(UNIVERSITY OF MUMBAI)

Syllabus for: F.Y.B.Sc./F.Y.B.A.

Program: B.Sc./B/A.
Course: Mathematics
Choice based Credit System (CBCS)
with effect from the
academic year 2018-19

SEMESTER I

CALCULUS I				
Course Code	UNIT	TOPICS	Credits	L/Week
USMT 101, UAMT 101	I	Real Number System	2	3
	II	Sequences		
	III	Limits and Continuity		
ALGEBRA I				
USMT 102	I	Integers and Divisibility	2	3
	II	Functions and equivalence Relation		
	III	Polynomials		
PRACTICALS				
USMTP01	-	Practicals based on USMT101, USMT102	2	2

SEMESTER II

CALCULUS I				
Course Code	UNIT	TOPICS	Credits	L/Week
USMT 201, UAMT 201	I	Infinite Series	2	3
	II	Continuous functions and Differentiation		
	III	Applications of Differentiability		
ALGEBRA II				
USMT 102	I	System of Linear Equations and Matrices	2	3
	II	Vector Spaces		
	III	Basis & Linear Transformation		
PRACTICALS				
USMTP02	-	Practicals based on USMT201, USMT202	2	2

Teaching Pattern for Semester I

[1.] Three lectures per week per course. Each lecture is of 48 minutes duration.

[2.] One Practical (2L) per week per batch for courses USMT101, USMT 102 combined (the batches to be formed as prescribed by the University. Each practical session is of 48 minutes duration.)

[3.] One Tutorial per week per batch for the course UAMT101 (the batches to be formed as prescribed by the University). Each tutorial session is of 48 minutes.

Teaching Pattern for Semester II

[1.] Three lectures per week per course. Each lecture is of 48 minutes duration.

[2.] One Practical (2L) per week per batch for courses USMT201, USMT 202 combined (the batches to be formed as prescribed by the University. Each practical session is of 48 minutes duration.)

[3.] One Tutorial per week per batch for the course UAMT101 (the batches to be formed as prescribed by the University). Each tutorial session is of 48 minutes.

F.Y.B.Sc. / F.Y.B.A. Mathematics

SEMESTER I

USMT 101, UAMT 101: CALCULUS I

Note: All topics have to be covered with proof in details (unless mentioned otherwise) and examples.

Unit 1 : Real Number System (15 Lectures)
Real number system $\mathbb{R}$ and order properties of $\mathbb{R}$, absolute value $|\ |$ and its properties.

AM-GM inequality, Cauchy-Schwarz inequality, Intervals and neighbourhoods, interior points, Hausdorff property.

Bounded sets, statements of I.u.b. axiom and its consequences, supremum and infimum, maximum and minimum, Archimedean property and its applications, density of rationals.

Unit II: Sequences (15 Lectures)
Definition of a sequence and examples, Convergence of sequences, every convergent sequences is bounded. Limit of a convergent sequence and uniqueness of limit, Divergent sequences.

Convergence of standard sequences like $\left(\dfrac{1}{1+na}\right)$ $\forall a > 0$, (b^n) $\forall b, 0 < b < 1$, $(c^{\frac{1}{n}})$ $\forall c > 0$, & $(n^{\frac{1}{n}})$
Algebra of convergent sequences, sandwich theorem, monotone sequences, monotone convergence theorem and consequences as convergence of $\left(\left(1+\dfrac{1}{n}\right)^n\right)$

Definition of subsequence, subsequence of a convergent sequence is convergent and converges to the same limit, definition of a Cauchy sequences, every convergent sequences s a Cauchy sequence and converse.

Unit III: Limits and Continuity (15 Lectures)

Brief review: Domain and range of a function, injective function, surjective function, bijective function, composite of two functions, (when defined) Inverse of a bijective function.

Graphs of some standard functions such as $|x|, e^x, \log x, ax^2+bx+c, \frac{1}{x}, x^n n \geq 3), \sin x, \cos x, \tan x, \sin\left(\frac{1}{x}\right), x^2$ s over suitable intervals of $\mathbb{R}$.

Definition of Limit $\lim\limits_{x \longrightarrow a} f(x)$ of a function $f(x)$, evaluation of limit of simple functions using the $\epsilon - \delta$ definition, uniqueness of limit if it exists, algebra of limits, limits of composite function, sandwich theorem, left-hand-limit $\lim\limits_{x \longrightarrow a^-} f(x)$, right-hand-limit $\lim\limits_{x \longrightarrow a^+} f(x)$, non-existence of limits, $\lim\limits_{x \longrightarrow -\infty} f(x)$, $\lim\limits_{x \longrightarrow \infty} f(x)$ and $\lim\limits_{x \longrightarrow a} f(x) = \pm\infty$.

Continuous functions: Continuity of a real valued function on a set in terms of limits, examples, Continuity of a real valued function at end points of domain, Sequential continuity, Algebra of continuous functions, discontinuous functions, examples of removable and essential discontinuity.

Reference Books:

1. R.R. Goldberg, Methods of Real Analysis, Oxford and IBH, 1964.
2. K.G. Binmore, Mathematical Analysis, Cambridge University Press, 1982.
3. R. G. Bartle- D. R. Sherbert, Introduction to Real Analysis, John Wiley & Sons, 1994.

Additional Reference Books

1. T.M. Apostol, Calculus Volume I, Wiley & Sons (Asia) Pte, Ltd.
2. Richard Courant-Fritz John, A Introduction to Calculus and Analysis, Volume I, Springer.
3. Ajit kumar- S. Kumaresan, A Basic Course in Real Analysis, CRC Press, 2014.
4. James Stewart, Calculus, Third Edition, Brooks/ cole Publishing Company, 1994.
5. Ghorpade, Sudhir R.-Limaye, Balmohan V., A Course and Real Analysis, Springer International Ltd.2000.

ALGEBRA I
USMT 102

Prerequisites:

Set Theory: Set, subset, union and intersection of two sets, empty set, universal set, complement of a set, De Morgans laws, Cartesian product of two sets, Relations, Permutations ${}^nP_r$ and Combinations ${}^nC_r$.

Complex numbers: Addition and multiplication of complex numbers, modulus, amplitude and conjugate of a complex number.

Unit I : Integers & Divisibility (15 Lectures)

Statements of well-ordering property of non-negative integers, Principle of finite induction (first and second) as a consequence of well-ordering property, Binomial theorem for non-negative exponents, Pascal Triangle.

Divisibility in integers, division algorithm, greatest common divisor (GCD) and least common multiple (L.C.M) of two integers, basic properties of GCD such as existence and uniqueness of GCD of integers a & b and that the GCD. can be expressed as $ma + nb$ for some $m, n\mathbb{Z}$, Euclidean algorithm, Primes, Euclids lemma, Fundamental Theorem of arithmetic, The set of primes is infinite.

Congruence, definition and elementary properties, Eulers ϕ function, statements of Eulers theorem, Fermats theorem and Wilsons theorem, Applications.

Unit II : Functions and Equivalence relations (15 Lectures)

Definition of function, domain, co-domain and range of a function, composite functions, examples, Direct image $f(A)$ and inverse image $f^{-1}(B)$ for a function f, injective, surjective, bijective functions, Composite of injective, surjective, bijective functions when defined, invertible functions, bijective functions are invertible and conversely examples of functions including constant, identity, projection, inclusion, Binary operation as a function, properties, examples.

Equivalence relation, Equivalence classes, properties such as two equivalences classes are either identical or disjoint, Definition of partition, every partition gives an equivalence relation and vice versa.

Congruence is an equivalence relation on $\mathbb{Z}$, Residue classes and partition of $\mathbb{Z}$, Addition modulo$n$, Multiplication modulo n, examples.

Unit III: Polynomials (15 Lectures)

Definition of a polynomial, polynomials over the field F where $lF = \mathbb{Q}, \mathbb{R}$ or $\mathbb{C}$, Algebra of polynomials, degree of polynomial, basic properties.

Division algorithm in $\mathcal{F}[X]$ (without proof), and g.c.d of two polynomials and its basic properties (without proof), Euclidean algorithm (without proof), applications, Roots of a polynomial, relation between roots and coefficients, multiplicity of a root, Remainder theorem, Factor theorem.

A polynomial of degree over n has at most n roots roots, Complex roots of a polynomial in $\mathbb{R}[X]$ occur in conjugate pairs, Statement of Fundamental Theorem of Algebra, A polynomial of degree in $\mathbb{C}[X]$ has exactly n complex roots counted with multiplicity, A non-constant polynomial in $\mathbb{R}[X]$ can be expressed as a product of linear and quadratic factors in $\mathbb{R}[X]$, necessary condition for a rational number $\frac{p}{q}$ to be a root a polynomial with integer coefficients, simple consequences such as $\sqrt{p}$ is a irrational number where p is a prime number, roots of unity, sum of all the roots of unity.

Reference Books:

David M. Burton, Elementary Number Theory, Seventh Edition, McGraw Hill Education (India) Private Ltd. Norman L.

PRACTICALS FOR F.Y.B.Sc
USMTP01 Practicals

A. **Practicals for USMT101:**

(1) Application based examples of Archimedean property, intervals, nieghbourhood, interior point, Absolute Value

(2) Consequences of l.u.b axiom, infimum and supremum of sets Bounded sets

(3) Calculating limits of sequences, Cauchy sequences, monotone sequences.

(4) Limits of function and Sandwich theorem, continuous and discontinuous functions.

(5) Miscellaneous Theoretical Questions based on full paper.

B. **Practicals for USMT102:**

(1) Mathematical induction ,Division Algorithm and Euclidean algorithm in $\mathbb{Z}$, primes and the Fundamental theorem of Arithmetic.

(2) Congruence Euler's ϕfunction, Fermat's little theorem, Euler's theorem and Wilson's theorem.

(3) Functions (direct image and inverse image), Injective, surjective, bijective functions, finding inverses of bijective functions. Equivalence relation.

(4) Factor Theorem, relation between roots and coefficients of polynomials, factorization and reciprocal polynomials.

(5) Miscellaneous Theoretical Questions based on full paper.

TUTORIALS FOR F.Y.B.A

Tutorials for UAMT101:

(1) Application based examples of Archimedean property, intervals, neighbourhood.

(2) Consequence of l.u.b axion, infimum and supremum of sets.

(3) Calculating limits of sequences.

(4) Cauchy sequences, monotone sequences.

(5) Limit of a function and Sandwich theorem.

(6) Continuous and discontinuous function.

(7) Miscellaneous Theoretical Questions based on full paper.

Semester II
USMT 201 CALCULUS II

UNIT - I: Series

Series $\sum_{n=1}^{\infty} a_n$ of real numbers, simple examples of series, Sequence of partial sums of a series, convergence of a series, convergent series, divergent series.

Necessary condition: $\sum_{n=1}^{\infty} a_n$ converges $\Longrightarrow a_n \longrightarrow 0$, but converse not true, algebra of convergent series, Cauchy Criterion, divergence of harmonic series, convergence of $\sum_{n=1}^{\infty} \frac{1}{n^p}$ $(p > 1)$, Comparison test, limit comparison test, alternating sereis, Leibnitz's theorem (alternating series test) and convergence of $\sum_{n=1}^{\infty} \frac{(-1)^n}{n}$, absolute convergence, conditional convergence, absolute convergence implies convergence but not conversely. Ratio test (without proof), root test (without proof) and examples.

UNIT - II: Continuity and differentiability of functions

Continuous function: Continuity of a real valued function on a set in terms of limits, examples, Continuity of a real valued function at end points of domain,Sequential continuity, Algebra of continuous functions, Discontinuous functions ,examples of removable and essential discontinuity.
Intermediate Value theorem and its applications, Bolzano-Weierstrass theorem (statement only): A continuous function on a closed and bounded interval is bounded and attains its bounds. Differentiation of real valued function of one variable: Definition of differentiation a point of an open interval, examples of differentiable and non differentiable functions, differentiable functions are continuous but not conversely, algebra of differentiable functions.

Chain rule, Higher order derivatives, Leibnitz rule, Derivative of inverse functions, Implicit differentiation (only examples)

UNIT - III: Applications of differentiation

Definition of local maximum and local minimum, necessary condition, stationary points, second derivative test, examples, Graphing of functions using first and second derivatives, concave, convex functions, point of inflection.

Rolle's Theorem, Lagranges's and Cauchy's Mean Value Theorems, applications and examples, Monotone increasing and decreasing functions, examples.

L-Hospital rule without proof, examples of indeterminate forms, Taylor's theorem with Langrange's form of remainder with proof, Taylor polynomial and applications.

Reference books:

1. R.R.Goldberg, Methods of Real Analysis, Oxford and IBH, 1964.

2. James Stewart, Calculus, Third Edition, Brooks/ Cole Publishing company, 1994.

3. T.M.Apostol, Calculus, Vol I, Wiley And Sons (Asia) Pte. Ltd.

4. Ghorpade, Sudhir R, -Limaye, Balmohan V, A course in Calculus and Real Analysis, Springer International Ltd, 2000.

Additional Reference:

1. Richard Courant- Fritz John, A Introduction to Calculus and Analysis, Volume-I, Springer.

2. Ajit Kumar- S.Kumaresan, A Basic course in Real Analysis, CRC Press, 2014.

3. K.G. Binmore, Mathematical Analysis, Cambridge University Press, 1982.

4. G.B.Thomas, Calculus, 12th Edition 2009

ALGEBRA II

Prerequisites: Review of vectors in $\mathbb{R}^2, \mathbb{R}^3$ and as points, Addition and scalar multiplication of vectors in terms of co-ordinates, dot-product structure, Scalar triple product, Length (norm) of a vector.

Unit I System of Equations and Matrices (15 Lectures)

Parametric Equation of Lines and Planes , System of homogeneous and non-homogeneous linear Equations, The solution of m homogeneous linear equations in n unknowns by elimination and their geometrical interpretation for $(m, n) = (1, 2), (1, 3), (2, 2), (2, 2), (3, 3)$; Definition of n-tuple of real numbers, sum of n-tuples and scalar multiple of n-tuple.
Matrices with real entries; addition, scalar multiplication of matrices and multiplication of matrices, transpose of a matrix, types of matrices: zero matrix, identity matrix, scalar matrix, diagonal matrix, upper and lower triangular matrices, symmetric matrix, skew symmetric matrix, invertible matrix; Identities such as $(AB)^t = A^tB^t, (AB)^{-1} = A^{-1}B^{-1}$.

System of linear equations in matrix form, Elementary row operations, row echelon matrix, Gaussian elimination method. Deduce that the system of m homogeneous linear equations in n unknowns has a non-trivial solution if $m < n$.

Unit II Vector Spaces (15 Lectures)

Definition of real vector space, Examples such as $\mathbb{R}^n, \mathbb{R}[X], M_{m\times n}(\mathbb{R})$, space of real valued functions on a non-empty set.

Subspace: definition, examples: lines , planes passing through origin as subspaces of respectively; upper triangular matrices, diagonal matrices, symmetric matrices, skew symmetric matrix as subspaces of $M_n(\mathbb{R})(n = 2, 3); P_n(X) = a_o + a_1x + a_2x^2 + \cdots + a_nx^n, a_i \in \mathbb{R}, \forall 1 \leq i \leq n$ as subspace of $\mathbb{R}[X]$, the space of all solutions of the system of m homogeneous linear equations in n unknowns as a subspace of $\mathbb{R}^n$.

Properties of a subspace such as necessary and sufficient conditions for a non-empty subset to be a subspace of a vector space, arbitrary intersection of subspaces of a vector space is a subspace, union of two subspaces is a subspace if and only if one is the subset of other.

Finite linear combination of vectors in a vector space; linear span $L(S)$ of a non-empty subset S of a vector space, S is a generating set for $L(S), L(S)$ is a vector subspace of V; Linearly independent/ Linearly Dependent subsets of a vector space, a subset $\{v_1, v_2, \ldots, v_k\}$ is linearly dependent if and only $\exists i \in \{1, 2, \ldots k\}$ such that v_i is a linear combination of other vectors $v_j s$.

Unit-III Basis of a Vector Space and Linear Transformation (15 Lectures)
Basis of a vector space, dimension of a vector space, maximal linearly independent subset of a vector space is a basis of a vector space, minimal generating set of a vector space is a basis of a vector space, any two basis of a vector space have same number of elements, any set of n linearly independent vectors in an n-dimensional vector space is a basis, any collection of $n+1$ vectors in an n-dimensional vector space is linearly dependent.

Extending any basis of a subspace W of a vector space V to a basis of the vector space V. If W_1, W_2 are two subspaces of a vector space V then $W_1 + W_2$ is a subspace of the vector space V of dimension $\dim(W_1 + W_2) = \dim(W_1) + \dim(W_2) - \dim(W_1 \cap W_2)$.

Linear Transformations; Kernel, Image of a Linear Transformation T , Rank T , Nullity T, and properties such as: kernel T is a subspace of domain space of T and Img T is a subspace of co-domain space of T. If $V = \{v_1, v_2, \ldots, v_n\}$ is a basis of V and $W = \{w_1, w_2, \ldots, w_n\}$ any vectors in W then there exists a unique linear transformation $T : V \longrightarrow W$ such that $T(v_j) = w_j \ \forall j, 1 \leq j \leq n$, Rank nullity theorem (statement only) and examples.

Reference Books:

1. Serge Lang, Introduction to Linear Algebra, Second edition Springer.
2. S. Kumaresan , Linear Algebra , Prentice Hall of India Pvt limited .
3. K.Hoffmann and R. Kunze Linear Algebra, Tata MacGraw Hill, New Delhi, 1971.
4. Gilbert Strang , Linear Algebra and its Applications, International Student Edition.
5. L. Smith , Linear Algebra, Springer Verlang.
6. A. Ramchandran Rao, P. Bhimashankaran; Linear Algebra Tata Mac Graw Hill.
7. T. Banchoff and J. Warmers: Linear Algebra through Geometry, Springer Verlag, New York, 1984.
8. Sheldon Axler: Linear Algebra done right, Springer Verlag, New York.
9. Klaus Janich': Linear Algebra.
10. Otto Bretcher: Linear Algebra with Applications, Pearson Education.
11. Gareth Williams: Linear Algebra with Applications.

PRACTICALS FOR F.Y.B.Sc
USMTP02-Practicals

A. **Practicals for USMT201:**

(1) Calculating limit of series, Convergence tests.

(2) Properties of continuous and differentiable functions.

(3) Higher order derivatives, Leibnitz theorem. Mean value theorems and its applications.

(4) Extreme values, increasing and decreasing functions. Applications of

(5) Taylors theorem and Taylors polynomials

(6) Miscellaneous Theoretical Questions based on full paper

B. **Practicals for USMT202:**

(1) Solving homogeneous system of m equations in n unknowns by elimination for $(m, n) = (1, 2), (1, 3), (2, 2), (2, 2), (3, 3)$, Row echelon form.

(2) Solving system $AX = b$ by Gauss elimination method, Solutions of system of Linear Equations.

(3) Examples of vector spaces , Subspaces,

(4) Linear span of an non-empty subset of a vector space, Basis and Dimension of Vector Space.

(5) Examples of Linear Transformation, Computing Kernel, Image of a linear map , Verifying Rank Nullity Theorem.

(6) Miscellaneous Theoretical Questions based on full paper.

TUTORIALS FOR F.Y.B.A

Tutorials for UAMT201:

(1) Calculating limit of series, Convergence tests.

(2) Properties of continuous functions.

(3) Differentiability, Higher order derivatives, Leibnitz theorem.

(4) Mean value theorems and its applications.

(5) Extreme values, increasing and decreasing functions.

(6) Applications of Taylors theorem and Taylor's polynomials.

(7) Miscellaneous Theoretical Questions based on full paper.

Scheme of Examination

I. **Semester End Theory Examinations:** There will be a Semester-end external Theory examination of 100 marks for each of the courses USMT101/UAMT101, USMT102 of Semester I and USMT201/UAMT201, USMT202 of semester II to be conducted by the University.

1. Duration: The examinations shall be of 3 Hours duration.
2. Theory Question Paper Pattern:
   a) There shall be FIVE questions. The first question Q1 shall be of objective type for 20 marks based on the entire syllabus. The next three questions Q2, Q2, Q3 shall be of 20 marks, each based on the units I, II, III respectively. The fifth question Q5 shall be of 20 marks based on the entire syllabus.

b) All the questions shall be compulsory. The questions Q2, Q3, Q4, Q5 shall have internal choices within the questions. Including the choices, the marks for each question shall be 30-32.

c) The questions Q2, Q3, Q4, Q5 may be subdivided into sub-questions as a, b, c, d & e, etc and the allocation of marks depends on the weightage of the topic.

d) The question Q1 may be subdivided into 10 sub-questions of 2 marks each.

II. **Semester End Examinations Practicals:**

At the end of the Semesters I & II Practical examinations of three hours duration and100 marks shall be conducted for the courses USMTP01, USMTP02.
In semester I, the Practical examinations for USMT101 and USMT102 are held together by the college.
In Semester II, the Practical examinations for USMT201 and USMT202 are held together by the college.

Paper pattern: The question paper shall have two parts A and B.
Each part shall have two Sections.

Section I Objective in nature: Attempt any Eight out of Twelve multiple choice questions. ($8 \times 3 = 24$ Marks)

Section II Problems: Attempt any Two out of Three. ($8 \times 2 = 16$ Marks)

Practical Course	Part A	Part B	Marks out of	duration
USMTP01	Questions from USMT101	Questions from USMT102	80	3 hours
USMTP02	Questions from USMT201	Questions from USMT202	80	3 hours

Marks for Journals and Viva:
For each course USMT101/UAMT101, USMT102, USMT201:

1. Journals: 5 marks.
2. Viva: 5 marks.

Each Practical of every course of Semester I and II shall contain 10 (ten) problems out of which minimum 05 (five) have to be written in the journal. A student must have a certified journal before appearing for the practical examination.

UNIVERSITY OF MUMBAI

No. UG/9 of 2018-19

CIRCULAR:-

Attention of the Principals of the affiliated Colleges and Directors of the recognized Institutions in Humanities, Sci. & Tech. Faculties is invited to this office Circular No.UG/122 of 2017-18 dated 28th July, 2017 relating to syllabus of the B.A./B.Sc. degree course.

They are hereby informed that the recommendations made by the Board of Studies in Mathematics at its meeting held on 3rd May, 2018 have been accepted by the Academic Council at its meeting held on 5th May, 2018 **vide** item No. 4.71 and that in accordance therewith, the revised syllabus as per the (CBCS) for the T.Y.B.A./T.Y.B.Sc. in Mathematics (Sem. –V) Paper-I Integral Calculas, Paper-III Topology of Metric Spaces and (Sem.VI) Paper-I Basic Complex Analysis, Paper-III Topology of Metric Spaces and Real Analysis, has been brought into force with effect from the academic year 2018-19, accordingly. (The same is available on the University's website www.mu.ac.in).

MUMBAI – 400 032
12th June, 2018

(Dr. Dinesh Kamble)
I/c REGISTRAR

To

The Principals of the affiliated Colleges & Directors of the recognized Institutions in Humanities, Sci. & Tech. Faculties. (Circular No. UG/334 of 2017-18 dated 9th January, 2018.)

A.C/4.71/05/05/2018

****

No. UG/ 9 -A of 2018 MUMBAI-400 032 12th June, 2018

Copy forwarded with Compliments for information to:-

1) The I/c Dean, Faculties of Humanities, Science & Technology,
2) The Chairman, Board of Studies in Mathematics,
3) The Director, Board of Examinations and Evaluation,
4) The Director, Board of Students Development,
5) The Co-Ordinator, University Computerization Centre,
6) The Professor-cum-Director, Institute of Distance & Open Learning.

(Dr. Dinesh Kamble)
I/c REGISTRAR

(UNIVERSITY OF MUMBAI)

Syllabus for: S.Y.B.Sc./S.Y.B.A.

Program: B.Sc./B/A.

Course: Mathematics

Choice based Credit System (CBCS)

with effect from the

academic year 2018-19

SEMESTER III

CALCULUS III				
Course Code	UNIT	TOPICS	Credits	L/Week
USMT 301, UAMT 301	I	Functions of several variables	2	3
	II	Differentiation		
	III	Applications		
ALGEBRA III				
USMT 302 ,UAMT 302	I	Linear Transformations and Matrices	2	3
	II	Determinants		
	III	Inner Product Spaces		
DISCRETE MATHEMATICS				
USMT 303	I	Permutations and Recurrence Relation	2	3
	II	Preliminary Counting		
	III	Advanced Counting		
PRACTICALS				
USMTP03		Practicals based on USMT301, USMT 302 and USMT 303	3	5
UAMTP03		Practicals based on UAMT301, UAMT 302	2	4

SEMESTER IV

CALCULUS IV				
Course Code	UNIT	TOPICS	Credits	L/Week
USMT 401, UAMT 401	I	Riemann Integration	2	3
	II	Indefinite Integrals and Improper Integrals		
	III	Beta and Gamma Functions And Applications		
ALGEBRA IV				
USMT 402 ,UAMT 402	I	Groups and Subgroups	2	3
	II	Cyclic Groups and Cyclic subgroups		
	III	Lagrange's Theorem and Group Homomorphism		
ORDINARY DIFFERENTIAL EQUATIONS				
USMT 403	I	First order First degree Differential equations	2	3
	II	Second order Linear Differential equations		
	III	Linear System of Ordinary Differential Equations		
PRACTICALS				
USMTP04		Practicals based on USMT401, USMT 402 and USMT 403	3	5
UAMTP04		Practicals based on UAMT401, UAMT 402	2	4

Teaching Pattern for Semester III

1. Three lectures per week per course. Each lecture is of 48 minutes duration.
2. One Practical (2L) per week per batch for courses USMT301, USMT 302 combined and one Practical (3L) per week for course USMT303 (the batches tobe formed as prescribed by the University. Each practical session is of 48 minutes duration.)

Teaching Pattern for Semester IV

1. Three lectures per week per course. Each lecture is of 48 minutes duration.
2. One Practical (2L) per week per batch for courses USMT301, USMT 302 combined and one Practical (3L) per week for course USMT303 (the batches tobe formed as prescribed by the University. Each practical session is of 48 minutes duration.)

S.Y.B.Sc. / S.Y.B.A. Mathematics

SEMESTER III

USMT 301, UAMT 301: CALCULUS III

Note: All topics have to be covered with proof in details (unless mentioned otherwise) and examples.

Unit I: Functions of several variables (15 Lectures)

1. The Euclidean inner product on $\mathbb{R}^n$ and Euclidean norm function on $\mathbb{R}^n$, distance between two points, open ball in $\mathbb{R}^n$, definition of an open subset of $\mathbb{R}^n$, neighbourhood of a point in $\mathbb{R}^n$, sequences in $\mathbb{R}^n$, convergence of sequences- these concepts should be specifically discussed for $n = 3$ and $n = 3$.
2. Functions from $\mathbb{R}^n \longrightarrow \mathbb{R}$ (scalar fields) and from $\mathbb{R}^n \longrightarrow \mathbb{R}^m$ (vector fields), limits, continuity of functions, basic results on limits and continuity of sum, difference, scalar multiples of vector fields, continuity and components of a vector fields.
3. Directional derivatives and partial derivatives of scalar fields.
4. Mean value theorem for derivatives of scalar fields.

Reference for Unit I:
Sections 8.1, 8.2, 8.3, 8.4, 8.5, 8.6, 8.7, 8.8, 8.9, 8.10 of Calculus, Vol. 2 (Second Edition) by Apostol.

Unit II: Differentiation (15 Lectures)

1. Differentiability of a scalar field at a point of $\mathbb{R}^n$ (in terms of linear transformation) and on an open subset of $\mathbb{R}^n$, the total derivative, uniqueness of total derivative of a differentiable function at a point, simple examples of finding total derivative of functions such as $f(x, y) = x^2 + y^2, f(x, y, z) = x + y + z,$, differentiability at a point of a function f implies continuity and existence of direction derivatives of f at the point, the existence of continuous partial derivatives in a neighbourhood of a point implies differentiability at the point.

2. Gradient of a scalar field, geometric properties of gradient, level sets and tangent planes.

3. Chain rule for scalar fields.

4. Higher order partial derivatives, mixed partial derivatives, sufficient condition for equality of mixed partial derivative.

Reference for Unit II:
Sections 8.11, 8.12, 8.13, 8.14, 8.15, 8.16, 8.17, 8.23 of Calculus, Vol.2 (Second Edition) by T. Apostol, John Wiley.

Unit III: Applications (15 lectures)

1. Second order Taylor's formula for scalar fields.

2. Differentiability of vector fields, definition of differentiability of a vector field at a point, Jacobian matrix, differentiability of a vector field at a point implies continuity. The chain rule for derivative of vector fields (statements only)

3. Mean value inequality.

4. Hessian matrix, Maxima, minima and saddle points.

5. Second derivative test for extrema of functions of two variables.

6. Method of Lagrange Multipliers.

Reference for Unit III:
Sections 8.18, 8.19, 8.20, 8.21, 8.22, 9.9, 9.10, 9.11, 9.12, 9.13, 9.14 9.13, 9.14 from Apostol, Calculus Vol. 2, (Second Edition) by T. Apostol.

Recommended Text Books:

1. T. Apostol: Calculus, Vol. 2, John Wiley.

2. J. Stewart, Calculus, Brooke/ Cole Publishing Co.

Additional Reference Books

(1) G.B. Thoman and R. L. Finney, Calculus and Analytic Geometry, Ninth Edition, Addison-Wesley, 1998.

(2) Sudhir R. Ghorpade and Balmohan V. Limaye, A Course in Multivariable Calculus and Analysis, Springer International Edition.

(3) Howard Anton, Calculus- A new Horizon, Sixth Edition, John Wiley and Sons Inc, 1999.

USMT 302/UAMT 302: ALGEBRA III

Note: Revision of relevant concepts is necessary.

Unit 1: Linear Transformations and Matrices (15 lectures)

1. Review of linear transformations: Kernel and image of a linear transformation, Rank-Nullity theorem (with proof), Linear isomorphisms, inverse of a linear isomorphism, Any $n-$ dimensional real vector space is isomorphic to $\mathbb{R}^n$.

2. The matrix units, row operations, elementary matrices, elementary matrices are invertible and an invertible matrix is a product of elementary matrices.

3. Row space, column space of an $m \times n$ matrix, row rank and column rank of a matrix, Equivalence of the row and the column rank, Invariance of rank upon elementary row or column operations.

4. Equivalence of rank of an $m \times n$ matrix A and rank of the linear transformation $L_A : \mathbb{R}^n \longrightarrow \mathbb{R}^m \quad (L_A(X) = AX)$. The dimension of solution space of the system of linear equations $AX = 0$ equals $n-$rank(A).

5. The solutions of non-homogeneous systems of linear equations represented by $AX = B$, Existence of a solution when rank$(A)=$ rank(A, B), The general solution of the system is the sum of a particular solution of the system and the solution of the associated homogeneous system.
   Reference for Unit 1: Chapter VIII, Sections 1, 2 of Introduction to Linear Algebra, Serge Lang, Springer Verlag and Chapter 4, of Linear Algebra A Geometric Approach, S. Kumaresan, Prentice-Hall of India Private Limited, New Delhi.

Unit II: Determinants (15 Lectures)

1. Definition of determinant as an $n-$linear skew-symmetric function from $\mathbb{R}^n \times \mathbb{R}^n \times \ldots \times \mathbb{R}^n \longrightarrow \mathbb{R}$ such that determinant of $(E^1, E^2, \ldots, E^n)$ is 1, where E^j denotes the j^{th} column of the $n \times n$ identity matrix I_n. Determinant of a matrix as determinant of its column vectors (or row vectors). Determinant as area and volume.

2. Existence and uniqueness of determinant function via permutations, Computation of determinant of $2 \times 2, 3 \times 3$ matrices, diagonal matrices, Basic results on determinants such as $\det(A^t) = \det(A), \det(AB) = \det(A)\det(B)$, Laplace expansion of a determinant, Vandermonde determinant, determinant of upper triangular and lower triangular matrices.

3. Linear dependence and independence of vectors in $\mathbb{R}^n$ using determinants, The existence and uniqueness of the system $AX = B$, where A is an $n \times n$ matrix wither $\det(A) \neq 0$, Cofactors and minors, Adjoint of an $n \times n$ matrix A, Basic results such as $A\text{adj}(A) = \det(A)I_n$. An $n \times n$ real matrix A is invertible if and only if $\det(A) \neq 0, A^{-1} = \dfrac{1}{\det(A)}\text{adj}(A)$ for an invertible matrix A, Cramer's rule.

4. Determinant as area and volume.

References for Unit 2: Chapter VI of Linear Algebra A geometric approach, S. Kumaresan, Prentice Hall of India Private Limited, 2001 and Chapter VII Introduction to Linear Algebra, Serge Lang, Springer Verlag.

Unit III: Inner Product Spaces (15 Lectures)

1. Dot product in $\mathbb{R}^n$, Definition of general inner product on a vector space over $\mathbb{R}$. Examples of inner product including the inner product $< f, g >= \displaystyle\int_{-\pi}^{\pi} f(t)g(t)\ dt$ on $C[-\pi, \pi]$, the space of continuous real valued functions on $[-\pi, \pi]$.

2. Norm of a vector in an inner product space. Cauchy-Schwartz inequality, Triangle inequality, Orthogonality of vectors, Pythagoras theorem and geometric applications in $\mathbb{R}^2$, Projections on a line, The projection being the closest approximation, Orthogonal complements of a subspace, Orthogonal complements in $\mathbb{R}^2$ and $\mathbb{R}^3$. Orthogonal sets and orthonormal sets in an inner product space, Orthogonal and orthonormal bases. Gram-Schmidt orthogonalization process, Simple examples in $\mathbb{R}^3, \mathbb{R}^4$.

Reference of Unit 3: Chapter VI, Sections 1,2 of Introduction to Linear Algebra, Serge Lang, Springer Verlag and Chapter 5, of Linear Algebra A Geometric Approach, S. Kumaresan, Prentice-Hall of India Private Limited, New Delhi.

Recommended Books:

1. Serge Lang: Introduction to Linear Algebra, Springer Verlag.
2. S. Kumaresan: Linear Algebra A geometric approach, Prentice Hall of India Private Limited.

Additional Reference Books:

1. M. Artin: Algebra, Prentice Hall of India Private Limited.
2. K. Hoffman and R. Kunze: Linear Algebra, Tata McGraw-Hill, New Delhi.
3. Gilbert Strang: Linear Algebra and its applications, International Student Edition.
4. L. Smith: Linear Algebra, Springer Verlag.
5. A. Ramachandra Rao and P. Bhima Sankaran: Linear Algebra, Tata McGraw-Hill, New Delhi.
6. T. Banchoff and J. Wermer: Linear Algebra through Geometry, Springer Verlag Newyork, 1984.
7. Sheldon Axler: Linear Algebra done right, Springer Verlag, Newyork.
8. Klaus Janich: Linear Algebra.
9. Otto Bretcher: Linear Algebra with Applications, Pearson Education.
10. Gareth Williams: Linear Algebra with Applications, Narosa Publication.

USMT 303: Discrete Mathematics

Unit I: Permutations and Recurrence relation (15 lectures)

1. Permutation of objects, S_n, composition of permutations, results such as every permutation is a product of disjoint cycles, every cycle is a product of transpositions, even and odd permutation, rank and signature of a permutation, cardinality of S_n, A_n
2. Recurrence Relations, definition of non-homogeneous, non-homogeneous, linear , non-linear recurrence relation, obtaining recurrence relation in counting problems, solving homogeneous as well as non homogeneous recurrence relations by using iterative methods, solving a homogeneous recurrence relation of second degree using algebraic method proving the necessary result.

Recommended Books:

1. Norman Biggs: Discrete Mathematics, Oxford University Press.
2. Richard Brualdi: Introductory Combinatorics, John Wiley and sons.
3. V. Krishnamurthy: Combinatorics-Theory and Applications, Affiliated East West Press.
4. Discrete Mathematics and its Applications, Tata McGraw Hills.
5. Schaum's outline series: Discrete mathematics,
6. Applied Combinatorics: Allen Tucker, John Wiley and Sons.

Unit II: Preliminary Counting (15 Lectures)

1. Finite and infinite sets, countable and uncountable sets examples such as $\mathbb{N}, \mathbb{Z}, \mathbb{N}\times\mathbb{N}, \mathbb{Q}, (0,1), \mathbb{R}$
2. Addition and multiplication Principle, counting sets of pairs, two ways counting.
3. Stirling numbers of second kind. Simple recursion formulae satisfied by $S(n,k)$ for $k = 1, 2, \cdots, n-1, n$
4. Pigeonhole principle and its strong form, its applications to geometry, monotonic sequences etc.

Unit III: Advanced Counting (15 Lectures)

1. Binomial and Multinomial Theorem, Pascal identity, examples of standard identities such as the following with emphasis on combinatorial proofs.
   - $\displaystyle\sum_{k=0}^{r} \binom{m}{k}\binom{n}{r-k} = \binom{m+n}{r}$
   - $\displaystyle\sum_{i=r}^{n} \binom{i}{r} = \binom{n+1}{r+1}$
   - $\displaystyle\sum_{i=0}^{k} \binom{k}{i}^2 = \binom{2k}{k}$
   - $\displaystyle\sum_{i=0}^{n} \binom{n}{i} = 2^n$
2. Permutation and combination of sets and multi-sets, circular permutations, emphasis on solving problems.
3. Non-negative and positive solutions of equation $x_1 + x_2 + \cdots + x_k = n$
4. Principal of inclusion and exclusion, its applications, derangements, explicit formula for d_n, deriving formula for Euler's function $\phi(n)$.

USMT P03/UAMTP03 Practicals

Suggested Practicals for USMT 301/UAMT303

1. Sequences in $\mathbb{R}^2$ and $\mathbb{R}^3$, limits and continuity of scalar fields and vector fields, using "definition and otherwise" , iterated limits.
2. Computing directional derivatives, partial derivatives and mean value theorem of scalar fields.
3. Total derivative, gradient, level sets and tangent planes.
4. Chain rule, higher order derivatives and mixed partial derivatives of scalar fields.
5. Taylor's formula, differentiation of a vector field at a point, finding Hessian/Jacobean matrix, Mean Value Inequality.
6. Finding maxima, minima and saddle points, second derivative test for extrema of functions of two variables and method of Lagrange multipliers.
7. Miscellaneous Theoretical Questions based on full paper

Suggested Practicals for USMT302/UAMT302:

1. Rank-Nullity Theorem.
2. System of linear equations.
3. Determinants , calculating determinants of 2×2 matrices, $n\times n$ diagonal, upper triangular matrices using definition and Laplace expansion.
4. Finding inverses of $n \times n$ matrices using adjoint.
5. Inner product spaces, examples. Orthogonal complements in $\mathbb{R}^2$ and $\mathbb{R}^3$.
6. Gram-Schmidt method.
7. Miscellaneous Theoretical Questions based on full paper

Suggested Practicals for USMT 303:

1. Derangement and rank signature of permutation.
2. Recurrence relation.
3. Problems based on counting principles, Two way counting.
4. Stirling numbers of second kind, Pigeon hole principle.
5. Multinomial theorem, identities, permutation and combination of multi-set.
6. Inclusion-Exclusion principle. Euler phi function.
7. Miscellaneous theory quesitons from all units.

SEMESTER IV

USMT 401/UAMT 401: CALCULUS IV

Note: All topics have to be covered with proof in details (unless mentioned otherwise) and examples.

Unit I: Riemann Integration (15 Lectures)

Approximation of area, Upper/Lower Riemann sums and properties, Upper/Lower integrals, Definition of Riemann integral on a closed and bounded interval, Criterion of Riemann integrability, if $a < c < b$ then $f \in R[a, b]$, if and only if $f \in R[a, c]$ and $f \in R[c, b]$ and $\int_a^b f = \int_a^c f + \int_c^b f$.

Properties:

(i) $f, g \in R[a, b] \Longrightarrow f + g, \lambda f \in R[a, b]$.

(ii) $\int_a^b (f + g) = \int_a^b f + \int_a^b g$.

(iii) $\int_a^b \lambda f = \lambda \int_a^b f$.

(iv) $f \in R[a, b] \Longrightarrow |f| \in R[a, b]$ and $|\int_a^b f| \leq \int_a^b |f|$,

(v) $f \geq 0, f \in C[a, b] \Longrightarrow f \in R[a, b]$.

(vi) If f is bounded with finite number of discontinuities then $f \in R[a, b]$, generalize this if f is monotone then $f \in R[a, b]$.

Unit II: Indefinite and improper integrals (15 lectures)

Continuity of $F(x) = \int_a^x f(t)\, dt$ where $f \in R[a, b]$, Fundamental theorem of calculus, Mean value theorem, Integration by parts, Leibnitz rule, Improper integrals-type 1 and type 2, Absolute convergence of improper integrals, Comparison tests, Abel's and Dirichlet's tests.

Unit III: Applications (15 lectures)

(1) β and Γ functions and their properties, relationship between β and Γ functions (without proff).

(2) Applications of definite Integras: Area between curves, finding volumes by sicing, volumes of solids of revolution-Disks and Washers, Cylindrical Shells, Lengths of plane curves, Areas of surfaces of revolution.

References:

(1) Calculus Thomas Finney, ninth edition section 5.1, 5.2, 5.3, 5.4, 5.5, 5.6.

(2) R. R. Goldberg, Methods of Real Analysis, Oxford and IBH, 1964.

(3) Ajit Kumar, S.Kumaresan, A Basic Course in Real Analysis, CRC Press, 2014.
(4) T. Apostol, Calculus Vol.2, John Wiley.
(5) K. Stewart, Calculus, Booke/Cole Publishing Co, 1994.
(6) J. E. Marsden, A.J. Tromba and A. Weinstein, Basic multivariable calculus.
(7) Bartle and Sherbet, Real analysis.

USMT 402/ UAMT 402: ALGEBRA IV

Unit I: Groups and Subgroups (15 Lectures)

(a) Definition of a group, abelian group, order of a group, finite and infinite groups. Examples of groups including:

  i) $\mathbb{Z}, \mathbb{Q}, \mathbb{R}, \mathbb{C}$ under addition.
  ii) $\mathbb{Q}^*(= \mathbb{Q} \setminus \{0\}), \mathbb{R}^*(= \mathbb{R} \setminus \{0\}), \mathbb{C}^*(= \mathbb{C} \setminus \{0\}).\mathbb{Q}^+$(= positive rational numbers) under multiplication.
  iii) $\mathbb{Z}_n$, the set of residue classes modulo n under addition.
  iv) $U(n)$, the group of prime residue classes modulo n under multiplication.
  v) The symmetric group S_n.
  vi) The group of symmetries of a plane figure. The Dihedral group D_n as the group of symmetries of a regular polygon of n sides (for $n = 3, 4$).
  vii) Klein 4-group.
  viii) Matrix groups $M_{n\times n}(\mathbb{R})$ under addition of matrices, $GL_n(\mathbb{R})$, the set of invertible real matrices, under multiplication of matrices.
  ix) Examples such as S^1 as subgroup of C, μ_n the subgroup of $n-$th roots of unity.

(b) Properties such as

  1) In a group $(G, .)$ the following indices rules are true for all integers n, m.
    i) $a^n a^m = a^{n+m}$ for all a in G.
    ii) $(a^n)^m = a^{nm}$ for all a in G.
    iii) $(ab)^n = a^n b^n$ for all ab in G whenever $ab = ba$.
  2) In a group $(G, .)$ the following are true:
    i) The identity element e of G is unique.
    ii) The inverse of every element in G is unique.
    iii) $(a^{-1})^{-1} = a$ for all a in G.
    iv) $(a.b)^{-1} = b^{-1}a^{-1}$ for all a, b in G.
    v) If $a^2 = e$ for every a in G then $(G, .)$ is an abelian group.
    vi) $(aba^{-1})^n = ab^n a^{-1}$ for every a, b in G and for every integer n.
    vii) If $(a.b)^2 = a^2.b^2$ for every a, b in G then $(G, .)$ is an abelian group.
    viii) $(\mathbb{Z}_n^*, .)$ is a group if and only if n is a prime.
  3) Properties of order of an element such as: (n and m are integers.)
    i) If $o(a) = n$ then $a^m = e$ if and only if n/m.
    ii) If $o(a) = nm$ then $o(a^n) = m$.
    iii) If $o(a) = n$ then $o(a^m) = \dfrac{n}{(n, m)}$,. where (n, m) is the GCD of n and m.

iv) $o(aba^{-1}) = o(b)$ and $o(ab) = o(ba)$.
v) If $o(a) = m$ and $o(b) = m, ab = ba, (n, m) = 1$ then $o(ab) = nm$.

(c) Subgroups

i) Definition, necessary and sufficient condition for a non-empty set to be a Subgroup.
ii) The center $Z(G)$ of a group is a subgroup.
iii) Intersection of two (or a family of) subgroups is a subgroup.
iv) Union of two subgroups is not a subgroup in general. Union of two subgroups is a subgroup if and only if one is contained in the other.
v) If H and K are subgroups of a group G then HK is a subgroup of G if and only if $HK = KH$.

Reference for Unit I:

(1) I.N. Herstein, Topics in Algebra.

(2) P.B. Bhattacharya, S.K. Jain, S. Nagpaul. Abstract Algebra.

Unit II: Cyclic groups and cyclic subgroups (15 Lectures)

(a) Cyclic subgroup of a group, cyclic groups, (examples including $\mathbb{Z}, \mathbb{Z}_n$ and μ_n).

(b) Properties such as:

(i) Every cyclic group is abelian.
(ii) Finite cyclic groups, infinite cyclic groups and their generators.
(iii) A finite cyclic group has a unique subgroup for each divisor of the order of the group.
(iv) Subgroup of a cyclic group is cyclic.
(v) In a finite group $G, G =< a >$ if and only if $o(G) = o(a)$.
(vi) If $G =< a >$ and $o(a) = n$ then $G =< a^m >$ if and only if $(n, m) = 1$.
(vii) If G is a cyclic group of order p^n and $H < G, K < G$ then prove that either $H \subseteq K$ or $K \subseteq H$.

References for Unit II:

(1) I.N. Herstein, Topics in Algebra.

(2) P.B. Bhattacharya, S.K. Jain, S. Nagpaul. Abstract Algebra.

Unit III: Lagrange's Theorem and Group homomorphism (15 Lectures)

(a) Definition of Coset and properties such as :

1) IF H is a subgroup of a group G and $x \in G$ then
   (i) $xH = H$ if and only if $x \in H$.
   (ii) $Hx = H$ if and only if $x \in H$.
2) If H is a subgroup of a group G and $x, y \in G$ then
   (i) $xH = yH$ if and only if $x^{-1}y \in H$.
   (ii) $Hx = Hy$ if and only if $xy^{-1} \in H$.

3) Lagrange's theorem and consequences such as Fermat's Little theorem, Euler's theorem and if a group G has no nontrivial subgroups then order of G is a prime and G is Cyclic.

(b) Group homomorphisms and isomorphisms, automorphisms

i) Definition.

ii) Kernel and image of a group homomorphism.

iii) Examples including inner automorphism.

Properties such as:

(1) $f : G \longrightarrow G'$ is a group homomorphism then $\ker f < G$.

(2) $f : G \longrightarrow G'$ is a group homomorphism then $\ker f = \{e\}$ if and only if f is 1-1.

(3) $f : G \longrightarrow G'$ is a group homomorphism then

(i) G is abelian if and only if G' is abelian.

(ii) G is cyclic if and only if G' is cyclic.

Reference for Unit III:

1. I.N. Herstein, Topics in Algebra.
2. P.B. Bhattacharya, S.K. Jain, S. Nagpaul. Abstract Algebra.

Recommended Books:

1. I.N. Herstein, Topics in Algebra, Wiley Eastern Limied, Second edition.
2. N.S. Gopalkrishnan, University Algebra, Wiley Eastern Limited.
3. M. Artin, Algebra, Prentice Hall of India, New Delhi.
4. P.B. Bhattacharya, S.K. Jain, S. Nagpaul. Abstract Algebra, Second edition, Foundation Books, New Delhi, 1995.
5. J.B. Fraleigh, A first course in Abstract Algebra, Third edition, Narosa, New Delhi.
6. J. Gallian. Contemporary Abstract Algebra. Narosa, New Delhi.
7. COmbinatroial Techniques by Sharad S. Sane, Hindustan Book Agency.

Additional Reference Books:

1. S. Adhikari. An introduction to Commutative Algebra and Number theory. Narosa Publishing House.
2. T. W. Hungerford. Algebra, Springer.
3. D. Dummit, R. Foote. Abstract Algebra, John Wiley & Sons, Inc.
4. I.S. Luther, I.B.S. Passi. Algebra. Vol. I and II.

USMT 403: ORDINARY DIFFERENTIAL EQUATIONS

Unit I: First order First degree Differential equations (15 Lectures)

(1) Definition of a differential equation, order, degree, ordinary differential equation and partial differential equation, linear and non linear ODE.

(2) Existence and Uniqueness Theorem for the solution of a second order initial value problem (statement only), Definition of Lipschitz function, Examples based on verifying the conditions of existence and uniqueness theorem

(3) Review of Solution of homogeneous and non-homogeneous differential equations of first order and first degree. Notion of partial derivatives. Exact Equations: General solution of Exact equations of first order and first degree. Necessary and sufficient condition for $Mdx + Ndy = 0$ to be exact. Non-exact equations: Rules for finding integrating factors (without proof) for non exact equations, such as :

i) $\dfrac{1}{M\ x + N\ y}$ is an I.F. if $M\ x + N\ y \neq 0$ and $Mdx + Ndy = 0$ is homogeneous.

ii) $\dfrac{1}{M\ x - N\ y}$ is an I.F. if $M\ x - N\ y \neq 0$ and $Mdx + Ndy = 0$ is of the form $f_1(x, y)\ y\ dx + f_2(x, y)\ x\ dy = 0$.

iii) $e^{\int f(x)\ dx}$ (resp $e^{\int g(y)\ dy}$) is an I.F. if $N \neq 0$ (resp $M \neq 0$) and $\dfrac{1}{N}\left(\dfrac{\partial M}{\partial y} - \dfrac{\partial N}{\partial x}\right)$ $\left(\text{resp}\dfrac{1}{M}\left(\dfrac{\partial M}{\partial y} - \dfrac{\partial N}{\partial x}\right)\right)$ is a function of x (resp y) alone, say $f(x)$ (resp $g(y)$).

iv) Linear and reducible linear equations of first order, finding solutions of first order differential equations of the type for applications to orthogonal trajectories, population growth, and finding the current at a given time.

Unit II: Second order Linear Differential equations (15 Lectures)

1. Homogeneous and non-homogeneous second order linear differentiable equations: The space of solutions of the homogeneous equation as a vector space. Wronskian and linear independence of the solutions. The general solution of homogeneous differential equations. The general solution of a non-homogeneous second order equation. Complementary functions and particular integrals.

2. The homogeneous equation with constant coefficients. auxiliary equation. The general solution corresponding to real and distinct roots, real and equal roots and complex roots of the auxiliary equation.

3. Non-homogeneous equations: The method of undetermined coefficients. The method of variation of parameters.

Unit III: Linear System of ODEs (15 Lectures)

Existence and uniqueness theorems to be stated clearly when needed in the sequel. Study of homogeneous linear system of ODEs in two variables: Let $a_1(t), a_2(t), b_1(t), b_2(t)$ be continuous real valued functions defined on $[a, b]$. Fix $t_0 \in [a, b]$. Then there exists a unique solution $x = x(t), y = y(t)$ valid throughout $[a, b]$ of the following system:

$$\frac{dx}{dt} = a_1(t)x + b_1(t)y,$$
$$\frac{dy}{dt} = a_2(t)x + b_2(t)y$$

satisfying the initial conditions $x(t_0) = x_0 \& y(t_0) = y_0$.
The Wronskian $W(t)$ of two solutions of a homogeneous linear system of ODEs in two variables, result: W (t) is identically zero or nowhere zero on [a, b]. Two linearly independent solutions and the general solution of a homogeneous linear system of ODEs in two variables.
Explicit solutions of Homogeneous linear systems with constant coefficients in two variables, examples.

Recommended Text Books for Unit I and II:

1. G. F. Simmons, Differential equations with applications and historical notes, McGraw Hill.

2. E. A. Coddington, An introduction to ordinary differential equations, Dover Books.

Recommended Text Book for Unit III:
G. F. Simmons, Differential equations with applications and historical notes, McGraw Hill.

USMT P04/UAMT P04 Practicals.

Suggested Practicals for USMT401/UAMT401:

1. Calculation of upper sum, lower sum and Riemann integral.
2. Problems on properties of Riemann integral.
3. Problems on fundamental theorem of calculus, mean value theorems, integration by parts, Leibnitz rule.
4. Convergence of improper integrals, applications of comparison tests, Abel's and Dirichlet's tests, and functions.
5. Beta Gamma Functions
6. Problems on area, volume, length.
7. Miscellaneous Theoretical Questions based on full paper.

Suggested Practicals for USMT402/UAMT 402:

1. Examples and properties of groups.
2. Group of symmetry of equilateral triangle, rectangle, square.
3. Subgroups.
4. Cyclic groups, cyclic subgroups, finding generators of every subgroup of a cyclic group.
5. Left and right cosets of a subgroup, Lagrange's Theorem.

6. Group homomorphisms, isomorphisms.
7. Miscellaneous Theoretical questions based on full paper.

Suggested Practicals for USMT403:

1. Solving exact and non exact equations.
2. Linear and reducible to linear equations, applications to orthogonal trajectories, population growth, and finding the current at a given time.
3. Finding general solution of homogeneous and non-homogeneous equations, use of known solutions to find the general solution of homogeneous equations.
4. Solving equations using method of undetermined coefficients and method of variation of parameters.
5. Solving second order linear ODEs
6. Solving a system of first order linear ODES.
7. Miscellaneous Theoretical questions from all units.

Scheme of Examination

I. **Semester End Theory Examinations:** There will be a Semester-end external Theory examination of 100 marks for each of the courses USMT301/UAMT301, USMT302/UAMT302, USMT303 of Semester III and USMT401/UAMT401, USMT402/UAMT402, USMT403 of semester IV to be conducted by the University.

   1. Duration: The examinations shall be of 3 Hours duration.
   2. Theory Question Paper Pattern:
      a) There shall be FIVE questions. The first question Q1 shall be of objective type for 20 marks based on the entire syllabus. The next three questions Q2, Q2, Q3 shall be of 20 marks, each based on the units I, II, III respectively. The fifth question Q5 shall be of 20 marks based on the entire syllabus.
      b) All the questions shall be compulsory. The questions Q2, Q3, Q4, Q5 shall have internal choices within the questions. Including the choices, the marks for each question shall be 30-32.
      c) The questions Q2, Q3, Q4, Q5 may be subdivided into sub-questions as a, b, c, d & e, etc and the allocation of marks depends on the weightage of the topic.
      d) The question Q1 may be subdivided into 10 sub-questions of 2 marks each.

II. **Semester End Examinations Practicals:**
At the end of the Semesters III and IV, Practical examinations of three hours duration and 150 marks shall be conducted for the courses USMTP03, USMTP04.

At the end of the Semesters III and IV, Practical examinations of three hours duration and 150 marks shall be conducted for the courses UAMTP03, UAMTP04.

In semester III, the Practical examinations for USMT301/UAMT301 and USMT302/UAMT302 are held together by the college. The Practical examination for USMT303 is held **separately** by the college.

In semester IV, the Practical examinations for USMT401/UAMT401 and USMT402/UAMT402 are held together by the college. The Practical examination for USMT403 is held **separately** by the college.

Paper pattern: The question paper shall have three parts A, B, C.
Each part shall have two Sections.

Section I Objective in nature: Attempt any Eight out of Twelve multiple choice questions. ($8 \times 3 = 24$ Marks)

Section II Problems: Attempt any Two out of Three. ($8 \times 2 = 16$ Marks)

Practical Course	Part A	Part B	**Part C**	Marks out of	duration
USMTP03	Questions from USMT301	Questions from USMT302	Questions from USMT303	120	3 hours
UAMTP03	Questions from UAMT301	Questions from UAMT302	—	80	2 hours
USMTP04	Questions from USMT401	Questions from USMT402	Questions from USMT403	120	3 hours
UAMTP03	Questions from UAMT401	Questions from UAMT402	—	80	2 hours

Marks for Journals and Viva:
For each course USMT301/UAMT301, USMT302/UAMT302, USMT303, USMT401/UAMT401, USMT402/UAMT402 and USMT403:

1. Journals: 5 marks.
2. Viva: 5 marks.

Each Practical of every course of Semester III and IV shall contain 10 (ten) problems out of which minimum 05 (five) have to be written in the journal. A student must have a certified journal before appearing for the practical examination.

UNIVERSITY OF MUMBAI

No. UG/9 of 2018-19

CIRCULAR:-

Attention of the Principals of the affiliated Colleges and Directors of the recognized Institutions in Humanities, Sci. & Tech. Faculties is invited to this office Circular No.UG/122 of 2017-18 dated 28th July, 2017 relating to syllabus of the B.A./B.Sc. degree course.

They are hereby informed that the recommendations made by the Board of Studies in Mathematics at its meeting held on 3rd May, 2018 have been accepted by the Academic Council at its meeting held on 5th May, 2018 **vide** item No. 4.71 and that in accordance therewith, the revised syllabus as per the (CBCS) for the T.Y.B.A./T.Y.B.Sc. in Mathematics (Sem. –V) Paper-I Integral Calculas, Paper-III Topology of Metric Spaces and (Sem.VI) Paper-I Basic Complex Analysis, Paper-III Topology of Metric Spaces and Real Analysis, has been brought into force with effect from the academic year 2018-19, accordingly. (The same is available on the University's website www.mu.ac.in).

MUMBAI – 400 032
12th June, 2018

(Dr. Dinesh Kamble)
I/c REGISTRAR

To

The Principals of the affiliated Colleges & Directors of the recognized Institutions in Humanities, Sci. & Tech. Faculties. (Circular No. UG/334 of 2017-18 dated 9th January, 2018.)

A.C/4.71/05/05/2018

****

No. UG/ 9 -A of 2018 MUMBAI-400 032 12th June, 2018

Copy forwarded with Compliments for information to:-

1) The I/c Dean, Faculties of Humanities, Science & Technology,
2) The Chairman, Board of Studies in Mathematics,
3) The Director, Board of Examinations and Evaluation,
4) The Director, Board of Students Development,
5) The Co-Ordinator, University Computerization Centre,
6) The Professor-cum-Director, Institute of Distance & Open Learning.

(Dr. Dinesh Kamble)
I/c REGISTRAR

(UNIVERSITY OF MUMBAI)

Syllabus for: T.Y.B.Sc./T.Y.B.A.

Program: B.Sc./B.A.

Course: Mathematics

Choice based Credit System (CBCS)

with effect from the

academic year 2018-19

SEMESTER V

Course Code	UNIT	TOPICS	Credits	L/Week
Multivariable Calculus II				
USMT 501, UAMT 501	I	Multiple Integrals	2.5	3
	II	Line Integrals		
	III	Surface Integrals		
Linear Algebra				
USMT 502 ,UAMT 502	I	Quotien spaces and Orthogonal Linear Transformations	2.5	3
	II	Eigen values and Eigen vectors		
	III	Diagonalisation		
Topology of Metric Spaces				
USMT 503/UAMT503	I	Metric spaces	2.5	3
	II	Sequences and Complete metric spaces		
	III	Compact Sets		
Numerical Analysis I(Elective A)				
USMT5A4 ,UAMT 5A4	I	Errors Analysis	2.5	3
	II	Transcendental and Polynomial & Equations		
	III	Linear System of Equations		
Number Theory and Its applications I (Elective B)				
USMT5B4 ,UAMT 5B4	I	Congruences and Factorization	2.5	3
	II	Diophantine equations and their & solutions		
	III	Primitive Roots and Cryptography		
Graph Theory (Elective C)				
USMT5C4 ,UAMT 5C4	I	Basics of Graphs	2.5	3
	II	Trees		
	III	Eulerian and Hamiltonian graphs		
Basic Concepts of Probability and Random Variables (Elective D)				
USMT5D4 ,UAMT 5D4	I	Basic Concepts of Probability and Random Variables	2.5	3
	II	Properties of Distribution function, Joint Density function		
	III	Weak Law of Large Numbers		
PRACTICALS				
USMTP05/UAMTP05		Practicals based on USMT501/UAMT 501 and USMT 502/UAMT 502	3	6
USMTP06/UAMTP06		Practicals based on USMT503/ UAMT 503 and USMT5A4/ UAMT 5A4 OR USMT5B4/ UAMT 5B4 OR USMT5C4/ UAMT 5C4 OR USMT5D4/ UAMT 5D4	3	6

SEMESTER VI

BASIC COMPLEX ANALYSIS				
Course Code	UNIT	TOPICS	Credits	L/Week
USMT 601, UAMT 601	I	Introduction to Complex Analysis	2.5	3
	II	Cauchy Integral Formula		
	III	Complex power series, Laurent series and isolated singularities		
ALGEBRA				
USMT 602 ,UAMT 602	I	Group Theory	2.5	3
	II	Ring Theory		
	III	Polynomial Rings and Field theory Homomorphism		
Topology of Metric Spaces and Real Analysis				
USMT 603 / UAMT 603	I	Continuous functions on Metric spaces	2.5	3
	II	Connected sets		
		Sequences and series of functions		
Numerical Analysis II(Elective A)				
USMT6A4 ,UAMT 6A4	I	Interpolation	2.5	3
	II	Polynomial Approximations and Numerical Differentiation		
	III	Numerical Integration		
Number Theory and Its applications II (Elective B)				
USMT6B4 ,UAMT 6B4	I	Quadratic Reciprocity	2.5	3
	II	Continued Fractions		
	III	Pell's equation, Arithmetic function & and Special numbers		
Graph Theory and Combinatorics (Elective C)				
USMT6C4 ,UAMT 6C4	I	Colorings of Graphs	2.5	3
	II	Planar graph		
	III	Combinatorics		
Operations Research (Elective D)				
USMT6D4 ,UAMT 6D4	I	Basic Concepts of Probability and Linear Programming I	2.5	3
	II	Linear Programming II		
	III	Queuing Systems		
PRACTICALS				
USMTP07/ UAMTP07		Practicals based on USMT601/UAMT 601 and USMT 602/UAMT 602	3	6
USMTP08/UAMTP08		Practicals based on USMT603/ UAMT 603 and USMT6A4/ UAMT 6A4 OR USMT6B4/ UAMT 6B4 OR USMT6C4/ UAMT 6C4 OR USMT6D4/ UAMT 6D4	3	6

Note: 1 . USMT501/UAMT501, USMT502/UAMT502, USMT503/UAMT503 are compulsory courses for Semester V.

2 . Candidate has to opt one Elective Course from USMT5A4/UAMT5A4, USMT5B4/UAMT5B4, USMT5C4/UAMT5C4 and USMT5D4/UAMT5D4 for Semester V.

3 . USMT601/UAMT601, USMT602/UAMT602, USMT603/UAMT603 are compulsory courses for Semester VI.

4 . Candidate has to opt one Elective Course from USMT6A4/UAMT6A4, USMT6B4/UAMT6B4, USMT6C4/UAMT6C4 and USMT6D4/UAMT6D4 for Semester VI.

5 . Passing in theory and practical shall be separate.

Teaching Pattern for T.Y.B.Sc/B.A.

1. Three lectures per week per course (1 lecture/period is of 48 minutes duration).
2. One practical of three periods per week per course (1 lecture/period is of 48 minutes duration).

Scheme of Examination

I. **Semester End Theory Examinations:** There will be a Semester-end external Theory examination of 100 marks for each of the courses USMT501/UAMT501, USMT502/UAMT502, USMT503 and USMT5A4 OR USMT5B4 OR USMT5C4 OR USMT 5D4 of Semester V and USMT601/UAMT601, USMT602/UAMT602, USMT603 and USMT6A4 OR USMT6B4 OR USMT 6C4 OR USMT 6D4 of semester VI to be conducted by the University.

   1. Duration: The examinations shall be of 3 Hours duration.
   2. Theory Question Paper Pattern:
      a) There shall be FIVE questions. The first question Q1 shall be of objective type for 20 marks based on the entire syllabus. The next three questions Q2, Q2, Q3 shall be of 20 marks, each based on the units I, II, III respectively. The fifth question Q5 shall be of 20 marks based on the entire syllabus.
      b) All the questions shall be compulsory. The questions Q2, Q3, Q4, Q5 shall have internal choices within the questions. Including the choices, the marks for each question shall be 30-32.
      c) The questions Q2, Q3, Q4, Q5 may be subdivided into sub-questions as a, b, c, d & e, etc and the allocation of marks depends on the weightage of the topic.
      d) The question Q1 may be subdivided into 10 sub-questions of 2 marks each.

II. **Semester End Examinations Practicals:**
There shall be a Semester-end practical examinations of three hours duration and 100 marks for each of the courses USMTP05/UAMTP05 of Semester V and USMTP06/UAMTP06 of semester VI.

In semester V, the Practical examinations for USMTP05/UAPTP05 and USMTP06/UAMTP06 are conducted by the college.

In semester VI, the Practical examinations for USMTP07/UAMTP07 and USMTP08/UAMTP08 are conducted by the University.

Question Paper pattern:

Paper pattern: The question paper shall have two parts A, B.
Each part shall have two Sections.

Section I Objective in nature: Attempt any Eight out of Twelve multiple choice questions. ($8 \times 3 = 24$ Marks)

Section II Problems: Attempt any Two out of Three. ($8 \times 2 = 16$ Marks)

Practical Course	Part A	Part B	Marks out of	duration
USMTP05/UAMTP05	Questions from USMT501/UAMT501	Questions from USMT502/UAMT502	80	3 hours
USMTP06/UAMTP06	Questions from USMT503/UAMT503	Questions from USMT504/UAMT504	80	2 hours
USMTP07/UAMTP07	Questions from USMT601/UAMT601	Questions from USMT602/UAMT602	80	3 hours
USMTP06/UAMTP08	Questions from USMT603/UAMT603	Questions from USMT604/UAMT604	80	2 hours

Marks for Journals and Viva:
For each course USMT501/UAMT501, USMT502/UAMT502, USMT503/UAMT503, USMT504/UAMT504, USMT601/UAMT601, USMT602/UAMT602 USMT603/UAMT603, and USMT604/UAMT604:

1. Journals: 5 marks.

2. Viva: 5 marks.

Each Practical of every course of Semester V and VI shall contain 10 (ten) problems out of which minimum 05 (five) have to be written in the journal. A student must have a certified journal before appearing for the practical examination.

SEMESTER V
MULTIVARIABLE CALCULUS II
Course Code: USMT501/UAMT501

ALL Results have to be done with proof unless otherwise stated.

Unit I-Multiple Integrals (15L)
Definition of double (resp: triple) integral of a function and bounded on a rectangle (resp:box). Geometric interpretation as area and volume. Fubini's Theorem over rectangles and any closed bounded sets, Iterated Integrals. Basic properties of double and triple integrals proved using the Fubini's theorem such as

(i) Integrability of the sums, scalar multiples, products, and (under suitable conditions) quotients of integrable functions. Formulae for the integrals of sums and scalar multiples of integrable functions.

(ii) Integrability of continuous functions. More generally, Integrability of functions with a "small set of (Here, the notion of "small sets should include finite unions of graphs of continuous functions.)

(iii) Domain additivity of the integral. Integrability and the integral over arbitrary bounded domains. Change of variables formula (Statement only).Polar, cylindrical and spherical coordinates, and integration using these coordinates. Differentiation under the integral sign. Applications to finding the center of gravity and moments of inertia.

References for Unit I:

1. Apostol, Calculus, Vol. 2, Second Ed., John Wiley, New York, 1969 Section 1.1 to 11.8
2. James Stewart , Calculus with early transcendental Functions - Section 15
3. J.E.Marsden and A.J. Tromba, Vector Calculus, Fourth Ed., W.H. Freeman and Co., New York, 1996.Section 5.2 to 5.6.

Unit 2: Line Integrals (15L)

Review of Scalar and Vector fields on $\mathbb{R}^n$, Vector Differential Operators, Gradient, Curl, Divergence.
Paths (parametrized curves) in $\mathbb{R}^n$ (emphasis on $\mathbb{R}^2$ and $\mathbb{R}^3$), Smooth and piecewise smooth paths. Closed paths. Equivalence and orientation preserving equivalence of paths. Definition of the line integral of a vector field over a piecewise smooth path. Basic properties of line integrals including linearity, path-additivity and behavior under a change of parameters. Examples.

Line integrals of the gradient vector field, Fundamental Theorem of Calculus for Line Integrals, Necessary and sufficient conditions for a vector field to be conservative. Greens Theorem (proof in the case of rectangular domains). Applications to evaluation of line integrals.

References for Unit II:

1. Lawrence Corwin and Robert Szczarba ,Multivariable Calculus, Chapter 12.
2. Apostol, Calculus, Vol. 2, Second Ed., John Wiley, New York, 1969 Section 10.1 to 10.5,10.10 to 10.18
3. James Stewart , Calculus with early transcendental Functions - Section 16.1 to 16.4.
4. J.E.Marsden and A.J. Tromba, Vector Calculus, Fourth Ed., W.H. Freeman and Co., New York, 1996. Section 6.1,7.1.7.4.

Unit III: Surface Integrals (15 L)

Parameterized surfaces. Smoothly equivalent parameterizations. Area of such surfaces.
Definition of surface integrals of scalar-valued functions as well as of vector fields defined on a surface.
Curl and divergence of a vector field. Elementary identities involving gradient, curl and divergence.
Stokes Theorem (proof assuming the general from of Greens Theorem). Examples.
Gauss Divergence Theorem (proof only in the case of cubical domains). Examples.

References for Unit III:

1. Apostol, Calculus, Vol. 2, Second Ed., John Wiley, New York, 1969 Section 1.1 to 11.8
2. James Stewart , Calculus with early transcendental Functions - Section 16.5 to 16.9
3. J.E.Marsden and A.J. Tromba, Vector Calculus, Fourth Ed., W.H. Freeman and Co., New York, 1996 Section 6.2 to 6.4.

Other References :

1. T Apostol, Mathematical Analysis, Second Ed., Narosa, New Delhi. 1947.
2. R. Courant and F.John, Introduction to Calculus and Analysis, Vol.2, Springer Verlag, New York, 1989.
3. W. Fleming, Functions of Several Variables, Second Ed., Springer-Verlag, New York, 1977.
4. M.H. Protter and C.B.Morrey Jr., Intermediate Calculus, Second Ed., Springer-Verlag, New York, 1995.
5. G.B. Thomas and R.L Finney, Calculus and Analytic Geometry, Ninth Ed. (ISE Reprint), Addison- Wesley, Reading Mass, 1998.
6. D.V.Widder, Advanced Calculus, Second Ed., Dover Pub., New York. 1989.
7. A course in Multivariable Calculus and Analysis., Sudhir R.Ghorpade and Balmohan Limaye, Springer International Edition.

Linear Algebra
Course Code: USMT502/UAMT502

Unit I. Quotient Spaces and Orthogonal Linear Transformations (15L)
Review of vector spaces over $\mathbb{R}$, sub spaces and linear transformation.
Quotient Spaces: For a real vector space V and a subspace W, the cosets $v + W$ and the quotient space V/W , First Isomorphism theorem of real vector spaces (fundamental theorem of homomorphism of vector spaces), Dimension and basis of the quotient space V/W , when V is finite dimensional.

Orthogonal transformations: Isometries of a real finite dimensional inner product space, Translations and Reflections with respect to a hyperplane, Orthogonal matrices over $\mathbb{R}$, Equivalence of orthogonal transformations and isometries fixing origin on a finite dimensional inner product space, Orthogonal transformation of $\mathbb{R}^2$, Any orthogonal transformation in $\mathbb{R}^2$ is a reflection or a rotation, Characterization of isometries as composites of orthogonal transformations and translation. Characteristic polynomial of an $n \times n$ real matrix. Cayley Hamilton Theorem and its Applications (Proof assuming the result $A(\text{adj}A) = I_n$ for an $n \times n$ matrix over the polynomial ring $\mathbb{R}[t]$.

Unit II. Eigenvalues and eigen vectors (15L)
Eigen values and eigen vectors of a linear transformation $T : V \longrightarrow V$, where V is a finite dimensional real vector space and examples, Eigen values and Eigen vectors of n n real matrices, The linear independence of eigenvectors corresponding to distinct eigenvalues of a linear transformation and a Matrix. The characteristic polynomial of an n real matrix and a linear transformation of a finite dimensional real vector space to itself, characteristic roots, Similar

matrices, Relation with change of basis, Invariance of the characteristic polynomial and (hence of the) eigen values of similar matrices, Every square matrix is similar to an upper triangular matrix. Minimal Polynomial of a matrix, Examples like minimal polynomial of scalar matrix, diagonal matrix, similar matrix, Invariant subspaces.

Unit III: Diagonalisation (15L)
Geometric multiplicity and Algebraic multiplicity of eigen values of an $n \times n$ real matrix, An $n \times n$ matrix A is diagonalizable if and only if has a basis of eigenvectors of A if and only if the sum of dimension of eigen spaces of A is n if and only if the algebraic and geometric multiplicities of eigen values of A coincide, Examples of non diagonalizable matrices, Diagonalisation of a linear transformation $T : V \longrightarrow V$, where V is a finite dimensional real vector space and examples. Orthogonal diagonalisation and Quadratic Forms. Diagonalisation of real Symmetric matrices, Examples, Applications to real Quadratic forms, Rank and Signature of a Real Quadratic form, Classification of conics in $\mathbb{R}^2$ and quadric surfaces in $\mathbb{R}^3$. Positive definite and semi definite matrices, Characterization of positive definite matrices in terms of principal minors.

Recommended Books.

1. S. Kumaresan, Linear Algebra: A Geometric Approach.

2. Ramachandra Rao and P. Bhimasankaram, Tata McGrawHillll Publishing Company.

Additional Reference Books

1. T. Banchoff and J. Wermer, Linear Algebra through Geometry, Springer.

2. L. Smith, Linear Algebra, Springer.

3. M. R. Adhikari and Avishek Adhikari, Introduction to linear Algebra, Asian Books Private Ltd.

4. K Hoffman and Kunze, Linear Algebra, Prentice Hall of India, New Delhi.

5. Inder K Rana, Introduction to Linear Algebra, Ane Books Pvt. Ltd.

Course: Topology of Metric Spaces
Course Code: USMT503/UAMT503

Unit I: Metric spaces (15 L)

Definition, examples of metric spaces $\mathbb{R}, \mathbb{R}^2$,Euclidean space $\mathbb{R}^n$ with its Euclidean, sup and sum metric, $\mathbb{C}$ (complex numbers), the spaces l^1 and l^2 of sequences and the space $C[a, b]$, of real valued continuous functions on $[a, b]$. Discrete metric space.
Distance metric induced by the norm, translation invariance of the metric induced by the norm. Metric subspaces, Product of two metric spaces. Open balls and open set in a metric space, examples of open sets in various metric spaces. Hausdorff property. Interior of a set. Properties of open sets. Structure of an open set in IR. Equivalent metrics.
Distance of a point from a set, between sets ,diameter of a set in a metric space and bounded sets. Closed ball in a metric space, Closed sets- definition, examples. Limit point of a set, isolated point, a closed set contains all its limit points, Closure of a set and boundary of a set.

Unit II: Sequences and Complete metric spaces (15L)

Sequences in a metric space, Convergent sequence in metric space, Cauchy sequence in a metric space, subsequences, examples of convergent and Cauchy sequence in finite metric spaces, $\mathbb{R}^n$ with different metrics and other metric spaces.
Characterization of limit points and closure points in terms of sequences, Definition and examples of relative openness/closeness in subspaces. Dense subsets in a metric space and Separability Definition of complete metric spaces, Examples of complete metric spaces, Completeness property in subspaces, Nested Interval theorem in $\mathbb{R}$, Cantor's Intersection Theorem, Applications of Cantors Intersection Theorem:

(i) The set of real Numbers is uncountable.

(ii) Density of rational Numbers(Between any two real numbers there exists a rational number)

(iii) Intermediate Value theorem: Let : $[a, b]\mathbb{R}$ be continuous, and assume that $f(a)$ and $f(b)$ are of different signs say, $f(a) < 0$ and $f(b) > 0$. Then there exists $c \in (a, b)$ such that $f(c) = 0$.

Unit III: Compact sets 15 lectures

Definition of compact metric space using open cover, examples of compact sets in different metric spaces $\mathbb{R}, \mathbb{R}^2, \mathbb{R}^n$, Properties of compact sets: A compact set is closed and bounded, (Converse is not true). Every infinite bounded subset of compact metric space has a limit point. A closed subset of a compact set is compact. Union and Intersection of Compact sets. Equivalent statements for compact sets in $\mathbb{R}$:

(i) Sequentially compactness property.

(ii) Heine-Borel property: Let be a closed and bounded interval. Let be a family of open intervals such that Then there exists a finite subset such that that is, is contained in the union of a finite number of open intervals of the given family.

(iii) Closed and boundedness property.

(iv) Bolzano-Weierstrass property: Every bounded sequence of real numbers has a convergent subsequence.

Reference books:

1. S. Kumaresan, Topology of Metric spaces.
2. E. T. Copson. Metric Spaces. Universal Book Stall, New Delhi, 1996.
3. Expository articles of MTTS programme

Other references :

1. W. Rudin, Principles of Mathematical Analysis.
2. T. Apostol. Mathematical Analysis, Second edition, Narosa, New Delhi, 1974
3. E. T. Copson. Metric Spaces. Universal Book Stall, New Delhi, 1996.
4. R. R. Goldberg Methods of Real Analysis, Oxford and IBH Pub. Co., New Delhi 1970.
5. P.K.Jain. K. Ahmed. Metric Spaces. Narosa, New Delhi, 1996.
6. W. Rudin. Principles of Mathematical Analysis, Third Ed, McGraw-Hill, Auckland, 1976.
7. D. Somasundaram, B. Choudhary. A first Course in Mathematical Analysis. Narosa, New Delhi
8. G.F. Simmons, Introduction to Topology and Modern Analysis, McGraw-Hi, New York, 1963.
9. Sutherland. Topology.

Course: Numerical Analysis I (Elective A)
Course Code: USMT5A4/UAMT5A4

N.B. Derivations and geometrical interpretation of all numerical methods have to be covered.

Unit I. Errors Analysis and Transcendental & Polynomial Equations (15L)
Measures of Errors: Relative, absolute and percentage errors. Types of errors: Inherent error, Round-off error and Truncation error. Taylors series example. Significant digits and numerical stability. Concept of simple and multiple roots. Iterative methods, error tolerance, use of intermediate value theorem. Iteration methods based on first degree equation: Newton-Raphson method, Secant method, Regula-Falsi method, Iteration Method. Condition of convergence and Rate of convergence of all above methods.

Unit II. Transcendental and Polynomial Equations (15L)
Iteration methods based on second degree equation: Muller method, Chebyshev method, Multipoint iteration method. Iterative methods for polynomial equations; Descarts rule of signs, Birge-Vieta method, Bairstrow method. Methods for multiple roots. Newton-Raphson method. System of non-linear equations by Newton- Raphson method. Methods for complex roots. Condition of convergence and Rate of convergence of all above methods.

Unit III. Linear System of Equations (15L)
Matrix representation of linear system of equations. Direct methods: Gauss elimination method.

Pivot element, Partial and complete pivoting, Forward and backward substitution method, Triangularization methods-Doolittle and Crouts method, Choleskys method. Error analysis of direct methods. Iteration methods: Jacobi iteration method, Gauss-Siedal method. Convergence analysis of iterative method. Eigen value problem, Jacobis method for symmetric matrices Power method to determine largest eigenvalue and eigenvector.

Recommended Books

1. Kendall E. and Atkinson, An Introduction to Numerical Analysis, Wiley.
2. M. K. Jain, S. R. K. Iyengar and R. K. Jain, Numerical Methods for Scientific and Engineering Computation, New Age International Publications.
3. S.D. Comte and Carl de Boor, Elementary Numerical Analysis, An algorithmic approach, McGrawHillll International Book Company.
4. S. Sastry, Introductory methods of Numerical Analysis, PHI Learning.
5. Hildebrand F.B., Introduction to Numerical Analysis, Dover Publication, NY.
6. Scarborough James B., Numerical Mathematical Analysis, Oxford University Press, New Delhi.

Course: Number Theory and its applications I (Elective B)
Course Code: USMT5B4 / UAMT5B4

Unit I. Congruences and Factorization (15L)

Review of Divisibility, Primes and The fundamental theorem of Arithmetic.
Congruences : Definition and elementary properties, Complete residue system modulo m, Reduced residue system modulo m , Euler's function and its properties, Fermat's little Theorem, Euler's generalization of Fermat's little Theorem, Wilson's theorem, Linear congruence, The Chinese remainder Theorem, Congruences ofHillgher degree, The Fermat-Kraitchik Factorization Method.

Unit II. Diophantine equations and their solutions (15L)

The linear equations $ax + by = c$. The equations $x^2 + y^2 = p$, where p is a prime. The equation $x^2 + y^2 = z^2$, Pythagorean triples, primitive solutions, The equations $x^4 + y^4 = z^2$ and $x^4 + y^4 = z^4$ have no solutions $(x; y; z)$ with $xyz \neq 0$. Every positive integer n can be expressed as sum of squares of four integers, Universal quadratic forms $x^2+y^2+z^2+t^2$. Assorted examples :section 5.4 of Number theory by Niven- Zuckermann-Montgomery.

Unit III. Primitive Roots and Cryptography (15L)

Order of an integer and Primitive Roots. Basic notions such as encryption (enciphering) and decryption (deciphering), Cryptosystems, symmetric key cryptography, Simple examples such as shift cipher, Affine cipher,Hillll's cipher, Vigenere cipher. Concept of Public Key Cryptosystem; RSA Algorithm. An application of Primitive Roots to Cryptography.

Reference for Unit III:

Elementary number theory, David M. Burton, Chapter 8 sections 8.1, 8.2 and 8.3, Chapter 10, sections 10.1, 10.2 and 10.3

Recommended Books

1. Niven, H. Zuckerman and H. Montogomery, An Introduction to the Theory of Numbers, John Wiley & Sons. Inc.

2. David M. Burton, An Introduction to the Theory of Numbers. Tata McGrawHillll Edition.

3. G. H. Hardy and E.M. Wright. An Introduction to the Theory of Numbers. Low priced edition. The English Language Book Society and Oxford University Press, 1981.

4. Neville Robins. Beginning Number Theory. Narosa Publications.

5. S.D. Adhikari. An introduction to Commutative Algebra and Number Theory. Narosa Publishing House.

6. N. Koblitz. A course in Number theory and Cryptography, Springer.

7. M. Artin, Algebra. Prentice Hall.

8. K. Ireland, M. Rosen. A classical introduction to Modern Number Theory. Second edition, Springer Verlag.

9. William Stalling. Cryptology and network security.

Course: Graph Theory (Elective C)
Course Code: USMT5C4 / UAMT5C4

Unit I. Basics of Graphs (15L)
Definition of general graph, Directed and undirected graph, Simple and multiple graph, Types of graphs- Complete graph, Null graph, Complementary graphs, Regular graphs Sub graph of a graph, Vertex and Edge induced sub graphs, Spanning sub graphs. Basic terminology- degree of a vertex, Minimum and maximum degree, Walk, Trail, Circuit, Path, Cycle. Handshaking theorem and its applications, Isomorphism between the graphs and consequences of isomorphism between the graphs, Self complementary graphs, Connected graphs, Connected components. Matrices associated with the graphs Adjacency and Incidence matrix of a graph- properties, Bipartite graphs and characterization in terms of cycle lengths. Degree sequence and Havel-Hakimi theorem, Distance in a graph- shortest path problems, Dijkstra's algorithm.

Unit II. Trees (15L)
Cut edges and cut vertices and relevant results, Characterization of cut edge, Definition of a tree and its characterizations, Spanning tree, Recurrence relation of spanning trees and Cayley formula for spanning trees of Kn , Algorithms for spanning tree-BFS and DFS, Binary and m-ary tree, Prefix codes and Huffman coding, Weighted graphs and minimal spanning trees - Kruskal's algorithm for minimal spanning trees.

Unit III. Eulerian and Hamiltonian graphs (15L)
Eulerian graph and its characterization- Fleury's Algorithm-(Chinese postman problem), Hamiltonian graph, Necessary condition for Hamiltonian graphs using G- S where S is a proper subset of V(G), Sufficient condition for Hamiltonian graphs- Ore's theorem and Dirac's theorem, Hamiltonian closure of a graph, Cube graphs and properties like regular, bipartite, Connected and Hamiltonian nature of cube graph, Line graph of graph and simple results.

Recommended Books.

1. Bondy and Murty Grapgh, Theory with Applications.
2. Balkrishnan and Ranganathan, Graph theory and applications.
3. West D G. , Graph theory.

Additional Reference Book.

1. Behzad and Chartrand Graph theory.
2. Choudam S. A., Introductory Graph theory.

Course: Basic Concepts of Probability and Random Variables (Elective D)
Course Code: USMT5D4 / UAMT5D4

Unit I. Basic Concepts of Probability and Random Variables.(15 L)
Basic Concepts: Algebra of events including countable unions and intersections, Sigma field $\mathcal{F}$, Probability measure$P$ on $\mathcal{F}$, Probability Space as a triple $(\Omega, \mathcal{F}, P)$, Properties of P including Subadditivity. Discrete Probability Space, Independence and Conditional Probability, Theorem of Total Probability. Random Variable on $(\Omega, \mathcal{F}, P)$ Definition as a measurable function, Classification of random variables - Discrete Random variable, Probability function, Distribution function, Density function and Probability measure on Borel subsets of $\mathbb{R}$, Absolutely continuous random variable. Function of a random variable; Result on a random variable R with distribution function F to be absolutely continuous, Assume F is continuous everywhere and has a continuous derivative at all points except possibly at finite number of points, Result on density function f_2 of R_2 where $R_2 = g(R_1), h_j$ is inverse of g over a suitable subinterval $f_2(y) + \sum_{i=1}^{n} f_1(h_j(y))|h_j'(y)|$ under suitable conditions.

Reference for Unit 1, Sections 1.1-1.6, 2.1-2.5 of Basic Probability theory by Robert Ash, Dover Publication, 2008.

Unit II. Properties of Distribution function, Joint Density function (15L) Properties of distribution function F, F is non-decreasing, $\lim_{x \longrightarrow \infty} F(x) = 1$, $\lim_{x \longrightarrow \infty} F(x) = 0$, Right continuity of F, $\lim_{x \longrightarrow x_0} F(x) = P(\{R < x_o\}, P(\{R = x_o\}) = F(x_o)F(\overline{x_0})$. Joint distribution, Joint Density, Results on Relationship between Joint and Individual densities, Related result for Independent random variables. Examples of distributions like Binomial, Poisson and Normal distribution. Expectation and $k-$th moments of a random variable with properties.

Reference for Unit II:
Sections 2.5-2.7, 2.9, 3.2-3.3,3.6 of Basic Probability theory by Robert Ash, Dover Publication, 2008.

Unit III. Weak Law of Large Numbers
Joint Moments, Joint Central Moments, Schwarz Inequality, Bounds on Correlation Coefficient ρ ,Result on ρ as a measure of linear dependence, $\mathrm{Var}\Big(\sum_{i=1}^{n} R_i\Big) = \sum_{i=1}^{n} Var(R_i) + 2 \sum_{i=1 \leq i<j \leq n}^{n} \mathrm{Cov}(R_i, R_j)$, Method of Indicators to find expectation of a random variable, Chebyshevs Inequality, Weak

law of Large numbers.

Reference for Unit III
Sections 3.4, 3.5, 3.7, 4.1-4.4 of Basic Probability theory by Robert Ash, Dover Publication, 2008.

Additional Reference Books. Marek Capinski, Probability through Problems, Springer.

Course: Practicals (Based on USMT501 / UAMT501 and USMT502 / UAMT502)
Course Code: USMTP05 / UAMTP05

Suggested Practicals (Based on USMT501 / UAMT501)

1. Evaluation of double and triple integrals.
2. Change of variables in double and triple integrals and applications
3. Line integrals of scalar and vector fields
4. Greens theorem, conservative field and applications
5. Evaluation of surface integrals
6. Stokes and Gauss divergence theorem
7. Miscellaneous theory questions on units 1, 2 and 3.

Suggested Practicals (Based on USMT502 / UAMT502)

1. Quotient Spaces, Orthogonal Transformations.
2. Cayley Hamilton Theorem and Applications
3. Eigen Values & Eigen Vectors of a linear Transformation/ Square Matrices
4. Similar Matrices, Minimal Polynomial, Invariant Subspaces
5. Diagonalisation of a matrix
6. Orthogonal Diagonalisation and Quadratic Forms.
7. Miscellaneous Theory Questions

Course: Practicals (Based on USMT503 / UAMT503 and USMT5A4 / UAMT5A4 OR USMT5B4 / UAMT5B4 OR USMT5C4 / UAMT5C4 OR USMT5D4 / UAMT5D4)
Course Code: USMTP06 / UAMTP06

Suggested Practicals USMT503 / UAMT503:

1. Examples of Metric Spaces, Normed Linear Spaces,
2. Sketching of Open Balls in IR2, Open and Closed sets, Equivalent Metrics
3. Subspaces, Interior points, Limit Points, Dense Sets and Separability, Diameter of a set, Closure.

4. Limit Points ,Sequences , Bounded , Convergent and Cauchy Sequences in a Metric Space
5. Complete Metric Spaces and Applications
6. Examples of Compact Sets
7. Miscellaneous Theory Questions

Suggested Practicals on USMT5A4 / UAMT5A4
The Practicals should be performed using non-programmable scientific calculator. (The use of programming language like C or Mathematical Software like Mathematica, Matlab, MuPad, and Maple may be encouraged).

1. Newton-Raphson method, Secant method, Regula-Falsi method, Iteration Method
2. Muller method, Chebyshev method, Multipoint iteration method
3. Descarts rule of signs, Birge-Vieta method, Bairstrow method
4. Gauss elimination method, Forward and backward substitution method,
5. Triangularization methods-Doolittles and Crouts method, Choleskys method
6. Jacobi iteration method, Gauss-Siedal method
7. Eigen value problem: Jacobis method for symmetric matrices and Power method to determine largest eigenvalue and eigenvector

Suggested Practicals based on USMT5B4 / UAMT5B4

1. Congruences.
2. Linear congruences and congruences of Hilgher degree.
3. Linear diophantine equation.
4. Pythagorean triples and sum of squares.
5. Cryptosystems (Private Key).
6. Cryptosystems (Public Key) and primitive roots.
7. Miscellaneous theoretical questions based on full USMT5B4 / UAMT5B4.

Suggested Practicals based on USMT5C4 / UAMT5C4

1. Handshaking Lemma and Isomorphism.
2. Degree sequence and Dijkstra's algorithm
3. Trees, Cayley Formula
4. Applications of Trees
5. Eulerian Graphs.
6. Hamiltonian Graphs.

7. Miscellaneous Problems.

Suggested Practicals based on USMT5D4 / UAMT5D4

1. Basic concepts of Probability (Algebra of events, Probability space, Probability measure, combinatorial problems)
2. Conditional Probability, Random variable (Independence of events. Definition, Classification and function of a random variable)
3. Distribution function, Joint Density function
4. Expectation of a random variable, Normal distribution
5. Method of Indicators, Weak law of large numbers
6. Conditional density, Conditional expectation
7. Miscellaneous Theoretical questions based on full paper

SEMESTER VI
BASIC COMPLEX ANALYSIS
Course Code: USMT501/UAMT501

Unit I: Introduction to Complex Analysis (15 Lectures)
Review of complex numbers: Complex plane, polar coordinates, exponential map, powers and roots of complex numbers, De Moivres formula, $\mathbb{C}$ as a metric space, bounded and unbounded sets, point at infinity-extended complex plane, sketching of set in complex plane (No questions to be asked).
Limit at a point, theorems on limits, convergence of sequences of complex numbers and results using properties of real sequences. Functions $f : \mathbb{C} \longrightarrow \mathbb{C}$, real and imaginary part of functions, continuity at a point and algebra of continuous functions. Derivative of $f : \mathbb{C} \longrightarrow \mathbb{C}$, comparison between differentiability in real and complex sense, Cauchy-Riemann equations, sufficient conditions for differentiability, analytic function, f, g analytic then $f + g, f - g, fg$ and f/g are analytic, chain rule.

Theorem: If $f(z) = 0$ everywhere in a domain D, then $f(z)$ must be constant throughout D
Harmonic functions and harmonic conjugate.

Unit II: Cauchy Integral Formula (15 Lectures)
Explain how to evaluate the line integral $\int f(z)\,dz$ over $|z-z_0| = r$ and prove the Cauchy integral formula : If f is analytic in $B(z_0, r)$ then for any w in $B(z_0, r)$ we have $f(w) = \dfrac{1}{2\pi i}\displaystyle\int \frac{f(z)}{z-w}\,dz$, over $|z - z_0| = r$.
Taylors theorem for analytic function , Mobius transformations: definition and examples
Exponential function, its properties, trigonometric function, hyperbolic functions.

Unit III: Complex power series, Laurent series and isolated singularities. (15 Lectures)
Power series of complex numbers and related results following from Unit I, radius of convergences, disc of convergence, uniqueness of series representation, examples.

Definition of Laurent series , Definition of isolated singularity, statement (without proof) of existence of Laurent series expansion in neighbourhood of an isolated singularity, type of isolated singularities viz. removable, pole and essential defined using Laurent series expansion, examples Statement of Residue theorem and calculation of residue.

Reference:

1. J.W. Brown and R.V. Churchill, Complex analysis and Applications : Sections 18, 19, 20, 21, 23, 24, 25, 28, 33, 34, 47, 48, 53, 54, 55 , Chapter 5, page 231 section 65, define residue of a function at a pole using Theorem in section 66 page 234, Statement of Cauchys residue theorem on page 225, section 71 and 72 from chapter 7.

Other References:

1. Robert E. Greene and Steven G. Krantz, Function theory of one complex variable

2. T.W. Gamelin, Complex analysis

Course: Algebra
Course Code: USMT602 / UAMT602

Unit I. Group Theory (15L)
Review of Groups, Subgroups, Abelian groups, Order of a group, Finite and infinite groups, Cyclic groups, The Center Z(G) of a group G, Cosets, Lagranges theorem, Group homomorphisms, isomorphisms, automorphisms, inner automorphisms (No questions to be asked)

Normal subgroups: Normal subgroups of a group, definition and examples including center of a group, Quotient group, Alternating group A_n, Cycles. Listing normal subgroups of A_4, S_3. First Isomorphism theorem (or Fundamental Theorem of homomorphisms of groups), Second Isomorphism theorem, third Isomorphism theorem, Cayleys theorem, External direct product of a group, Properties of external direct products, Order of an element in a direct product, criterion for direct product to be cyclic, Classification of groups of order ≤ 7.

Unit II. Ring Theory (15L)
Motivation: Integers & Polynomials.
Definitions of a ring (The definition should include the existence of a unity element), zero divisor, unit, the multiplicative group of units of a ring. Basic Properties & examples of rings, including $\mathbb{Z}, \mathbb{Q}, \mathbb{R}, \mathbb{C}, Mn(\mathbb{R}), \mathbb{Q}[X], \mathbb{R}[X], \mathbb{C}[X], \mathbb{Z}[i], \mathbb{Z}[\sqrt{2}], \mathbb{Z}[\sqrt{-5}], \mathbb{Z}_n$.
Definitions of Commutative ring, integral domain (ID), Division ring, examples. Theorem such as: A commutative ring R is an integral domain if and only if for $a, b, c \in R$ with $a \neq 0$ the relation $ab = ac$ implies that $b = c$. Definitions of Subring, examples. Ring homomorphisms, Properties of ring homomorphisms, Kernel of ring homomorphism, Ideals, Operations on ideals and Quotient rings, examples. Factor theorem and First and second Isomorphism theorems for rings, Correspondence Theorem for rings: (If $f : R \longrightarrow R'$ is a surjective ring homomorphism, then there is a $1-1$ correspondence between the ideals of R containing the ker f and the ideals of R. Definitions of characteristic of a ring, Characteristic of an ID.

Unit III. Polynomial Rings and Field theory (15L)
Principal ideal, maximal ideal, prime ideal, the characterization of the prime and maximal ideals

in terms of quotient rings. Polynomial rings, R[X] when R is an integral domain/ Field. Divisibility in Integral Domain, Definitions of associates, irreducible and primes. Prime (irreducible) elements in $\mathbb{R}[X], \mathbb{Q}[X], \mathbb{Z}_p[X]$. Eisensteins criterion for irreducibility of a polynomial over $\mathbb{Z}$. Prime and maximal ideals in polynomial rings. Definition of field, subfield and examples, characteristic of fields. Any field is an ID and a finite ID is a field. Characterization of fields in terms of maximal ideals, irreducible polynomials. Construction of quotient field of an integral domain (Emphasis on $\mathbb{Z}, \mathbb{Q}$). A field contains a subfield isomorphic to $\mathbb{Z}_p$ or $\mathbb{Q}$.

Recommended Books

1. P. B. Bhattacharya, S. K. Jain, and S. R. Nagpaul, Abstract Algebra, Second edition, Foundation Books, New Delhi, 1995.

2. N. S. Gopalakrishnan, University Algebra, Wiley Eastern Limited.

3. N. Herstein. Topics in Algebra, Wiley Eastern Limited, Second edition.

4. M. Artin, Algebra, Prentice Hall of India, New Delhi.

5. J. B. Fraleigh, A First course in Abstract Algebra, Third edition, Narosa, New Delhi.

6. J. Gallian, Contemporary Abstract Algebra, Narosa, New Delhi.

Additional Reference Books:

1. S. Adhikari, An Introduction to Commutative Algebra and Number theory, Narosa Publishing House.

2. T.W. Hungerford. Algebra, Springer.

3. D. Dummit, R. Foote. Abstract Algebra, John Wiley & Sons, Inc.

4. I.S. Luthar, I.B.S. Passi. Algebra, Vol. I and II.

5. U. M. Swamy, A. V. S. N. Murthy Algebra Abstract and Modern, Pearson.

6. Charles Lanski, Concepts Abstract Algebra, American Mathematical Society

7. Sen, Ghosh and Mukhopadhyay, Topics in Abstract Algebra, Universities press

Course: Topology of Metric Spaces and Real Analysis
Course Code: USMT603/ UAMT603

Unit I: Continuous functions on metric spaces (15 L) Epsilon-delta definition of continuity at a point of a function from one metric space to another. Characterization of continuity at a point in terms of sequences, open sets and closed sets and examples, Algebra of continuous real valued functions on a metric space. Continuity of composite continuous function. Continuous image of compact set is compact, Uniform continuity in a metric space, definition and examples (emphasis on $\mathbb{R}$). Let (X, d) and (Y, d) be metric spaces and $f : X \longrightarrow Y$ be continuous. If (X, d) is compact metric, then $f : X \longrightarrow Y$ is uniformly continuous.
Contraction mapping and fixed point theorem, Applications.

Unit II: Connected sets: (15L)

Separated sets- Definition and examples, disconnected sets, disconnected and connected metric spaces, Connected subsets of a metric space, Connected subsets of $\mathbb{R}$. A subset of $\mathbb{R}$ is connected if and only if it is an interval. A continuous image of a connected set is connected. Characterization of a connected space, viz. a metric space is connected if and only if every continuous function from X to $\{1, -1\}$ is a constant function. Path connectedness in Rn, definition and examples. A path connected subset of Rn is connected, convex sets are path connected. Connected components. An example of a connected subset of Rn which is not path connected.

Unit III : Sequence and series of functions:(15 lectures)

Sequence of functions - pointwise and uniform convergence of sequences of real- valued functions, examples. Uniform convergence implies pointwise convergence, example to show converse not true, series of functions, convergence of series of functions, Weierstrass M-test. Examples. Properties of uniform convergence: Continuity of the uniform limit of a sequence of continuous function, conditions under which integral and the derivative of sequence of functions converge to the integral and derivative of uniform limit on a closed and bounded interval. Examples. Consequences of these properties for series of functions, term by term differentiation and integration. Power series in $\mathbb{R}$ centered at origin and at some point in $\mathbb{R}$, radius of convergence, region (interval) of convergence, uniform convergence, term by-term differentiation and integration of power series, Examples. Uniqueness of series representation, functions represented by power series, classical functions defined by power series such as exponential, cosine and sine functions, the basic properties of these functions.

References for Units I, II, III:

1. S. Kumaresan, Topology of Metric spaces.
2. E. T. Copson. Metric Spaces. Universal Book Stall, New Delhi, 1996.
3. Robert Bartle and Donald R. Sherbert, Introduction to Real Analysis, Second Edition, John Wiley and Sons.
4. Ajit Kumar, S. Kumaresan, Introduction to Real Analysis
5. R.R. Goldberg, Methods of Real Analysis, Oxford and International Book House (IBH) Publishers, New Delhi.

Other references :

1. W. Rudin, Principles of Mathematical Analysis.
2. T. Apostol. Mathematical Analysis, Second edition, Narosa, New Delhi, 1974
3. E. T. Copson. Metric Spaces. Universal Book Stall, New Delhi, 1996.
4. R. R. Goldberg Methods of Real Analysis, Oxford and IBH Pub. Co., New Delhi 1970.
5. P.K.Jain. K. Ahmed. Metric Spaces. Narosa, New Delhi, 1996.
6. W. Rudin. Principles of Mathematical Analysis, Third Ed, McGraw-Hill, Auckland, 1976.
7. D. Somasundaram, B. Choudhary. A first Course in Mathematical Analysis. Narosa, New Delhi

8. G.F. Simmons, Introduction to Topology and Modern Analysis, McGraw-Hi, New York, 1963.

9. Sutherland. Topology.

Course: Numerical Analysis II (Elective A)
Course Code: USMT6A4 / UAMT6A4

N.B. Derivations and geometrical interpretation of all numerical methods with theorem mentioned have to be covered.

Unit I. Interpolation (15L)
Interpolating polynomials, Uniqueness of interpolating polynomials. Linear, Quadratic andHill-gher order interpolation. Lagranges Interpolation. Finite difference operators: Shift operator, forward, backward and central difference operator, Average operator and relation between them. Difference table, Relation between difference and derivatives. Interpolating polynomials using finite differences Gregory-Newton forward difference interpolation, Gregory-Newton backward difference interpolation, Stirlings Interpolation. Results on interpolation error.

Unit II. Polynomial Approximations and Numerical Differentiation (15L)
Piecewise Interpolation: Linear, Quadratic and Cubic. Bivariate Interpolation: Lagranges Bivariate Interpolation, Newtons Bivariate Interpolation. Numerical differentiation: Numerical differentiation based on Interpolation, Numerical differentiation based on finite differences (forward, backward and central), Numerical Partial differentiation.

Unit III. Numerical Integration (15L)
Numerical Integration based on Interpolation. Newton-Cotes Methods, Trapezoidal rule, Simpson's 1/3rd rule, Simpson's 3/8th rule. Determination of error term for all above methods. Convergence of numerical integration: Necessary and sufficient condition (with proof). Composite integration methods; Trapezoidal rule, Simpson's rule.

Reference Books

1. Kendall E, Atkinson, An Introduction to Numerical Analysis, Wiley.

2. M. K. Jain, S. R. K. Iyengar and R. K. Jain,, Numerical Methods for Scientific and Engineering Computation, New Age International Publications.

3. S.D. Comte and Carl de Boor, Elementary Numerical Analysis, An algorithmic approach, McGrawHillll International Book Company.

4. S. Sastry, Introductory methods of Numerical Analysis, PHI Learning.

5. Hildebrand F.B, .Introduction to Numerical Analysis, Dover Publication, NY.

6. Scarborough James B., Numerical Mathematical Analysis, Oxford University Press, New Delhi.

Course: Number Theory and its applications II (Elective B)
Course Code: USMT6B4 / UAMT6B4

Unit I. Quadratic Reciprocity (15 L)

Quadratic residues and Legendre Symbol, Gausss Lemma, Theorem on Legendre Symbol $\left(\frac{2}{p}\right)$, the result: If p is an odd prime and a is an odd integer with $(a, p) = 1$ then

$\left(\frac{a}{p}\right) = (-1)^t$ where $t = \sum_{k=1}^{\frac{p-1}{2}} \left[\frac{ka}{p}\right]$, Quadratic Reciprocity law. Theorem on Legendre Symbol $\left(\frac{3}{p}\right)$. The Jacobi Symbol and law of reciprocity for Jacobi Symbol. Quadratic Congruences with Composite moduli.

Unit II. Continued Fractions (15 L)

Finite continued fractions. Infinite continued fractions and representation of an irrational number by an infinite simple continued fraction, Rational approximations to irrational numbers and order of convergence, Best possible approximations. Periodic continued fractions.

Unit III. Pells equation, Arithmetic function and Special numbers (15 L)

Pell's equation $x^2 dy^2 = n$, where d is not a square of an integer. Solutions of Pell's equation (The proofs of convergence theorems to be omitted). Arithmetic functions of number theory: $d(n)(or \tau(n)), \sigma(n), \sigma_k(n), \omega(n)$ and their properties, $\mu(n)$ and the Mbius inversion formula. Special numbers: Fermat numbers, Mersenne numbers, Perfect numbers, Amicable numbers, Pseudo primes, Carmichael numbers.

Recommended Books

1. Niven, H. Zuckerman and H. Montogomery. An Introduction to the Theory of Numbers. John Wiley & Sons. Inc.
2. David M. Burton. An Introduction to the Theory of Numbers. Tata McGraw-Hill Edition.
3. G. H. Hardy and E.M. Wright. An Introduction to the Theory of Numbers. Low priced edition. The English Language Book Society and Oxford University Press, 1981.
4. Neville Robins. Beginning Number Theory. Narosa Publications.
5. S. D. Adhikari. An introduction to Commutative Algebra and Number Theory. Narosa Publishing House
6. .N. Koblitz. A course in Number theory and Crytopgraphy. Springer.
7. M. Artin. Algebra. Prentice Hall.
8. K. Ireland, M. Rosen. A classical introduction to Modern Number Theory. Second edition, Springer Verlag.
9. William Stalling. Cryptology and network security.

Course: Graph Theory and Combinatorics (Elective C)
Course Code: USMT6C4 /UAMT6C4

Unit I. Colorings of graph (15L)

Vertex coloring- evaluation of vertex chromatic number of some standard graphs, critical graph. Upper and lower bounds of Vertex chromatic Number- Statement of Brooks theorem. Edge coloring- Evaluation of edge chromatic number of standard graphs such as complete graph, complete bipartite graph, cycle. Statement of Vizing Theorem. Chromatic polynomial of graphs- Recurrence Relation and properties of Chromatic polynomials. Vertex and Edge cuts vertex and edge connectivity and the relation between vertex and edge connectivity. Equality of vertex and edge connectivity of cubic graphs. Whitney's theorem on 2-vertex connected graphs.

Unit II. Planar graph (15L)

Definition of planar graph. Euler formula and its consequences. Non planarity of $K5; K(3; 3)$. Dual of a graph. Polyhedran in $\mathbb{R}^3$ and existence of exactly five regular polyhedra- (Platonic solids) Colorabilty of planar graphs- 5 color theorem for planar graphs, statement of 4 color theorem. Networks and flow and cut in a network- value of a flow and the capacity of cut in a network, relation between flow and cut. Maximal flow and minimal cut in a network and Ford-Fulkerson theorem.

Unit III. Combinatorics (15L)

Applications of Inclusion Exclusion Principle- Rook polynomial, Forbidden position problems Introduction to partial fractions and using Newtons binomial theorem for real power find series, expansion of some standard functions. Forming recurrence relation and getting a generating function. Solving a recurrence relation using ordinary generating functions. System of Distinct Representatives and Hall's theorem of SDR. Introduction to matching, M alternating and M augmenting path, Berge theorem. Bipartite graphs.

Recommended Books.

1. Bondy and Murty Grapgh, Theory with Applications.

2. Balkrishnan and Ranganathan, Graph theory and applications. 3 West D G. , Graph theory.

3. Richard Brualdi, Introduction to Combinatorics.

Additional Reference Book.

1. Behzad and Chartrand Graph theory.

2. Choudam S. A., Introductory Graph theory. 3 Cohen, Combinatorics.

Course: Operations Research Elective D)
Course Code: USMT6D4 / UAMT6D4

Unit I. Linear Programming-I (15L)

Prerequisites: Vector Space, Linear independence and dependence, Basis, Convex sets, Dimension of polyhedron, Faces.

Formation of LPP, Graphical Method. Theory of the Simplex Method- Standard form of LPP, Feasible solution to basic feasible solution, Improving BFS, Optimality Condition, Unbounded solution, Alternative optima, Correspondence between BFS and extreme points. Simplex Method Simplex Algorithm, Simplex Tableau.

Reference for unit I

1. G. Hadley, Linear Programming, Narosa Publishing, (Chapter 3).

Unit II. Linear programming-II (15L)
Simplex Method Case of Degeneracy, Big-M Method, Infeasible solution, Alternate solution, Solution of LPP for unrestricted variable. Transportation Problem: Formation of TP, Concepts of solution, feasible solution, Finding Initial Basic Feasible Solution by North West Corner Method, Matrix Minima Method, Vogels Approximation Method. Optimal Solution by MODI method, Unbalanced and maximization type of TP.

Reference for Unit II

1. G. Hadley, Linear Programming, Narosa Publishing, (Chapter 4 and 9).
2. J. K. Sharma, Operations Research, Theory and Applications, (Chapter 4, 9).

Unit III. Queuing Systems (15L)
Elements of Queuing Model, Role of Exponential Distribution. Pure Birth and Death Models; Generalized Poisson Queuing Mode. Specialized Poisson Queues: Steady- state Measures of Performance, Single Server Models, Multiple Server Models, Self- service Model, Machine-servicing Model.

Reference for Unit III:

1. J. K. Sharma, Operations Research, Theory and Applications.
2. H. A. Taha, Operations Research, Prentice Hall of India.

Additional Reference Books:

1. Hillier and Lieberman, Introduction to Operations Research.
2. Richard Broson, Schaum Series Book in Operations Research, Tata McGrawHill Publishing Company Ltd.

Course: Practicals (Based on USMT601 / UAMT601 and USMT602 / UAMT602)
Course Code: USMTP07 / UAMTP07
Suggested Practicals (Based on USMT601 / UAMT601):

1. Limit continuity and derivatives of functions of complex variables,
2. Steriographic Projection , Analytic function, finding harmonic conjugate,
3. Contour Integral, Cauchy Integral Formula ,Mobius transformations
4. Taylors Theorem , Exponential , Trigonometric, Hyperbolic functions
5. Power Series , Radius of Convergence, Laurents Series

6. Finding isolated singularities- removable, pole and essential, Cauchy Residue theorem.
7. Miscellaneous theory questions.

Suggested Practicals (Based on USMT602 / UAMT602)

1. Normal Subgroups and quotient groups.
2. Cayleys Theorem and external direct product of groups.
3. Rings, Subrings, Ideals, Ring Homomorphism and Isomorphism
4. Prime Ideals and Maximal Ideals
5. Polynomial Rings
6. Fields.
7. Miscellaneous Theoretical questions on Unit 1, 2 and 3.

Course: Practicals (Based on USMT603 / UAMT603 and USMT6A4 / UAMT6A4 OR USMT6B4 / UAMT6B4 OR USMT6C4 / UAMT6C4 OR USMT6D4 / UAMT6D4)
Course Code: USMTP08 / UAMTP08

Suggested practicals Based on USMT603 / UAMT603:

1 Continuity in a Metric Spaces

2 Uniform Continuity, Contraction maps, Fixed point theorem

3 Connected Sets , Connected Metric Spaces

4 Path Connectedness, Convex sets, Continuity and Connectedness

5 Pointwise and uniform convergence of sequence functions, properties

6 Point wise and uniform convergence of series of functions and properties

7 Miscellaneous Theory Questions

Suggested Practicals based on USMT6A4 / UAMT6A4

The Practicals should be performed using non-programmable scientific calculator. (The use of programming language like C or Mathematical Software like Mathematica, Matlab, MuPad, and Maple may be encouraged).

1 Linear, Quadratic andHillgher order interpolation, Interpolating polynomial by Lagranges Interpolation

2 Interpolating polynomial by Gregory-Newton forward and backward difference Interpolation and Stirling Interpolation.

3 Bivariate Interpolation: Lagranges Interpolation and Newtons Interpolation

4 Numerical differentiation: Finite differences (forward, backward and central), Numerical Partial differentiation

5 Numerical differentiation and Integration based on Interpolation

6 Numerical Integration: Trapezoidal rule, Simpsons 1/3rd rule, Simpsons 3/8th rule

7 Composite integration methods: Trapezoidal rule, Simpsons rule.

Suggested Practicals based on USMT6B4 / UAMT6B4

1. Legendre Symbol.
2. Jacobi Symbol and Quadratic congruences with composite moduli.
3. Finite continued fractions.
4. Infinite continued fractions.
5. Pells equations and Arithmetic functions of number theory.
6. Special Numbers.
7. Miscellaneous Theoretical questions based on full USMT6B4 / UAMT6B4.

Suggested Practicals based on USMT6C4 / UAMT6C4

1. Coloring of Graphs
2. Chromatic polynomials and connectivity.
3. Planar graphs
4. Flow theory.
5. Inclusion Exclusion Principle and Recurrence relation.
6. SDR and Mathching.
7. Miscellaneous theoretical questions.

Suggested Practicals based on USMT6D4 / UAMT6D4
All practicals to be done manually as well as using software TORA / EXCEL solver.

1. LPP formation, graphical method and simple problems on theory of simplex method
2. LPP Simplex Method
3. Big-M method, special cases of solutions.
4. Transportation Problem
5. Queuing Theory; single server models
6. Queuing Theory; multiple server models
7. Miscellaneous Theory Questions.

XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX

UNIVERSITY OF MUMBAI

Syllabus for Semester V and Semester VI
Program: B.Sc.

Course: Computer Programming and System Analysis

(APPLIED COMPONENT)

(CBCS)

With effect from 2018-19

Course Code USACCS501

UNIT I RELATIONAL DATA BASE MANAGEMENT SYSTEM – 15 Lectures

1. **Introduction to Data base Concepts**: Database, Overview of data base management system. Data base Languages- Data Definition Languages (DDL) and Data Manipulation Languages (DML).

2. Entity Relation Model : Entity, artibutes, keys, relations, Designing ER diagram, integrity Constraints over relations, conversion of ER to relations with and without constrains.

3. SQL Commands and functions

    a) Creating and altering tables: CREATE statement with constraints like KEY, CHECK, DEFAULT, ALTER and DROP statement.
    b) Handling data using SQL: selecting data using SELECT statement, FROM clause, WHERE clause, HAVING clause, ORDERBY, GROUP BY, DISTINCT and ALL predicates, Adding data with INSERT statement, changing data with UPDATE statement, removing data with DELETE statement.
    c) Functions: Aggregate functions- AVG, SUM, MIN, MAX and COUNT, Date functions- ADD_MONTHS(), CURRENT_DATE(), LAST_DAY(), MONTHS_BETWEEN(), NEXT_DAY(). String functions- LOWER(), UPPER(), LTRIN(), RTRIM(), TRIN(), INSERT(), RIGHT(), LEFT(), LENGTH(), SUBSTR(). Numeric functions: ABS(), EXP(), LOG(), SQRT(), POWER(), SIGN(), ROUND(number).
    d) Joining tables: Inner, outer and cross joins, union.

UNIT II INTRODUCTION TO PL/SQL – 15 Lectures

1. **Fundamentals of PL/SQL:** Defining variables and constants, PL/SQL expressions and comparisons: Logical Operators, Boolean Expressions, CASE Expressions Handling, Null Values in Comparisons and Conditional Statements,
2. **PL/SQL Data Types:** Number Types, Character Types, Boolean Type. Date time and Interval types.
3. **Overview of PL/SQL Control Structures:** Conditional Control: IF and CASE Statements, IF-THEN Statement, IF-THEN-ELSE Statement, IF-THEN-ELSIF Statement, CASE Statement,
4. **Iterative Control:** LOOP and EXIT Statements, WHILE-LOOP, FOR-LOOP, Sequential Control: GOTO and NULL Statements.

UNIT III INTRODUCTION TO JAVA PROGRAMMING – 15 Lectures

1. **Object-Oriented approach:** Features of object-orientations: Abstraction, Inheritance, Encapsulation and Polymorphism.
2. **Introduction:** History of Java features, different types of Java programs, Differentiate Java with C. Java Virtual Machine.
3. **Java Basics:** Variables and data types, declaring variables, literals numeric, Boolean, character and string literals, keywords, type conversion and casting. Standard default values. Java Operators, Loops and Controls
4. **Classes:** Defining a class, creating instance and class members: creating object of a class, accessing instance variables of a class, creating method, naming method of a class, accessing method of a class, overloading method, ‘this’ keyword, constructor and Finalizer: Basic Constructor, parameterized constructor, calling another constructor, finalize() method, overloading constructor.
5. **Arrays:** one and two – dimensional array, declaring array variables, creating array objects, accessing array elements.
6. **Access control:** public access, friendly access, protected access, private access.

UNIT IV Inheritance, Exception Handling

a) **Inheritance:** Various types so finheritance, super and sub classes, keywords-‘extends’, ‘super’, over riding method, final and abstract class: final variables and methods, final classes, abstract methods and classes. Concepts of inter face.

b) **Exception Handling and Packages:** Need for Expectional Hndling, Exception Handling techniques: try and catch, multiple catch statements, finally block, us age of throw and throws. Concept of packages. Inter class method: parseInt().

References:

1. Data base management system, RamKrishnam, Gehrke, McGraw-Hill
2.Ivan Bayross, “SQL, PL/SQL – The Programming languages of Oracle” B.P.B. Publications, 3rd Revised Edition.
3.George Koch and Kevin Loney, ORACLE “The complete Reference”, Tata McGraw Hill, New Delhi.
4.Elsmasri and Navathe, “Fundamentals of Database Systems” Pearson Education.
5.Peter Roband Coronel, “Database System, Design, Implementation and Management”, Thomson Learning.
6.C.J. Date, Longman, “Introduction database system”, Pearson Education.
7.Jeffrey D. Ullman, Jennifer Widsom, “A First Course in Database Systems”, Pearson Education.
8.Martin Gruber, “Understanding SQL”, B.P.B. Publications.
9.Michael Abbey, Micheal. Corey, Ian Abramson, Oracle8i- A Beginner’s Guide, Tata McGraw- Hill.

10. Programming with Java: a Primer 4th Edition by E. Balagurusamy, Tata McGraw Hill.
11. Java the complete Reference, 8th Edition, Herbert Schildt, Tata McGraw Hill.

Additional References:

1. Eric Jend rock, Jennifer Ball, D Carson and others, The Java EE5 Tutorial, Pearson Education, Third Edition 2003.
2. Ivan Bayross, Web Enabled Commercial Applications Development using Java 2, BPB Publications. Revised Edition, 2006.
3. Joe Wiggles worth and Paula Mc Millan, Java Programming: Advanced Topics, Thomson Course Technology (SPPD), Third Edition 2004.

The Java Tutorials of Sun Microsystems Inc .http://docs.oracle.com/javase/tutorial

Suggested Practicals

1. Creating a single table with/without constraints and executing queries.Queries containing aggregate, string and date functions fired on a single table.
2. Updating tables, altering table structure and deleting table Creating and altering a single table and executing queries. Joining tables and processing queries.
3. Writing PL/SQL Blocks with basic programming constructs.
4. Writing PL/SQL Blocks with control structures.
5. Write a Java program to create a Java class:(a)without instance variables and methods,(b)with instance variables and without methods,(c)with out instance variables and with methods.(d) with instance variables and methods.
6. Write a Java program that illustrates the concepts of one, two dimension arrays.
7. Write a Java program that illustrates the concepts of Java class that includes(a)construct or with and with out parameters (b) Over loading methods.
8. Write a Java program to demonstrate inheritance by creating suitable classes.
9. Write a program that illustrates the error handling using exception handling.

SEMESTER VI

Course code USACCS601

UNITI JAVAAPPLETSANDGRAPHICSPROGRAMMING- 15 LECTURES

1. **Applets:** Difference of applet and application, creating applets, applet life cycle, passing parameters to applets.
2. **Graphics, Fonts and Color:** The graphics class, painting, repainting and updating an applet, sizing graphics. Font class, draw graphical figures-lines and rectangle, circle and ellipse, drawing arcs, drawing polygons. Working with Colors: Color methods, setting the paint mode.
3. **AWT package:** Containers: Frame and Dialog classes, Components: Label; Button; Checkbox; Text Field, Text Area.

UNIT II PYTHON 3.x 15 LECTURES

1. **Introduction**: The Python Programming Language, History, features, Installing Python.
   Running Code in the Interactive Shell, IDLE. Input, Processing, and Output , Editing, Saving, and Running a Script, Debugging : Syntax Errors, Runtime Errors, Semantic Errors, Experimental Debugging.
2. **Data types and expressions**: Variables and the Assignment Statement , Program Comments and Docstrings . Data Types-Numericintegers & Floating-point numbers. Boolean, string. Mathematical operators +, - *, ** , %. PEMDAS.Arithmetic expressions, Mixed-Mode Arithmetic and type Conversion, type( ). Input( ), print( ), program comments. id( ), int( ), str( ), float( ).
3. **Loops and selection statements**: Definite Iteration: The for Loop, Executing statements a given number of times , Specifying the steps usingrange( ) , Loops that count down, Boolean and Comparison operators and Expressions, Conditional and alternative statements- Chained and Nested Conditionals: if, if-else, if-elif-else, nested if, nested if-else. Compound Boolean Expressions , Conditional Iteration: The while Loop –with True condition, the break Statement. Random Numbers. Loop Logic, errors, and testing.

Reference Fundamentals of Python First programs 2nd edition by Kenneth A Lambert chapter 1,2,3

Unit III STRINGS, LIST AND DICTIONARIES. 15 LECTURES

1. **Strings, Lists, Tuple, Dictionary**: Accessing characters, indexing, slicing, replacing.Concatenation (+), Repetition (*).Searching a substring with the 'in' Operator, Traversing string using while and for. String methods- find, join, split, lower, upper. len( ).
2. Lists – Accessing and slicing, Basic Operations (Comparison, +),List membership and for loop.Replacing element (list is mutable). List methods- append, extend, insert, pop, sort. Max( ), min( ). Tuples.
   Dictionaries-Creating a Dictionary, Adding keys and replacing Values , dictionary -key( ), value( ), get( ), pop( ) , Traversing a Dictionary.
   Math module: sin(), cos(),exp(), sqrt(), constants- pi, e.
3. **Design with functions** : Defining Simple Functions- Parameters and Arguments, the return Statement, tuple as return value. Boolean Functions. Defining a main function. Defining and tracing recursive functions.
4. **Exception handling**: try- except.

Reference Fundamentals of Python First programs 2nd edition by Kenneth A Lambert chapter 4,5,6.

UNIT IV DOING MATH WITH PYTHON 15 LECTURES

1. **Working with Numbers:** Calculating the Factors of an Integer, Generating Multiplication Tables , converting units of Measurement ,Finding the roots of a Quadratic Equation
2. **Algebra and Symbolic Math with SymPy:** symbolic math using the SymPy library.
   Defining Symbols and Symbolic Operations, factorizing and expanding expressions, Substituting in Values, Converting strings to mathematical expressions. Solving equations, Solving Quadratic equations, Solving for one variable in terms of others, Solving a system of linear equations, Plotting using SymPy , Plotting expressions input by the user, Plotting multiple functions .

Reference Doing math with Python by AmitSaha (Internet source) chapter 1, 4

Software – *http://continuum.io/downloads.*Anaconda 3.x

References:

1. Programming with Java:A Primer 4th Edition by E.Balagurusamy, Tata McGraw Hill.
2. JavaTheCompleteReference,8thEdition,HerbertSchildt,TataMcGrawHill
3. Fundamentals of Python First programs 2nd edition - Kenneth A Lambert, Cengage Learning India.
4. Doing Math with Python - Amit Saha, No starch ptress,

Additional References:

5. Eric Jendrock, JenniferBall, DCarsonandothers,TheJavaEE5Tutorial, PearsonEducation,Third Edition,2003.
6. Ivan Bay Ross, Web Enabled Commercial Applications Development UsingJava2, BPB Publications, Revised Edition, 2006
7. Joe Wigglesworth and Paula McMillan, Java Programming: Advanced Topics, Thomson Course Technology(SPD),ThirdEdition,2004
8. The Java Tutorials of Sun Microsystems Inc. http://docs.oracle.com/javase/tutorial
9. Problem solving and Python programming- E. Balgurusamy, TataMcGrawHill.

Suggested Practical:

1. Write a program that demonstrates the use of input from the user using parse Int().
2. Write a Java applet to demonstrate graphics, Font and Color classes.
3. Write a Java program to illustrate AWT package.
4. Preparing investment report by calculating compound interest, computing approximate value of π by using the $\frac{\pi}{4} = 1 - \frac{1}{3} + \frac{1}{5} - \frac{1}{7} + \cdots$ (Gottfried Leibniz)
5. Convert decimal to binary, octal using string, Write the encrypted text of each of the following words using a Caesar cipher with a distance value of 3.
6. Hexadecimal to binary using dictionary, finding median of list of numbers.
7. Enhanced Multiplication Table Generator, Unit Converter, Fraction Calculator .
8. Factor Finder, Graphical Equation Solver
9. Summing a Series, Solving Single-Variable Inequalities

Theory: At the end of the semester, examination of three hours duration and 100 marks based on the four units shall be held for each course.

Pattern of **Theory question** paper at the end of the semester for **each course**: There shall be Five compulsory Questions of 20 marks each with internal option. Question 1 based on Unit I, Question 2 based on Unit II, Question 3 based on Unit III, Question 4 based on Unit IV and Question 5 based on all four Units combined.

Q1 to Q4 pattern

(a) Attempt any one out of two (08 Marks)

(b) Attempt any two out of four (12 Marks)

Q5 Attempt any four out of eight (20 Marks)

Semester End Practical Examination (Total 100 marks)

Semester V: Total evaluation is of 100 marks-

(a)	Question on Unit 1 and Unit 2	-40 Marks
(b)	Question on Unit 3 and Unit 4	-40 Marks
(c)	Certified Journal	-10 Marks
(d)	Viva Voce	-10 Marks

Semester VI: Total evaluation is of 100 marks-

(a)	Question on Unit 1 and Unit 2	-40 Marks
(b)	Question on Unit 3 and Unit 4	-40 Marks
(c)	Certified Journal	-10 Marks
(d)	Viva Voce	-10 Marks

1. The questions to be asked in the practical examination shall be from the list of practical experiments mentioned in the practical topics. A few simple modifications may be expected during the examination.
2. The semester end practical examination on the machine will be of THREE hours.
3. Students should carry a certified journal with minimum of 06 practicals (mentioned in the practical topics) at the time of examination.
4. Number of students per batch for the regular practical should not exceed 20. Not more than two students are allowed to do practical experiment on one computer at a time.

Workload

Theory : 4 lectures per week .

Practicals: 2 practicals each of 2 lecture periods per week per batch. Two lecture periods of the practicals shall be conducted in succession together on a single day.