups: Gln(F), order of Gln(F) The Quaternion Group Homomorphisms and Isomorphisms.	**10**
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	**10**

	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.	
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.

References:

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.

Title of the Course and Course Code	**Financial Mathematics-I** **MTA3503**	**Number of Credits : 03**
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.

Title of the Course and Course Code	**Advanced Linear Algebra - MTA3504**	**Number of Credits : 04**
Course Outcomes (COs) On completion of the course, the students will be able to:		
CO1	Recall and state definitions of regarding rank of matrix, determinants, eigenvalues and eigenvectors, canonical forms. Identify proper elementary operation on matrices, eigenvectors, Jordan canonical forms.	
CO2	Classify canonical forms of matrices, compare nature of matrices, Associate linear transform with matrix. Differentiate matrices, linear transformations according to rank, eigenvalues and eigenvectors, Jordan canonical forms. Predict determinant, canonical forms of matrix and represent matrices into canonical form.	
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. Reduce matrix to echelon form and get rank of a matrix, evaluate solutions of system of equations. Determine invertible matrix to diagonalize a matrix, diagonalize the matrix and verify its validity. Evaluate canonical form of a matrix and use it to find minimal polynomial.	
CO6	Hypothesize the conditions for invertibility of matrix, solving system of equations, to get specific canonical forms. Produce the examples and counter examples in support to the theory. Develop the technics to find determinant of matrix, to get canonical form of matrix in specific cases. Write possible matrices form eigenvalue, eigenvectors, determinant and canonical forms.	

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

References:

1. Howard Anton, Chris Rorres, *Elementary Linear Algebra: Applications Version*,
2. Wiley (11th Edition)
3. Steven J. Leon, *Linear Algebra with Applications*, Pearson
4. Titu Andreescu, *Essential Linear Algebra with Applications-A Problem Solving Approach,*
5. Birkhauser.
6. Gene H. Golub, Charles F. Van Loan, *Matrix Computations*, The Johns Hopkins
7. University Press, Baltimore (Fourth Edition)
8. Theodore Shifrin, Malcolm R. Adams, *Linear Algebra-A Geometric Approach*, W. H.
9. Freeman and Company, New York.

Title of the Course and Course Code	**Complex Analysis-I - MTA3505**	**Number of Credits : 04**
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	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.	

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 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	**4**

	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.

References:

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).

Title of the Course and Course Code	**Metric Spaces - MTA3506**	**Number of Credits : 02**
Course Outcomes (COs) **On completion of the course, the students will be able to:**		
CO1	Recall and articulate basic concepts of real numbers, discuss open and explain the open and closed intervals in R. Classify the intervals and sets into, open and closed sets.	
CO2	Examine continuous functions, compact sets in R, Discriminate, check, evaluate and create different types of functions and compact sets in R.	
CO3	Define metric spaces. Explain, solve and test different metrices on general metric space. Define different inequalities and apply them to check metrices. Examine the structure of open sets in R.	
CO4	Define sequences and their properties. Apply it to check and classify compact, connected, dense sets.	
CO5	Define, classify, illustrate, examine, verify continuous functions on general metric space. Discriminate, check, evaluate and create different types of functions.	
CO6	Recall and articulate basic concepts of real numbers, discuss open and explain the open and closed intervals in R. Classify the intervals and sets into, open and closed sets.	

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	**10**

	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	
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 lemma for metric spaces, Tietze extension theorem for metric spaces (statement only) ,Uniform continuity, limit of a function, open and closed maps	**10**

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.

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.A. Semester VI		
Title of the Course and Course Code	**Real Analysis-II - MTA3601**	**Number of Credits :03**
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. State the convergence tests for sequences and series of functions, conditions for convergence of improper integrals, conditions for DUIS. 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. Discuss the convergence of sequences and series of functions, domain, range and properties of elementary functions, convergence of improper integrals. Estimate the limit of sequences and series, improper integrals, integrals using DUIS. Illustrate the validity of statements by suitable examples. Restate the statements in order to get the desired conclusion.	
CO3	Apply tests of convergence for sequences and series for functions, improper integrals. Apply properties of elementary functions to prove identities. Apply 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. Demonstrate the proofs of theorems, validity of statements. Generalize the statements for large class of functions/sequences of functions. Manipulate the statements by inserting parameter(s)/conditions in the original statements. Interpret the theorems/statements geometrically.	
CO4	Analyse the sequence and series of function to test the pointwise or uniform convergence. Analyse 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. Integrate the properties in order to apply the theorem/result. Identify the suitable function to test absolute convergence of series of functions, improper integrals.	
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. Judge the validity of statements by producing supporting example. Justify the validity of statements by arguments/supporting examples.	
CO6	Produce counter examples for false statements, non-validity of converse of the statement. Combine statements and predict the result. Design the	

	statement form examples. State the hypothesis for validity of statement. Modify the statement/theorem and state the conclusion. Formulate the new statement from given data.

Unit. No.	Title of Unit 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.

References:

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
6. Publishing House, 1997.

Title of the Course and Course Code	**Ring Theory - MTA3602**	**Number of Credits :03**

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.

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.

References:

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. N. Herstein, Abstract Algebra.

Title of the Course and Course Code	**Financial Mathematics-II - MTA3603**	**Number of Credits :03**
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**

References:

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

Title of the Course and Course Code	**Dynamical Systems - MTA3604**	**Number of Credits :04**
Course Outcomes (COs) **On completion of the course, the students will be able to:**		
CO1	Recall differentiable functions, eigenvalues and eigenvectors of matrix, canonical forms of matrices. Match the system of equations with phase portrait, 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. Differentiate systems according to the equilibrium points, differentiate equilibrium points according to their stability. Transform nonlinear system to linear system locally. 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. Dramatize the bifurcation by manipulating the arbitrary constants in the system. Predict the nature of the system when the system is modified.	
CO4	Analyse the nature of solution by the differential equations. Connect nonlinear systems with conjugate linear systems. Discriminate the systems according to the stability, type of critical points, type of bifurcations. Explain the bifurcation in detail. 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. Discriminate systems according to the type of critical points, bifurcations. Recommend the appropriate techniques for solving the 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. Modify the system and describe the nature of solution.	

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, on-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.

References:

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

Title of the Course and Course Code	**Complex Analysis-II - MTA3605**	**Number of Credits :04**
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 Books:

1. S. Ponnusamy, Complex Analysis, Second Edition Narosa.

2 J. M. Howie, Complex Analysis, Springer, 2003.
1. S. Lang, Complex Analysis, (Springer, Verlag).
2. A. R. Shastri, An Introduction to Complex Analysis, (MacMillan)

Title of the Course and Course Code	**Metric Spaces-II - MTA3606**	**Number of Credits :02**
Course Outcomes (COs) On completion of the course, the students will be able to:		
CO1	Recall and articulate basic concepts of metric spaces, Discuss continuous functions and their properties. Classify connected subsets of R.	
CO2	Examine connected spaces. Discriminate, check, evaluate and create different types connected spaces, sets.	
CO3	Define compact metric spaces. Explain, solve and test different compact metric space.	
CO4	Discuss continuous functions on compact metric spaces. Classify, illustrate, verify, invent different compact metric spaces.	
CO5	Define complete metric space. Discuss, classify, verify, invent and create different complete metric spaces.	
CO6	Recall and articulate basic concepts of metric spaces, Discuss continuous functions and their properties. Classify connected subsets of R.	

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 without proof), 5.1
and 6.1 (Theorems 6.1.1, 6.1.3, 6.1.11, without proofs).

Reference Books:

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