SHIVAJI UNIVERSITY, KOLHAPUR.

Accredited By NAAC with 'A++' Grade

Structure and Syllabus in Accordance with

National Education Policy - 2020

with Multiple Entry and Multiple Exit

Bachelor of Science (Mathematics) Part III (Level-5.5)

Semester V and VI

under the

Faculty of Science and Technology

(To be implemented from academic year 2026-27)

SHIVAJI UNIVERSITY, KOLHAPUR
NEP-2020(2.0): Credit Framework for UG(B.Sc.) Programme under Faculty of Science and Technology

PROGRAM STRUCTURE:

SHIVAJIUNIVERSITY,KOLHAPUR NEP-2020 (2.0): Credit Framework for UG (B. Sc.) Programme under Faculty of Science and Technology								
SEM (Level)	COURSES		OE	VSC/SEC	AEC/VEC/IKS	OJT/FP/CEP /CC/RP	Total Credits	Degree/Cum. Cr. MEME
	Major	Major (ELEC)						
SEM V (5.5)	Major IX (2): Real Analysis Major X (2): Modern Algebra Major P-V (a) (2): Mathematics Practical (Major) V (a) Major P-V (b) (2) : Mathematics Practical (Major) V (b)	Major I -A (ELEC) (2): Partial Differential Equations Major (ELEC) P-IA (2): Mathematics Practical (Elective) IA OR Major I -B (ELEC) (2): Operations Research Major (ELEC) P-IB (2): Mathematics Practical (Elective) IB	OE-5(2) (P) Financial Mathematics	VSC II (2) (Major specific) (P): Mathematical Computation using Python – I	AEC III (2) (English)	OJT (04)	22	UG Degree 132
SEM VI (5.5)	Major XI (2): Metric Spaces Major XII (2): Linear Algebra Major P-VI (a) (2): Mathematics Practical (Major) VI (a) Major P-VI (b) (2): Mathematics Practical (Major) VI (b)	Major II-A (ELEC) (2): Integral Transforms Major (ELEC) P-IIA (2): Mathematics Practical (Elective) IIA OR Major II -B (ELEC)(2): Complex Analysis Major (ELEC) P-IIB (2): Mathematics Practical (Elective) IIB		VSC III (2) (Major specific) (P): Mathematical Computation using Python – II SEC III (2) (P): Geogebra	AEC IV (2) (English) IKS 2 (Major specific) (2): Ancient Indian Mathematics	FP-(02)	22	
Credits	8(T)+8(P)=16	4(T)+4(P)=8	2(T/P)	2(T/P)+4(P)=6	4+2=6	4+2=6	44	

Abbreviations:

AEC	Ability Enhancement Course
CC	Co-curricular Courses
CEP	Community Engagement and Service
DSC	Department Specific Core
DSE	Department Specific Elective
FP	Field Project
GE	Generic Elective
IDC	Inter-Disciplinary Course
IKS	Indian Knowledge System
MDC	Multidisciplinary Course
MIN	Minor
OE	Open Elective
OEC	Open Elective Course
OJT	On Job Training
P	Practical
RP	Research Project
SEC	Skill Enhancement Course
T	Theory
VEC	Value Education Course
VSC	Vocational Skill Course
ELEC	Elective

Semester V

B.Sc. (Mathematics) (Part III) (Level 5.5) (Semester – V)
(NEP – 2020)
Syllabus to be implemented from Academic Year 2026-27

Course type	**:**	**Major -IX (Theory)**
Title of course	**:**	**Real Analysis**
Credit	**:**	**02**

Course Learning Outcomes: Upon successful completion of the course students will be able to:

CO 1. understand the basic facts about functions and countability of sets.
CO 2. recognize bounded, convergent, divergent, Cauchy and monotonic sequences.
CO 3. calculate limit superior, limit inferior, and the existence of limit of a sequence.
CO 4. apply different tests for convergence and absolute convergence of an infinite series of real numbers.

Unit: 1 Functions and Sequence of real numbers (15 hrs.)

Cartesian product, Function, domain and range of a function, inverse image and image of a set under a function, extension and restriction of functions, one - to - one (or 1 - 1) function, onto function, Real-valued functions, Equivalence and Countability, Real numbers, least upper bound and greatest lower bound.
Sequence and subsequence, limit of a sequence, Convergent sequence, Divergent sequences, Bounded sequences, Monotone sequences, Operations on convergent sequences, Limit superior and limit inferior, Cauchy sequences, Summability of sequences.

Unit: 2 Series of real numbers (15 hrs.)

Convergence and divergence, Series with nonnegative terms, Alternating series, Conditional convergence and absolute convergence, Tests for absolute convergence, Series whose terms form non-increasing sequence, (C, 1) Summability of series, the class l_2.

Recommended Books:

1. **Methods of Real Analysis**, R. R. Goldberg, Indian Edition, Oxford & IBH Publishing Co. Pvt. Ltd., New Delhi.
   Scope of Syllabus:
   Unit 1: Chapter 1: Sec.: 1.3, 1.4, 1.5, 1.6, 1.7; Chapter 2: Sec.: 2.1, 2.2, 2.3, 2.4, 2.5, 2.6, 2.7, 2.8, 2.9, 2.10, 2.11
   Unit 2: Chapter 3: Sec.: 3.1, 3.2, 3.3, 3.4, 3.6, 3.7, 3.9, 3.10

Reference Books:

1. Elements of Real Analysis, Shanti Narayan and M. D. Raisinghania**,** Fifteenth Revised Edition, S. Chand & Company Ltd. New Delhi, 2014.
2. Elementary Analysis: The Theory of Calculus, Kenneth. A. Ross, Second Edition, Undergraduate Texts in Mathematics, Springer, 2013.
3. Real Analysis and Foundations, Steven G. Krantz, Second Edition, Chapman and Hall/CRC.
4. Introduction to Real Analysis, R. G. Bartle and D. R. Sherbert, Fourth Edition, Wiley India Pvt. Ltd., 2016.

B.Sc. (Mathematics) (Part III) (Level 5.5) (Semester – V)
(NEP – 2020)
Syllabus to be implemented from Academic Year 2026-27

Course type	**:**	**Major -X (Theory)**
Title of course	**:**	**Modern Algebra**
Credit	**:**	**02**

Course Learning Outcomes: Upon successful completion of this course students will be able to:

CO 1. understand and apply the fundamental concepts of group theory and ring theory.
CO 2. analyze algebraic structures using definitions, theorems, and examples.
CO 3. develop logical reasoning and proof techniques in modern algebra.
CO 4. solve algebraic problems involving groups, subgroups, rings, homomorphisms, and isomorphisms.

Unit 1: Groups (13 hrs.)

Group, Commutative group, Order of a group, Quaternion group, Group of residues, Permutation group, Subgroup, Centre of a group, Normalizer of an element , Left and Right cosets, Congruence relation, Lagrange's Theorem, Index of subgroup in group, Centralizer of subgroup, Normalizer of a subgroup, Cyclic group, Order of an element of a group, Euler's $\varphi -$ function, Euler's Theorem(without proof), Fermat's Theorem, Examples related to Euler's Theorem and Fermat's Theorem.

Unit 2: Normal Subgroups, Homomorphism of Groups, Ring (17 hrs.)

Normal subgroup, Simple group , Quotient group, Homomorphism, Isomorphism, Monomorphism, Epimorphism, Endomorphism and Automorphism, Kernel of homomorphism, Fundamental Theorem of group homomorphism, Second Theorem of isomorphism, Third Theorem of isomorphism, Cayley's Theorem(without proof), Ring, Commutative ring, Ring with unity, Zero divisor, Integral Domain, Division Ring, Field, Boolean ring, Subring, Characteristic of a ring, Idempotent, Nilpotent, Product of rings, Ideal, Sum of two ideals, Simple Ring.

Recommended book:

1. **A Course in Abstract Algebra,** Vijay K. Khanna, S.K. Bhambri; Vikas Publishing House Pvt. Ltd., New - Delhi – 110055, Fifth Edition 2016.

   Scope of Syllabus:

   Unit 1: Chapter 1: page no. 7 to 40; Chapter 2: page no.45 to 100.

   Unit 2: Chapter 3: page no. 102 to,127,145 to 147; Chapter 7**:** page no. 337 to 373

Reference books:

1. Topics in Algebra, Herstein I. N.; Vikas Publishing House,1979.
2. Fundamentals of Abstract Algebra, Malik D. S. Morderson J. N. and Sen M. K. McGraw Hill,1997.
3. Modern Algebra, Surjeet Sing and Quazi Zameeruddin; Vikas Publishing House, 1991.
4. Lectures on Abstract Algebra, T. M. Karade, J. N. Salunkhe, K. S. Adhav, M. S. Bendre, Sonu Nilu, Einstein Foundation International, Nagpur 440022.
5. Basic Algebra Vol. I & II, N. Jacobson, W. H. Freeman 1980.
6. Algebra, Vivek Sahai and Vikas Bist Narosa Publishing House,1997.
7. A First Course in Abstract Algebra, J. B. Fraleigh Pearson Education; Seventh edition (2014)

B.Sc. (Mathematics) (Part III) (Level 5.5) (Semester – V)
(NEP – 2020)
Syllabus to be implemented from Academic Year 2026-27

Course type : Major P – V (a) (Practical)
Title of course : Mathematics Practical (Major) – V (a)
Credit : 02

Sr. No	Title of the Practical	No. of Practical(s)
1	Function, one-one and onto function, inverse function	01
2	Countable and uncountable sets	01
3	Sequence and subsequence	01
4	Limit of a sequence	01
5	Convergent and divergent sequences	01
6	Examples on bounded sequence	01
7	Examples on monotone sequence	01
8	Operations on convergent sequences	01
9	Limit superior and limit inferior	01
10	Convergence and divergence of series	01
11	Examples on alternating series	01
12	Conditional and absolute convergence of series	01
13	Ratio test for absolute convergence	01
14	Series whose terms form non-increasing sequence	01
15	(C,1) - summability of series.	01
	T O T A L	**15**

(continue to next page)

B.Sc. (Mathematics) (Part III) (Level 5.5) (Semester – V)
(NEP – 2020)
Syllabus to be implemented from Academic Year 2026-27

Course type : Major P – V (b) (Practical)
Title of course : Mathematics Practical (Major) – V (b)
Credit : 02

Sr. No	Title of the Practical	No. of Practical(s)
1	Examples on groups	01
2	Examples on commutative groups	01
3	Examples on subgroup and index of subgroup	01
4	Examples on Permutations	01
5	Center of a group and normalizer of an element.	01
6	Cyclic group, number of generators, order of an element	01
7	Examples on cosets and index	01
8	Examples on Euler's theorem and Fermat's theorem	01
9	Examples on homomorphism, isomorphism, kernel	02
10	Examples on rings and subrings	01
11	Examples on commutative rings, rings with unity	01
12	Examples on zero divisors	01
13	Examples on integral domains, division rings, fields	01
14	Examples on ideals	01
	T O T A L	**15**

B.Sc. (Mathematics) (Part III) (Level 5.5) (Semester – V)
(NEP – 2020)
Syllabus to be implemented from Academic Year 2026-27

Course type	**:**	**Major I -A (ELEC) (Theory)**
Title of course	**:**	**Partial Differential Equations**
Credit	**:**	**02**

Course Learning Outcomes: Upon successful completion of this course students will be able to:

CO 1. understand basic concepts, terminology, and classification of partial differential equations.

CO 2. formulate first-order partial differential equations by eliminating arbitrary constants and arbitrary functions.

CO 3. solve first order partial differential equations using Lagrange's and Charpit's method.

CO 4. determine complementary functions and particular integrals for linear PDEs with constant coefficients.

Unit: 1 First order Partial Differential Equations: (15 hrs.)

Introduction, order, degree and classification of partial differential equations, notations in partial differential equations, classification of first order partial differential equations, derivation of partial differential equation by the elimination of arbitrary constants, derivation of partial differential equation by the elimination of arbitrary functions, Lagrange's linear partial differential equations and it's geometrical interpretation, types of solutions (integrals) of first order partial differential equations, non-linear first order partial differential equations: solutions of standard forms, Charpit's Method.

Unit: 2 Linear Partial Differential Equations with constant coefficients: (15 hrs.)

Introduction of linear partial differential equations of order n, solution of linear partial differential equations with constant coefficients, homogeneous linear partial differential equations with constant coefficients, method for finding the complementary function (C. F.) and methods of finding particular integral (P. I.) of a linear homogeneous partial differential equation with constant coefficients, non-homogeneous linear partial differential equation with constant coefficients, reducible and irreducible linear differential operator and linear partial differential equation with constant coefficients, methods for finding the complementary function (C. F.) and methods of finding particular integral (P. I.) of a non-homogeneous linear partial differential equation with constant coefficients.

Recommended Book:

1. Ordinary and Partial differential equations, M. D. Raisinghania, S. Chand & Company Ltd., New Delhi (20th Edition, 2025).

Scope:

Unit 1: Part III Section 1.1 to Section 1.12, Section 2.1 to Section 2.12, Section 1.18a and Section 1.18b, Section 3.1, Section 3.7 to Section 3.18

Unit 2: Part III Section 4.1 to Section 4.13, Section 5.1 to Section 5.3, Section 5.5 to Section 5.16

Reference Books:

1. Advanced Partial differential equations, Sudhir K. Pundir and Rimple Pundir, A Pragati Edition, Meerut (4th Edition, 2012).
2. Differential Equations, R. K. Gupta and J. N. Sharma, Krishna Prakashan Media Ltd., Meerut (15^{th} Edition, 2015).
3. Differential Equations, P. P. Gupta, G. S. Malik, S. K. Mittal and S. K. Pundir, A Pragati Edition, Meerut (16^{th} Edition, 2022).

B.Sc. (Mathematics) (Part III) (Level 5.5) (Semester – V)
(NEP – 2020)
Syllabus to be implemented from Academic Year 2026-27

Course type : Major (ELEC) P-IA (Practical)
Title of course : Mathematics Practical (Elective) IA
Credit : 02

Sr. No	Title of the Practical	No. of Practical(s)
1	Formation of partial differential equation by elimination of arbitrary constants.	01
2	Formation of partial differential equations by elimination of arbitrary functions.	01
3	Lagrange's linear partial differential equations.	01
4	Partial differential equations of the form $f(p,q)=0$.	01
5	Clairaut form of partial differential equations.	01
6	Partial differential equations of the form $f(z,p,q)=0$.	01
7	Partial differential equations of the form $f_1(x,p)=f_2(y,q)$.	01
8	Charpit's method.	01
9	C.F. of Homogeneous linear partial differential equations with constant coefficients.	01
10	Homogeneous linear partial differential equations with constant coefficients $F(D,D')z=f(x,y)$, where $f(x,y)$ is of the form $f(ax+by)$.	01
11	Homogeneous Linear partial differential equations with constant coefficients $F(D,D')z=f(x,y)$, where $f(x,y)$ is of the form $x^m y^n$.	01
12	General method of finding P.I. of Homogeneous linear partial differential equations with constant coefficients.	01
13	C. F. of Non-homogeneous linear partial differential equations with constant coefficients.	01
14	Non-homogeneous Linear partial differential equations with constant coefficients $F(D,D')z=f(x,y)$, where $f(x,y)$ is of the form e^{ax+by}, $\sin(ax+by)$, $\cos(ax+by)$, provided the denominator is non-zero	01
15	Non-homogeneous Linear partial differential equations with constant coefficients $F(D,D')z=f(x,y)$, where $f(x,y)$ is of the form $x^m y^n$ or Ve^{ax+by}, V is a function of x and y	01
	T O T A L	**15**

B.Sc. (Mathematics) (Part III) (Level 5.5) (Semester – V)
(NEP – 2020)
Syllabus to be implemented from Academic Year 2026-27

Course type	**:**	**Major I -B (ELEC) (Theory)**
Title of course	**:**	**Operations Research**
Credit	**:**	**02**

Course Learning Outcomes: Upon successful completion of this course students will be able to:

CO 1. understand the fundamental concepts of operations research.
CO 2. identify and develop operations research model describing a real-life problem.
CO 3. apply simplex and dual simplex methods to solve the LPP.
CO 4. analyze various linear programming, transportation, assignment problems related to real life.

Unit: 1 Linear Programming Problem (15 hrs.)

Operations Research (OR): main characteristics (features), scope of OR, Linear Programming Problem (LPP): introduction and formulation, graphical method, general formulation of Linear Programming Problem: Definitions - slack variables and surplus variables, The standard form, Matrix form, some important definitions: solution to linear programming problem, feasible solution, basic feasible solution, optimum basic feasible solution and unbounded solution, Simplex method for LPP, Artificial variable technique: Duality, Dual simplex method, examples.

Unit: 2 Transportation Problem and Assignment Problem (15 hrs.)

Transportation Problem (TP): mathematical formulation of the Transportation Problem, basic definitions, Theorem (Existence of Feasible Solution): statement and proof, basic feasible solution of TP: Theorem- statement and proof, methods for initial basic feasible solution: North - West Corner Rule (NWCR) (Stepping stone method), Lowest Cost Entry Method (Matrix Minima method), Vogel's Approximation Method (VAM) (Unit Cost penalty method), Unbalanced Transportation Problem, examples.

Assignment Problem: mathematical formulation of the Assignment Problem, fundamental theorem of assignment problem (Reduction Theorem): statement and proof, method for solving the assignment problem: Hungarian assignment method, maximization case in assignment problem. unbalanced assignment problem, Travelling salesman problem, examples.

Recommended Book:

1. Operations Research – Theory, Methods and Applications, S. D. Sharma, Kedar Nath Ram Nath Publisher, Meerut, Delhi, Eighteenth Revised Edition 2017.

Scope:

Unit 1: Chapter 2 - Page no. OR? /1 to OR? /3 and OR? /8 to OR? /10.
Chapter 3 - Page no. LPP/1 to LPP/27.
Chapter 5 - Page no. SMX/1 to SMX/2 and SMX/14 to SMX/31.
Chapter 7 - Page no. Dual /1 to Dual /5.
Chapter 8 - Page no. Dual Simplex /1 to Dual Simplex /9.

Unit 2: Chapter 15 - Page no. TP/1 to TP/3, TP/6 to TP/13 and TP/50 to TP/68.
Chapter 16 - Page no. ASS/1 to ASS/40.

Reference Books:

1. Operation Research: Theory and Applications, J. K. Sharma, Laxmi Publications, Sixth Edition, 2017.
2. Operations Research, Sultan Chand and Sons, Kanti Swarup, P. K. Gupta and Man Mohan, New Delhi, Nineteenth Edition 2017.
3. Operations Research, P. K. Gupta, D. S. Hira, S. Chand and Company Limited, New Delhi, Reprint 2021
4. Operations Research: An Introduction, H. A. Taha, Pearson Education Limited 2017.

B.Sc. (Mathematics) (Part III) (Level 5.5) (Semester – V)
(NEP – 2020)
Syllabus to be implemented from Academic Year 2026-27

Course type : Major (ELEC) P-IB (Practical)
Title of course : Mathematics Practical (Elective) IB
Credit : 02

Sr. No	Title of the Practical	No. of Practical(s)
1	Formulation of linear programming problems	01
2	Graphical method for linear programming problems	01
3	Simplex method for linear programming problems	02
4	Two phase method for linear programming problems	01
5	Dual simplex method for linear programming problems	02
6	North-West corner rule	01
7	Lowest Cost Entry method	01
8	Vogel Approximation method	01
9	Test for optimality: MODI method	01
10	Unbalanced transportation problem	01
11	Hungarian method	01
12	Maximization case of assignment problems	01
13	Unbalanced assignment problems	01
	T O T A L	**15**

B.Sc. (Mathematics) (Part III) (Level 5.5) (Semester – V)
(NEP – 2020)
Syllabus to be implemented from Academic Year 2026-27

Course type : Open Elective-V (Practical)
Title of course : Financial Mathematics
Credit : 02

Sr. No.	Title of Practical	No. of Practical's
1	Simple Interest Calculations	1
2	Compound Interest – Annual Compounding	1
3	Compound Interest – Half-Yearly and Quarterly Compounding	1
4	Effective Rate of Interest and Multiple Compounding	1
5	Present Value and Future Value	1
6	Ordinary Annuity (Immediate Annuity)	1
7	Annuity Due	1
8	Equated Monthly Instalments (EMI) – Reducing Balance Method	1
9	EMI – Flat Interest System	1
10	Concepts of Shares	1
11	Equity Shares and Preference Shares	1
12	Bonus Shares and Share Transactions	1
13	Mutual Funds and NAV	1
14	Mutual Funds with Entry Load and Exit Load	1
15	Systematic Investment Plan (SIP) and Price Averaging	1
	Total	15

Recommended Books:

1. Financial Mathematics, 2nd Edition, A. Lenin Jothi, Himalaya Publishing House.
   Scope: Practical 1 to 9 from Unit 1, covering pp. 49–98, 142–197, and 235–249.
2. Financial Mathematics-II, Second Revised Edition – November 2025, Mrs. P. M. Saraph, MANAN PRAKASHAN.
   Scope: Practical 10 to 15 from Unit II, Module 1.

Reference Books:

1. Fundamentals of Mathematical Statistics, 12th Edition, S. C. Gupta and V. K. Kapoor, Sultan Chand & Sons, 2020.
2. Statistics for Business and Economics, 11th Edition, David R. Anderson, Dennis J. Sweeney and Thomas A. Williams, Cengage Learning, 2011.
3. Introductory Statistics, 8th Edition, Prem S. Mann, John Wiley & Sons Inc., 2013.
4. A First Course in Statistics, 12th Edition, James McClave and Terry Sincich, Pearson Education Limited, 2018.
5. Introductory Statistics, Barbara Illowsky, Susan Dean and Laurel Chiappetta, OpenStax, 2013.

B.Sc. (Mathematics) (Part III) (Level 5.5) (Semester – V)
(NEP – 2020)
Syllabus to be implemented from Academic Year 2026-27

Course type : Vocational Skill Course II (Major Specific) (Practical)
Title of course : Mathematical Computation using Python – I
Credit : 02

Sr. No.	Title of the Practical	No. of Practical(s)
1.	**Introduction to Python:** Python IDE Spyder (or Anaconda), Python identifiers and keywords, data types, simple mathematical operation, indentation and comments.	01
2.	**Expressions and Operators:** Expressions, Boolean expressions, logical operations, comparison operators, membership operator, identity operator, bitwise operator, order of evaluation.	01
3.	**Input – Output statements**	01
4.	**Conditional Statements:** if-else, nested if-else, if-elif-else, try-except block.	01
5.	**Looping Statements:** for loop, while loop, Nested loops, control statements: break, continue and pass.	01
6.	**Functions:** Built-in functions, user-defined functions, arguments, recursive function, Python anonymous/Lambda function, global, local and nonlocal variables and return statement.	01
7.	**Modules and Packages:** Modules, import, import with renaming, from-import statement, math module.	01
8.	**cmath and random modules:** cmath, numpy and sympy module.	02
9.	**Roots of Equations**: Bisection Method, Newton-Raphson Method (Algorithm – Python program – Execution)	03
10.	**Initial Value Problem:** Euler's, Euler's Modified Method ((Algorithm – Python program – Execution))	03
	T O T A L	**15**

Reference books:

1. Numerical Methods in Engineering with Python 3, Jaan Kiusalaas, Cambridge University Press.
2. Doing Math with Python, Amit Saha, No Starch Press, 2015.
3. Let Us Python, Yashwant Kanetkar and Aditya Kanetkar, BPB Publication, 2019.
4. Learning Python, Mark Lutz, O'Reilly Media, 2013.
5. Think Python: How to Think Like a Computer Scientist, Allen B. Downey, O'Reilly Media, 2015.

B.Sc. (Mathematics) (Part III) (Level 5.5) (Semester – V)
(NEP – 2020)
Syllabus to be implemented from Academic Year 2026-27

Course type	**:**	**On Job Training (OJT)**
Title of course	**:**	**On Job Training (OJT)**
Credit	**:**	**04**
Minimum hours	**:**	**120 hrs.**

On Job Training (or Internship) shall be completed by the student as per the norms of Shivaji University, Kolhapur. For more details refer the circular of Board of studies section dated 22/04/2024.

Semester VI

B. Sc. (Mathematics) (Part III) (Level 5.5) (Semester – VI)
(NEP – 2020)
Syllabus to be implemented from Academic Year 2026-27

Course type	**:**	**Major -XI (Theory)**
Title of course	**:**	**Metric Spaces**
Credit	**:**	**02**

Course Learning Outcomes: Upon successful completion of this course students will be able to:

CO 1. understand the concepts of limit and continuity in metric spaces.
CO 2. understand the concepts of open sets, closed sets.
CO 3. demonstrate the properties of continuous functions on metric spaces.
CO 4. analyze the concepts of connectedness, completeness, and compactness in metric spaces.

Unit 1: Limits and Continuous Functions on Metric Spaces (15 hrs.)

Limit and metric spaces: Limit of a function on the real line, Metric spaces, limits in metric spaces. Continuous functions on metric spaces: functions continuous at a point on the real line, reformulation, functions continuous on a metric space, Open Sets, Closed Sets.

Unit 2: Connectedness, Completeness and Compactness (15 hrs.)

More about open sets, connected sets, bounded sets and totally bounded sets, complete metric spaces, compact metric spaces, continuous functions on compact metric spaces.

Recommended book:

1. Methods of Real Analysis, R. R. Goldberg, Oxford and IBH Publishing House. (2017).

   Scope: Unit 1: Chapter 4: 4.1, 4.2, 4.3
   Chapter 5: 5.1, 5.2, 5.3, 5.4, 5.5
   Unit 2: Chapter 6: 6.1, 6.2, 6.3, 6.4, 6.5, 6.6

Reference books:

1. Mathematical Analysis, T. M. Apostol, Narosa Publishing House (2002).
2. Mathematical Analysis, Satish Shirali, H. L. Vasudeva, Narosa Publishing House (2021).
3. First Course in Mathematical Analysis, D. Somasundaram, B. Choudhary, Narosa Publishing House (1996).
4. Principles of Mathematical Analysis, W. Rudin, McGraw Hill Book Company (1976).
5. A Course of Mathematical Analysis, Shanti Narayan, P. K. Mittal, S. Chand and Company (2013).
6. Mathematical Analysis-I, J. N. Sharma, Krishna Prakashan Mandir, Meerut (2014).
7. Mathematical Analysis, S. C. Malik, Savita Arora, New Age International Ltd. (2005).

B. Sc. (Mathematics) (Part III) (Level 5.5) (Semester – VI)
(NEP – 2020)
Syllabus to be implemented from Academic Year 2026-27

Course type	**:**	**Major -XII (Theory)**
Title of course	**:**	**Linear Algebra**
Credit	**:**	**02**

Course Learning Outcomes: Upon successful completion of this course students will be able to:

CO 1. analyze and manipulate vector spaces, linear transformations.
CO 2. identify the relationship between matrices and linear transformations.
CO 3. acquire skills to perform computations related to inner product and orthogonalization techniques.
CO 4. compute Eigen values and Eigen vectors of a linear transformation.

Unit 1: Vector Spaces and Linear Transformations (18 hrs.)

Vector space, subspace, sum of subspaces, direct sum, quotient space, homomorphism or linear transformation, kernel and range of homomorphism, fundamental theorem of homomorphism, isomorphism theorems, linear span, finite dimensional vector space, linear dependence and independence, basis, dimension of vector space and subspaces.

Linear transformations: rank and nullity of a linear transformation, Sylvester's law, algebra of linear transformations: sum and scalar multiple of linear transformations, the vector space Hom (V, W), product (composition) of linear transformations, linear operator, linear functional, invertible linear transformations, non-singular linear transformations, matrix of a linear transformations and its examples.

Unit 2: Eigenvalues, Eigenvectors and Inner Product Spaces (12 hrs.)

Eigen values and eigen vectors, eigen space, characteristic polynomials of a matrix, similar matrices, characteristic polynomial of a linear operator and remarks on it.

Inner product spaces, norm of a vector, Cauchy-Schwarz inequality, triangle inequality, parallelogram law, orthogonality, orthogonal complement, generalized Pythagoras theorem, orthonormal set, Gram-Schmidt orthogonalization process, Bessel's inequality.

Recommended book:

1. **A Course in Abstract Algebra,** Khanna V. K. and Bhambri S. K., Vikas Publishing House PVT Ltd., New Delhi, 2016, 5th edition.
   [Scope: Unit-1: Page No.512-545 & Page No.559-578
   Unit-2: Page No.617-628 & Page No.701-711**]**

Reference books:

1. Theory and Problems of Linear Algebra, Sharma R. D. and Jain R., I.K. International Pvt. Ltd., New Delhi-110002
2. Textbook of Linear Algebra, Vasishtha A. R. and Vasistha A. K., Krishna Prakashan Media

(P) Ltd., KRISHNA HOUSE, 11, Shivaji Road, Meerut-250001 (UP), India
3. Linear Algebra, Sharma J. N and Vasishtha A. R., Krishna Prakashan Mandir, Meerut, Shivaji Road, Meerut-250001 (UP), India
4. Elementary Linear Algebra (with Supplemental Applications), Anton H & Rorres C, 11th Edition, Wiley India Pvt. Ltd (Wiley Student Edition), New Delhi, 2016.
5. Linear Algebra, Friedberg S., Insel A and Spence L, 4th Edition, Prentice Hall of India, 2014.
6. Linear Algebra, Holfman K. and Kunze R., Prentice Hall of India, 1978.
7. Linear Algebra, Lipschutz' S, Schaum's Outline Series, McGraw Hill, Singapore, 1981.

B. Sc. (Mathematics) (Part III) (Level 5.5) (Semester – VI)
(NEP – 2020)
Syllabus to be implemented from Academic Year 2026-27

Course type : Major P VI (a) (Practical)
Title of course : Mathematics Practical (Major) – VI (a)
Credit : 02

Sr. No	Title of the Practical	No. of Practical(s)
1	Examples on $\in -\delta$ definition of limit of a function	01
2	Examples on Metric Spaces	02
3	Open balls in Metric Spaces	01
4	Open and Closed sets in Metric Spaces	01
5	Open and Closed sets on Continuous Maps	01
6	Limit points in Metric Spaces	01
7	Examples on Homeomorphism in Metric Spaces	02
8	Connected sets in Metric Spaces	01
9	Totally bounded sets in Metric Spaces	01
10	Examples on Complete Metric Spaces	01
11	Examples on Compact Metric Spaces	01
12	Examples on Contraction Mappings	01
13	Examples on Uniform continuous Functions	01
	T O T A L	**15**

B. Sc. (Mathematics) (Part III) (Level 5.5) (Semester – VI)
(NEP – 2020)
Syllabus to be implemented from Academic Year 2026-27

Course type : Major P VI (b) (Practical)
Title of course : Mathematics Practical (Major) – VI (b)
Credit : 02

Sr. No	Title of the Practical	No. of Practical(s)
1	Examples on Vector Spaces	01
2	Examples on Subspaces	01
3	Linear combination and linear span	01
4	Linear independence and dependence	01
5	Examples on the basis of vector spaces	01
6	Examples on linear transformations	01
7	Matrix representation of linear transformations	01
8	Rank and Nullity of a linear transformation	01
9	Examples on inner product spaces	01
10	Examples on norm of vectors	01
11	Examples on angle between vectors	01
12	Orthogonality and orthogonal basis	01
13	Orthogonal compliments and basis of orthogonal complement	01
14	Gram-Schmidt orthogonalization process	01
15	Matrix representation of an inner product	01
	T O T A L	**15**

B.Sc. (Mathematics) (Part III) (Level 5.5) (Semester – VI)
(NEP – 2020)
Syllabus to be implemented from Academic Year 2026-27

Course type	**:**	**Major II -A (ELEC) (Theory)**
Title of course	**:**	**Integral transforms**
Credit	**:**	**02**

Course Learning Outcomes: Upon successful completion of this course students will be able to:

CO 1. understand meaning of Laplace Transform.
CO 2. apply properties of Laplace transform to solve differential equations.
CO 3. understand relation between Laplace and Fourier transform.
CO 4. understand infinite and finite Fourier transform.

Unit 1 Laplace and Inverse Laplace Transform (18 hrs.)

Laplace Transform: piecewise continuity, function of exponential order, function of class A and Laplace transform, Existence theorem of Laplace transforms. Laplace transform of standard functions, first shifting theorem, second shifting theorem, change of scale property, Laplace transform of derivatives, Laplace transform of integrals, effect of multiplication, effect of division, Laplace transform of periodic functions, Laplace transforms of Heaviside's unit step function and Dirac delta function, examples.

Inverse Laplace Transform: inverse Laplace transform, standard results of inverse Laplace transform, first shifting theorem, second shifting theorem, change of scale property, inverse Laplace transform of derivatives, inverse Laplace transform of integrals, the convolution theorem, effect of multiplication and division. inverse Laplace by partial fractions, examples.

Unit 2 Fourier Transform (12 hrs.)

Infinite Fourier transform, infinite Fourier sine and cosine transform, infinite inverse Fourier sine and cosine transform, relationship between Fourier transform and Laplace transform, change of scale property, modulation theorem, the derivative theorem, extension theorem, convolution theorem, finite Fourier sine and cosine transform, finite inverse Fourier sine and cosine transform, examples.

Recommended Books:

First Reading

1. Integral Transforms, J. K. Goyal, K. P. Gupta, Pragati Prakashan, Meerut, 21st edition, 2021.
   Scope: Unit 1: Part I: 1.0 to 1.6, Part II: 1.0 to 1.3. Pages 1 to 130
   Unit 2: Part I: 2.0 to 2.3, Part II: 2.0 to 2.1. Page 195 to 263

Second Reading

2. Fourier series and Integral Transform, Dr. S. Sreenadh, S. Chand, New Delhi, 2018

Reference Books:

1. Integral Transforms and Their Applications, B. Davies, Springer Science, 2017.
2. Laplace Transforms, Murray R. Spiegel, Schaum's outlines 2018.

B.Sc. (Mathematics) (Part III) (Level 5.5) (Semester – V)
(NEP – 2020)
Syllabus to be implemented from Academic Year 2026-27

Course type : Major (ELEC) P-IIA (Practical)
Title of course : Mathematics Practical (Elective) IIA
Credit : 02

Sr. No	Title of the Practical	No. of Practical(s)
1	Laplace transform of elementary functions	01
2	Effect of multiplication	01
3	Effect of division	01
4	Laplace transform of integrals	01
5	Laplace transform of periodic functions	01
6	Evaluation of integrals by Laplace Transform	01
7	Inverse Laplace by using standard results	01
8	Inverse Laplace by convolution theorem	01
9	Inverse Laplace by partial fractions	02
10	Infinite Fourier sine transform and inverse	01
11	Infinite Fourier cosine transform and inverse	01
12	Convolution theorem of Fourier transform	01
13	Finite Fourier sine transform and inverse	01
14	Finite Fourier cosine transform and inverse	01
	T O T A L	**15**

B.Sc. (Mathematics) (Part III) (Level 5.5) (Semester – VI)
(NEP – 2020)
Syllabus to be implemented from Academic Year 2026-27

Course type	**:**	**Major II -B (ELEC) (Theory)**
Title of course	**:**	**Complex Analysis**
Credit	**:**	**02**

Course Learning Outcomes: Upon successful completion of this course students will be able to:

CO 1. understand differentiability, analyticity, and Cauchy–Riemann equations.
CO 2. construct analytic functions and analyze harmonic and orthogonal functions.
CO 3. evaluate complex integrals using Cauchy's theorems and Cauchy's integral formula.
CO 4. find singularities and apply residue theorem to evaluate integrals.

Unit 1: Analytic Functions (15 hrs.)

Differentiable functions of a complex variable, differentiability and continuity, Analytic functions, elementary rules of differentiations (without proof), chain rule (without proof), derivatives of polynomials and rational functions, necessary and sufficient condition for f(z) to be analytic, Cauchy Riemann equations, analytic functions in a domain, determination of the conjugate function, polar form of Cauchy Riemann equations, derivative of w in a polar form, orthogonal systems, Harmonic functions, construction of analytic function when one conjugate function is given.

Unit 2: Complex Integration (15 hrs.)

Some important definitions (partitions, continuous arc, multiple arc, Jordan arc, contour, orientation of the curve, rectifiable curve), some properties of integral (without proof), examples on evaluation of $\int_C f(z)\,dz$, reduction of real integrals.

Cauchy theorem, Fundamental Cauchy theorem (without proof), connected region, a more general form of Cauchy theorem (without proof), extension to multiply-connected domains, Cauchy integral formula, higher order derivative of analytic function (without proof), development of Analytic functions as a power series: statements of Taylors series, Maclaurin's series and Laurent's series expansion, related examples.

Zeroes of an analytic function, singularities of an analytic function, residue at an isolated singularity, residue at infinity, computation of residues, Cauchy residue theorem, evaluation of real definite integrals.

Recommended Books:

1. Shanti Narayan, Dr. P. K. Mittal, Theory of functions of a complex variable, S. Chand, Revised edition, 2010.
   Scope: Unit 1: Chapter 5: 5.2, 5.4, 5.6,5.7,5.8,5.9
   Unit 2: Chapter 8: 8.2,8.3,8.6, Chapter 9: 9.4, 9.5, 9.6, 9.6.1, 9.7.1, 9.10, 9.12,
   Chapter 10: 10.2, 10.3,10.4, 10.8, 10.9,10.10, Chapter 11: 11.2, 11.3.

Reference books:

1. Functions of a Complex Variables, J. N. Sharma, Krishna Prakashan mandir, Meerut.
2. Complex Analysis (an introduction course), G. R. Viswanath, South Carolina State University.
3. Foundations of Complex Analysis, S. Ponnusamy, Narosa Publishing House, Second Edition, 2005, Ninth reprint 2013.
4. Complex variables and Applications, James Ward Brown and Ruel V. Churchill, 8th Ed., McGraw – Hill Education (India) Edition, 2014. Eleventh reprint 2018.
5. Functions of a Complex Variable, Goyal J. K. & Gupta K. P., (29th ed.), Pragati Prakashan.

B.Sc. (Mathematics) (Part III) (Level 5.5) (Semester – V)
(NEP – 2020)
Syllabus to be implemented from Academic Year 2026-27

Course type : Major (ELEC) P-IIB (Practical)
Title of course : Mathematics Practical (Elective) IIB
Credit : 02

Sr. No	Title of the Practical	No. of Practical(s)
1	Test of analyticity of a complex function at a point	01
2	Construction of an analytic function when real/imaginary part is given	01
3	Verification of Cauchy–Riemann equations in cartesian form	01
4	Verification of harmonic nature of a function	01
5	Determination of harmonic conjugate of a harmonic function	01
6	Verification of Cauchy–Riemann equations in polar coordinates	01
7	Determination of derivative of a complex function in polar form	01
8	Evaluation of contour integrals by direct parameterization	01
9	Evaluation of contour integrals using Cauchy Integral Formula	01
10	Expansion of an analytic function using Taylor series	01
11	Expansion of a function using Laurent series in a given region	01
12	Determination of zeroes and their multiplicities	01
13	Computation of residue at an isolated singularity	01
14	Evaluation of real definite integrals using Residue Theorem	02
	T O T A L	**15**

B. Sc. (Mathematics)(Part III) (Level 5.5) (Semester – VI)
(NEP – 2020)
Syllabus to be implemented from Academic Year 2026-27

Course type : Vocational Skill Course III (Major Specific) (Practical)
Title of course : Mathematical Computation using Python – II
Credit : 02

Sr. No.	Title of the Practical	No. of Practical(s)
1.	File Handling	01
2.	String, List and Tuples, and operations	02
3.	Dictionary, Sets and their operations	02
4.	Arrays and their Operations	02
5.	**System of Linear Algebraic Equations:** Gaussian Elimination, LU Decomposition. (Algorithm – Python program – Execution).	03
6.	**Initial Value Problem:** Runge-Kutta 2nd Order, Runge-Kutta 4th Order. (Algorithm – Python program – Execution).	03
7.	**Graph Theory:** Networkx Graph, nodes, edges, directed graph, multigraph, drawing graph, Google page rank by random walk method.	01
8.	**Data visualization in Python:** 2D and 3D plot in python: line plot, bar plot, histogram plot, scatter plot, pie plot, area plot	01
	T O T A L	**15**

Reference books:

1. Numerical Methods in Engineering with Python 3, Jaan Kiusalaas, Cambridge University Press.
2. Doing Math with Python, Amit Saha, No Starch Press, 2015.
3. Let Us Python, Yashwant Kanetkar and Aditya Kanetkar, BPB Publication, 2019.
4. Learning Python, Mark Lutz, O'Reilly Media, 2013.
5. Think Python: How to Think Like a Computer Scientist, Allen B. Downey, O'Reilly Media, 2015.

B. Sc. (Mathematics)(Part III) (Level 5.5) (Semester – VI)
(NEP – 2020)
Syllabus to be implemented from Academic Year 2026-27

Course type : Skill Enhancement Course III (Practical)
Title of course : GeoGebra
Credit : 02

Sr. No.	Title of the Practical	No. of Practical(s)
1.	Introduction to GeoGebra	01
2.	Basics of lines and triangles	02
3.	Congruency of triangles	01
4.	Properties of quadrilaterals	01
5.	Symmetry & Transformations	02
6.	Polynomials	02
7.	Pythagoras, midpoint theorem using constructions	01
8.	Properties of circles	01
9.	Create & manage tools	01
10.	Sequences in GeoGebra	01
11.	Scripting & LaTeX	02
	T O T A L	**15**

Reference Books:

1. Exploring Geometry with GeoGebra, Gerard A. Venema, Mathematical Association of America, 2013.
2. GeoGebra in Action: Mathematics with Interactive Geometry, Algebra, and Calculus, Alex Herbert, Manning Publications, 2016.
3. IIT Bombay Spoken Tutorial GeoGebra Course. https://spoken-tutorial.org/tutorial-search/?search_foss=GeoGebra
4. Introduction to GeoGebra. https://research.shu.ac.uk/geogebra/GIS_Guides/Introduction%20to%20GeoGebra.pdf
5. GeoGebra Builder's Handbook. https://www.geogebra.org/m/t6v92Gdz

B.Sc. (Mathematics) (Part III) (Level 5.5) (Semester – VI)
(NEP – 2020)
Syllabus to be implemented from Academic Year 2026-27

Course type	**:**	**IKS 2 (Major specific) (Theory)**
Title of course	**:**	**Ancient Indian Mathematics**
Credit	**:**	**02**

Course Learning Outcomes: Upon successful completion of this course students will be able to:

CO 1. understand, connect up and explain basics of Indian Mathematical Knowledge in the modern Mathematics perspective.
CO 2. describe the development and significance of mathematics in ancient India, focusing on Hindu contributions and their historical context.
CO 3. analyze the development of numeral systems, including the decimal place-value system, zero symbol, and various numerical notations in Hindu literature.
CO 4. appreciate ethical values and societal relevance of mathematics.
CO 5. explain contributions of major Indian mathematicians.

Unit 1: **(15 hrs.)**

Indian Mathematics in the colonial period and after: Life history and contribution of the Sulva Sutras, Aryabhata, Brahmagupta, Mahaviracharya.

Unit 2: **(15 hrs.)**

Life history and contribution of Bhaskara, Kuttaka, Varga-prakriti.

Recommended book:

1. Srinivasa Iyengar C. N. (1988), The History of Ancient Indian Mathematics. World Press Private Ltd. Calcutta. Digitized Book (2009).
   Scope: Unit 1- Ch. II, V, VI, VII. Unit 2- Ch. VIII, IX, X.

Reference Books:

1. The History of Mathematics: A Brief Course, Cooks, R. L., John Wiley & Sons, Inc., 2014
2. The Aryabhatiya of Aryabhata, Clark, Walter Eugene, University of Chicago Press, Chicago, 1930.
3. Algebra with Arithmetic and Mensuration from the Sanskrit of Brahmagupta and Bhaskara, Colebrooke, Henry Thomas, J. Murray, Londan, 1817.
4. Geometry in Ancient and Medieval India, Saraswati, T. A., Delhi, 1979.
5. Mathematical Achievements of Pre-Modern Indian Mathematicians, Puttaswamy, T. K., Elsevier lnc. USA, (2012).

B.Sc. (Mathematics) (Part III) (Level 5.5) (Semester – V)
(NEP – 2020)
Syllabus to be implemented from Academic Year 2026-27

Course type	**:**	**Field Project (FP)**
Course Name	**:**	**Field Project (FP)**
Credit	**:**	**02**

Suggested topics / Areas (for illustration Only)

1) Mathematics in Climate Change Modeling.
2) Study of Differential Equations in Physical Systems.
3) Mathematics Behind Artificial Intelligence.
4) Graph Theory and Network Analysis (Shortest path algorithms, social network models).
5) Applications of Eigenvalues and Eigenvectors in Real Life (Google PageRank concept).
6) Optimization Techniques in Transportation and Supply Chain Management.
7) Data Analysis Using Python for Real-Life Datasets.
8) Cryptography and Number Theory in Cyber Security.
9) Machine Learning Basics: Mathematical Foundations and Applications (Linear regression, gradient descent, matrix methods).
10) Statistical survey (health, education, agriculture, local business trends)
11) Traffic flow analysis and queuing models
12) Population growth modelling
13) Inventory analysis of small enterprises
14) Financial data analysis of cooperative societies
15) Optimization problems in local industries
16) Environmental data modelling (rainfall, pollution levels)
17) Cost–Benefit Analysis of Sugarcane Farming (Break-even analysis, profit modeling, linear programming approach).
18) Mathematical Modeling of Irrigation Water Distribution (Optimization of water usage in farms).
19) Survey-Based Study of Agricultural Loan Repayment Patterns.
20) Mathematical Study of Loan Interest Calculations in Cooperative Banks (Compound interest, EMI structure analysis).
21) Rainfall Data Analysis of Kolhapur / Sangali / Satara District (or a particular Taluka) (Last 10 Years).

*Any other topic may be added.

Equivalence of Courses

B. Sc. Part III (Semester V and VI)

Old Course				Equivalent Course		
Sem No.	**Course Code**	**Title of Old Course**	**Credit**	**Course Code**	**Title of New Course**	**Credit**
V	DSC – E9	Real Analysis	2	Major -IX	Real Analysis	2
V	DSC – E10	Modern Algebra	2	Major -X	Modern Algebra	2
V	DSC – E11	Partial Differential Equations	2	Major Elective I-A	Partial Differential Equations	2
V	DSC – E12	Integral Transform	2	Major Elective II-A	Integral Transform	2
VI	DSC – F9	Metric Spaces	2	Major -XI	Metric Spaces	2
VI	DSC – F10	Linear Algebra	2	Major -XII	Linear Algebra	2
VI	DSC – F11	Complex Analysis	2	Major Elective II-B	Complex Analysis	2
VI	DSC – F12	Operations Research	2	Major Elective I-B	Operations Research	2
V and VI (annual)	CCPM – IV, V, VI, VII	Problems on Operations Research	16	Major P V(a) Major P V(b)	Mathematics Practical (Major) V (a & b)	16
				Major Elective I (Practical) (A or B any one)	Practical Course in A) PDE B) Operations Research	
		Problems on Laplace and Fourier Transform		Major VI (Practical)	Mathematics Practical (Major) VI	
				Major Elective II- (Practical) (A or B any one)	Practical Course in A) Integral Transforms B) Complex Analysis	
		Mathematical Computation Using Python		Vocational Skill Course II and III	Mathematical Computation using Python – II and III	
		Project and Study Tour				