SHIVAJI UNIVERSITY, KOLHAPUR

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Accredited by NAAC: A++ Grade with CGPA 3.52

Choice Based Credit System with Multiple Entry and Multiple Exit Option
(NEP-2020)

Syllabus For

M.A. / M.Sc. Mathematics Part -I

Semester I and II

(Syllabus to be implemented from the Academic Year 2022-23)

Choice Based Credit System with Multiple Entry and Multiple Exit Option (NEP-2020)
M. A. / M.Sc. (Mathematics) Programme Structure
M. A. / M.Sc. (Mathematics) Part – I (Level-8)

SEMESTER-I (Duration- Six Month)											
	Sr. No.	Course Code	Teaching Scheme			Examination Scheme					
			Theory and Practical			University Assessment (UA)			Internal Assessment (IA)		
			Lectures + Tutorial (Per week)	Hours (Per week)	Credit	Maximum Marks	Minimum Marks	Exam. Hours	Maximum Marks	Minimum Marks	Exam. Hours
CGPA	1	CC-101	4+1	5	4	80	32	3	20	8	1
	2	CC-102	4+1	5	4	80	32	3	20	8	1
	3	CC-103	4+1	5	4	80	32	3	20	8	1
	4	CC-104	4+1	5	4	80	32	3	20	8	1
	5	CC-105	4+1	5	4	80	32	3	20	8	1
	6	OE-106	4+1	5	4	80	32	3	20	8	1
Total (A)			**--**	**--**	**24**	**480**	**--**	**--**	**120**	**--**	**--**
Non-CGPA	1	AEC-107	2	2	2	--	--	--	50	20	2
SEMESTER-II (Duration- Six Month)											
CGPA	1	CC-201	4+1	5	4	80	32	3	20	8	1
	2	CC-202	4+1	5	4	80	32	3	20	8	1
	3	CC-203	4+1	5	4	80	32	3	20	8	1
	4	CC-204	4+1	5	4	80	32	3	20	8	1
	5	CC-205	4+1	5	4	80	32	3	20	8	1
	6	OE-206	4+1	5	4	80	32	3	20	8	1
Total (B)			**--**	**--**	**24**	**480**	**--**	**--**	**120**	**--**	**--**
Non-CGPA	1	SEC-207	2	2	2	--	--	--	50	20	2
Total (A+B)					**48**	**960**	**--**	**--**	**240**	**--**	**--**

• Student contact hours per week : **30** Hours	• Total Marks for M.Sc.-I : **1200**
• Theory and Tutorial Lectures : **60** Minutes Each	• Total Credits for M.Sc.-I (Semester I & II) : **48**
• CC-Core Course • OE-Open Elective Course • AEC-Mandatory Non-CGPA compulsory Ability Enhancement Course • SEC- Mandatory Non-CGPA compulsory Skill Enhancement Course	• ***Separate passing is mandatory for Theory and Internal Examinations***
• **Requirement for Entry at Level 8:** **1) Completed the Bachelor of science degree with principal / major subject Mathematics.** **or** **2) Completed the Bachelor of science degree with Mathematics courses upto Second Year of Bachelor's degree.** **or** **3) Completed the Bachelor's degree (Level 7) with principal / major subject Mathematics.** **or** **4) Completed the Bachelor's degree (Level 7) with Mathematics courses upto undergraduate Diploma (Level 6)**	
• **Exit Option at Level 8:** **Students can exit after completion of Level 8 with Post Graduate Diploma in Mathematics.**	

Choice Based Credit System with Multiple Entry and Multiple Exit Option (NEP-2020)
M. A. / M.Sc. (Mathematics) Programme Structure
M. A. / M.Sc. (Mathematics) Part – II (Level-9)

SEMESTER-III (Duration- Six Month)											
	Sr. No.	Course Code	Teaching Scheme			Examination Scheme					
			Theory and Practical			University Assessment (UA)			Internal Assessment (IA)		
			Lectures + Tutorial (Per week)	Hours (Per week)	Credit	Maximum Marks	Minimum Marks	Exam. Hours	Maximum Marks	Minimum Marks	Exam. Hours
CGPA	1	CC-301	4+1	5	4	80	32	3	20	8	1
	2	DSE-302	4+1	5	4	80	32	3	20	8	1
	3	CCS -303	4+1	5	4	80	32	3	20	8	1
	4	CCS -304	4+1	5	4	80	32	3	20	8	1
	5	CCS -305	4+1	5	4	80	32	3	20	8	1
	6	CCS -306	4+1	5	4	80	32	3	20	8	1
Total (C)			**--**	**--**	**24**	**480**	**--**	**--**	**120**	**--**	**--**
Non-CGPA	1	AEC-307	2	2	2	--	--	--	50	20	2
	2	EC (SWM MOOC)-308/ OE-308	Number of lectures and credit shall be as specified on SWAYAM- MOOC or as specified on OE								
SEMESTER-IV (Duration- Six Month)											
CGPA	1	CC-401	4+1	5	4	80	32	3	20	8	1
	2	DSE -402	4+1	5	4	80	32	3	20	8	1
	3	CCS -403	4+1	5	4	80	32	3	20	8	1
	4	CCS -404	4+1	5	4	80	32	3	20	8	1
	5	CCS -405	4+1	5	4	80	32	3	20	8	1
	6	CCS -406	4+1	5	4	80	32	3	20	8	1
Total (D)			**--**	**--**	**24**	**480**	**--**	**--**	**120**	**--**	**--**
Non-CGPA	1	SEC-407	2	2	2	--	--	--	50	20	2
	2	GE-408	2	2	2	--	--	--	50	20	2
Total (C+D)					**48**	**960**	**--**	**--**	**240**	**--**	**--**

• Student contact hours per week : **30** Hours	• Total Marks for M.Sc.-II : **1200**
• Theory and Tutorial Lectures : **60** Minutes Each	• Total Credits for M.Sc.-II (Semester III & IV) : **48**
• ***Separate passing is mandatory for Theory and Internal Examination***	
• CC-Core Course • CCS- Core Course Specialization • DSE-Discipline Specific Elective • AEC-Mandatory Non-CGPA compulsory Ability Enhancement Course	• SEC- Mandatory Non-CGPA compulsory Skill Enhancement Course • EC (SWM MOOC) - Non-CGPA Elective Course • GE- Multidisciplinary Generic Elective
• **Requirement for Entry at Level 9:** **1) Students of Shivaji University Kolhapur who have completed learning of Post Graduate Diploma (Level 8) in Mathematics.** **2) Completed all requirements of the relevant Post Graduate Diploma (Level 8) in Mathematics.** **3) Bachelor's Degree (Honours / Research) (Level 8) with principal / major subject Mathematics**	
• **Exit at Level 9:** **Students will exit after completion of Level 9 with Master's Degree in Mathematics.**	

	M.Sc.-I	**M.Sc.-II**	**Total**
Marks	**1200**	**1200**	**2400**
Credits	**48**	**48**	**96**

I. CGPA course:

1. There shall be 12 Core Courses (CC) of 48 credits per programme.
2. There shall be 08 Core Course Specialization (CCS) of 32 credits per programme.
3. There shall be 02 Discipline Specific Elective (DSE) courses of 08 credits per programme
4. There shall be 02 Open Elective Courses (OE) of 08 credits per programme.
5. Total credits for CGPA courses shall be of 96 credits per programme

II. Mandatory Non-CGPA Courses:

1. There shall be 02 Mandatory Non-CGPA compulsory Ability Enhancement Courses (AEC) of 02 credits each per programme.
2. There shall be 02 Mandatory Non-CGPA compulsory Skill Enhancement Course (SEC) of 02 credits per programme.
3. There shall be one Elective Course (EC) (SWAYAM -MOOC). The credits of this course shall be as specified on SWAYAM -MOOC.
4. If for a particular program there is no compatible SWAYAM-MOOC then for that program OE shall be offered.
5. There shall be one Multidisciplinary Generic Elective (GE) course of 02 credits per programme. Each student has to take generic elective from the department other than parent department.
6. For Non-CGPA courses the total credits shall be 10 + the credits of EC or OE as per availability.
7. The credits assigned to the course and the programmes are to be earned by the students and shall not have any relevance with the work load of the teacher.

M.A. / M. Sc. (Mathematics) (Part-I / Level-8) (Semester I)

Course code	**Title of course**
CC-101	Advanced Calculus
CC-102	Linear Algebra
CC-103	Complex Analysis
CC-104	Classical Mechanics
CC-105	Ordinary Differential Equations
OE-106	Any one of the following 1. Number Theory 2. Mathematical Methods 3. Any course from other Department

M. A. / M. Sc. Part-I (Mathematics) (Level-8) (Semester I)
(NEP-2020)
(Introduced from Academic Year 2022-23)

Course Code: CC-101
Title of Course: Advanced Calculus

Course Outcomes: Upon successful completion of this course, the student will be able to:
(i) Analyze convergence of sequences and series, double sequences and double series
(ii) Analyze convergence of sequences and series of functions
(iii)check differentiability of functions of several variables
(iv) Apply inverse and implicit function theorems for functions of several variables

Unit I : Sequences and series of functions: Pointwise convergence of sequences of functions, Examples of sequences of real valued functions, Definition of uniform convergence, Uniform convergence and continuity, Cauchy condition for uniform convergence, Uniform convergence and Riemann integration, Uniform convergence and differentiation **15 Lectures**

Unit II: Rearrangement of series, subseries, Double sequences, Double series, rearrangement of double series, sufficient condition for equality of iterated series, multiplication of series, Cesaro summability, sufficient conditions for uniform convergence of series, uniform convergence and double sequences, mean convergence, Taylor series generated by a function, Bernstein's theorem, binomial series. **15 Lectures**

Unit III: Multivariable differential Calculus: The Directional derivatives, directional derivatives and continuity, total derivative, total derivatives expressed in terms of partial derivatives, The matrix of linear function, mean value theorem for differentiable functions, A sufficient condition for differentiability, sufficient condition for equality of mixed partial derivatives, Taylor's formula for functions from R^n to R^1. **15 Lectures**

Unit IV: Implicit functions: Functions of several variables, Linear transformations, Differentiation, Contraction principle, The inverse function theorem, The implicit function theorem and their applications. **15 Lectures**

Seminars, Tutorials, Problem solving session and group discussions on above four units

Recommended books:
1. Mathematical Analysis, Apostal, Second Edition, Narosa Publishing House.1974

Reference books:
1.Principles of mathematical Analysis, Walter Rudin, third Edition, McGraw Hill book company
2. Calculus Vol. I , Vol II, Tom M. Apostol, Second EditionWiley India Pvt. Ltd.
3. W.Fleming, Functions of several Variables,2nd Edition ,Springer Verlag, 1977.

M. A. / M. Sc. Part-I (Mathematics) (Level-8) (Semester I)
(NEP-2020)
(Introduced from Academic Year 2022-23)

Course Code: CC-102
Title of Course: Linear Algebra
Course Outcomes: Upon successful completion of this course, the student will be able to:

1. understand basic notions in Linear Algebra and use the results in developing advanced mathematics.
2. study the properties of Vector Spaces, Linear Transformations, Algebra of Linear Transformations and Inner product space in some details.
3. construct Canonical forms and Bilinear forms.
4. apply knowledge of Vector space, Linear Transformations, Canonical Forms and Bilinear Transformations.

Unit I: Elementary Basic concepts, Linear Independence and Bases, Dual Spaces, Annihilator of a subspace, Quotient Spaces. Inner product spaces, The Algebra of Linear transformations.
15 Lectures

Unit II: Characteristic Roots, Matrices, Eigen values and eigenvectors of a linear transformation, Canonical Forms: Similarity of linear transformations, Triangular form. **15 Lectures**

Unit III: Canonical Forms: Nilpotent transformations, Decomposition of Vector space: Jordan Form, Rational Canonical Form, Trace and transpose. **15 Lectures**

Unit IV: Determinants, Hermitian, Unitary and Normal linear transformations, Bilinear Forms, Symmetric Bilinear Forms, Skew Symmetric Bilinear Forms. **15 Lectures**

Seminars, Tutorials, Problem solving session and group discussions on above four units

Recommended Book(s):

1. Herstein I. N. : Topics in Algebra, 2nd Edition, Willey Eastern Limited.
2. Hoffman, Kenneth and Kunze R: Linear Algebra, Prentice Hill of India Private Limited., 1984.

Reference Books:

1. A. R. Rao and P. Bhimashankaran, Linear Algebra, Hidustan Book Agency.
2. Surjit Singh, Linear Algebra, Vikas publishing House (1997).
3. Gilbert Strang: Introduction to Linear Algebra, Wellesley-Cambridge Press

M. A. / M. Sc. Part-I (Mathematics) (Level-8) (Semester I)
(NEP-2020)
(Introduced from Academic Year 2022-23)

Course Code: CC-103
Title of Course: Complex Analysis
Course Outcomes: Upon successful completion of this course, the student will be able to:

1. compute the region of convergence for power series,
2. prove the Cauchy-Riemann equations and apply them to complex functions in order to examine differentiability and analyticity of complex functions,
3. evaluate complex integration along the curve via Cauchy's theorem and integral formula
4. prove the Cauchy residue theorem and apply it to several kinds of real integrals.
5. compute the Taylor series and Laurent series expansions of complex functions and apply it to for checking the nature of singularities and calculating residues,

UNIT– 1: Power series, Radius of convergence, Analytic functions, Cauchy-Riemann equations, Harmonic functions, Conformal mappings, Mobius transformations. **15 Lectures**

UNIT– 2: Line integral, Power series representation of analytic functions, zeros of an analytic function, Liouville's Theorem, Fundamental theorem of algebra, Maximum modulus theorem. **15 Lectures**

UNIT– 3: The index of a closed curve, Cauchy's theorem and integral formula, Morera's theorem, Counting zeros, open mapping theorem, Goursat's theorem, classification of singularities, Laurent series development, Casorati–Weierstrass theorem. **15 Lectures**

UNIT– 4: Residues, residue theorem, evaluation of real integrals, The argument principle, Rouche's theorem, Schwarz's lemma and its application to characterize conformal maps. **15 Lectures**

Seminars, Tutorials, Problem solving session and group discussions on above four units

Recommended Book:

1. J. B. Conway: Functions of One Complex Variable, 3rd Edition, Narosa Publishing House, 1973.

Reference Books:

1. S. Ponnusamy, Foundations of Complex Analysis, 2nd Edition, Narosa Publishing House, 2015
2. Alfors L. V.: Complex Analysis, McGraw Hill, 1979.
3. S. Ponnusamy, H Silverman, Complex Variables with Applications, Birkhauser Bostan, 2006
4. J. Brown, R.Churchill , Complex Variables and Applications, MacGraw Hill(India). (8th Edition, 2014.
5. Serge Lang, Complex Analysis, Fourth Edition, Springer,1999.

M. A. / M. Sc. Part-I (Mathematics) (Level-8) (Semester I)
(NEP-2020)
(Introduced from Academic Year 2022-23)

Course Code: CC-104
Title of Course: Classical Mechanics
Course Outcomes: Upon successful completion of this course, the student will be able to:

1. discuss the motion of system of particles using Lagrangian and Hamiltonian approach.
2. solve extremization problems using variational calculus.
3. discuss the motion of rigid body.
4. construct Hamiltonian using Routh process.
5. use infinitesimal and finite rotations to analyze motion of rigid body.

Unit – I: Mechanics of a particle, Mechanics of a system of particles, conservation theorems, constraints, Generalized coordinates, D' Alembert's Principle, Lagrange's equations of motion, Simple applications of Lagrangian formulation, Cyclic co-ordinates and generalised momentum, conservation theorems. **15 Lectures**

Unit – II: Euler- Lagrange's equations, first integrals of Euler- Lagrange's equations, the problem of Brachistochrone, Hamilton's Principle, Derivation of Hamilton's principle from D'Alembert's principle, Lagrange's equations from Hamilton's principle. Extension of Hamilton's principle to nonholonomic systems, Lagrange's equations of motion for nonconservative systems (Method of Langrange's undetermined multipliers) **15 Lectures**

Unit – III: Hamiltonian function, Hamilton's canonical equations of motion, cyclic co-ordinates and Routh's procedure, Derivation of Hamilton's equations from variational principle, Physical significance of Hamiltonian, The principle of least action. Equations of canonical transformation, generating function, examples of canonical transformations. **15 Lectures**

Unit – IV: The Kinematics of rigid body motion: The independent co-ordinates of a rigid body, the Eulerian angles, Euler's theorem on the motion of a rigid body, infinitesimal rotations, rate of change of a vector, Angular momentum and kinetic energy of a rigid body about a point, the inertia tensor and moment of inertia, Euler's equations of motion. **15 Lectures**

Seminars, Tutorials, Problem solving session and group discussions on above four units

Recommended Books :

1. Goldstein, H. Classical Mechanics. (1998), Narosa Publishing House, New Delhi.
2. Herbert Goldstein, Charles Poole, John Safko, Classical Mechanics (2013) Pearson, Delhi

Reference Books :-

1. Whittaker, E. T. A Treatise on the Analytical Dynamics of Particles and Rigid Bodies. (1965), Cambridge University Press.
2. Gupta, A. S. Calculus of Variations with Applications (1997), Prentice Hall of India.
3. Gelfand, I. M. and Fomin, S. V. Calculus of Variations (1963), Prentice Hall of India.
4. Rana, N.C. and Joag, P. S. Classical Mechanics. (1991) Tata McGraw Hill, New Delhi.

M. A. / M. Sc. Part-I (Mathematics) (Level-8) (Semester I)
(NEP-2020)
(Introduced from Academic Year 2022-23)

Course Code: CC-105
Title of Course: Ordinary Differential Equations
Course Outcomes: Upon successful completion of this course, the student will be able to:
1. solve problems modeled by linear differential equations
2. use power series methods to solve differential equations about ordinary points and regular singular points.
3. construct approximate solutions using method of successive approximation.
4. establish uniqueness of solutions.

Unit I : Linear differential equations with constant coefficients: The second order homogeneous equation, Initial value problems for second order equations, Linear dependence and independence, A formula for the Wronskian, The non-homogeneous equations of order two, The homogeneous equations of order n. **15 Lectures**
Unit II: Initial value problems for the nth order equations, The non-homogeneous equation of nth order, Linear Equations with variable coefficients: Initial value problems for the homogeneous equations. Solutions of the homogeneous equations, The Wronskian and linear independence, Reduction of the order of a homogeneous equation, The non-homogenous equations. **15 Lectures**
Unit III: Homogeneous equations with analytic coefficients, The Legendre equations, Linear Equations with regular singular points: The Euler equations, Second order equations with regular singular points, The Bessel equation, Regular singular points at infinity. **15 Lectures**
Unit IV: Existence and uniqueness of solutions: The method of successive approximations, The Lipschitz condition. Convergence of the successive approximation, Non-local existence of solutions, Approximations to solutions and uniqueness of solutions. **15 Lectures**

Seminars, Tutorials, Problem solving session and group discussions on above four units

Recommended books:

1. E.A.Coddington: An introduction to ordinary differential equations. (2012) Prentice Hall of Pvt.Ltd. New Delhi.

Reference books:

1. G.F. Simmons, Differential Equations with Applications and Historical note, MeGraw Hill, Inc. New York. (1972)
2. E.A. Coddington and Levinson, Theory of ordinary differential equations McGraw Hill, New York(1955)
3. E.D. Rainvills, Elementary differential equations, The Macmillan company, New York. (1964)
4. G. Birkoff and G.G.Rota, Ordinary Differential equations, John Willey and Sons

M. A. / M. Sc. Part-I (Mathematics) (Level-8) (Semester I)
(NEP-2020)
(Introduced from Academic Year 2022-23)

Course Code: OE-106
Title of Course: Number Theory
Course Outcome-: Upon successful completion of this course, the student will be able to:-

1. learn more advanced properties of primes and pseudo primes.
2. apply Mobius Inversion formula to number theoretic functions.
3. explore basic idea of cryptography.
4. understand concept of primitive roots and index of an integer relative to a given primitive root.
5. derive Quadratic reciprocity law and its apply to solve quadratic congruences.

Unit I: Review of divisibility : The division algorithm, G.C.D., Euclidean algorithm, Diophantine equation ax + by = c. Primes and their distribution : Fundamental theorem of Arithmetic, The Goldbach Conjecture. **15 Lectures**

Unit II : Congruences : Properties of Congruences, Linear congruences, Special divisibility tests. Fermat's theorem : Fermat's factorization method, Little theorem, Wilsons theorem. Number theoretic functions : The functions τ and σ. The Mobius Inversion formula, The greatest integer function. **15 Lectures**

Unit III: Euler's Generalization of Fermat's theorem: Euler's phi function, Euler's theorem, properties of phi function, An application to Cryptography. Primitive roots : The order of an integer modulo n. **15 Lectures**

Unit IV Primitive roots for primes, composite numbers having primitive roots, The theory of Indices. The Quadratic reciprocity law : Eulerian criteria, the Legendre symbol and its properties, quadratic reciprocity, quadratic reciprocity with composite moduli . **15 Lectures**

Seminars, Tutorials, Problem solving session and group discussions on above four units

Recommended Books :

1. D.M.Burton : Elementary Number Theory, Seventh Ed.MacGraw Hill Education(India)Edition 2012, Chennai.

Reference Books :

1. S.B.Malik :Baisc Number theory, Vikas publishing House.
2. George E.Andrews : Number Theory, Hindusthan Pub. Corp.(1972).
3. Niven, Zuckerman : An Introduction to Theory of Numbers. John Wiley & Sons.
4. S. G. Telang , Number Theory, Tata Mc.Graw-Hill Publishing Co., New Delhi.
5. M.B. Nathanson, Methods in Number Theory, Springer(2009).

M. A. / M. Sc. Part-I (Mathematics) (Level-8) (Semester I)
(NEP-2020)
(Introduced from Academic Year 2022-23)

Course Code: OE-106
Title of Course: Mathematical Methods
Course Outcomes: Upon successful completion of this course, the student will be able to:
1) solve linear and nonlinear difference equations.
2) find minimum surface of revolution of a curve.
3) determine volume of a solid, calculate area of a region.
4) obtain extrema of given multi-variable function.
5) apply Greens, Stokes and Gauss diversion theorems for applied Mathematics problems.

Unit I: Difference Equations: Existence and Uniqueness theorem, the fundamental operators, first order linear difference equations, general linear difference equations (Theorems without proof). Fundamental theorems (without proof) for homogeneous equations. Inhomogeneous equations, linear difference equations with constant coefficients (Theorems without proof). Nonlinear difference equations: Riccati equations and Clairaut's equation. Examples on difference equations. **15 Lectures**
Unit II: Calculus of variations: Functionals, variation of a functional, a basic lemma, the Euler-Lagrange equation, first integrals of Euler- Lagrange equation, Geodesics in a plane and space, the minimum surface of revolution, the case of several dependent variables. Undetermined end conditions, Isoperimetric problems, problem of maximum enclosed area. **15 Lectures**
Unit III: Applications of multi-variable differential calculus: Maxima, minima, stationary points and saddle points. Second derivative test (without proof) for extrema of functions of two variables. Extrema with constraints. Lagrange's multipliers. Derivatives of functions defined implicitely. **15 Lectures**
Unit IV: Integral Calculus: Path and line integrals, Multiple integrals, Double integral (theorems without proof). Application to area and volume. Greens theorem in the plane (without proof). Some application of Green's Theorem. Change of variables in a double integral. Special cases of transformation formula. Surface integrals, change of parametric representation. Stoke's Theorem, the curl and divergence of a Vector field. Gauss divergence Theorem (only statement). **15 Lectures**

Seminars, Tutorials, Problem solving session and group discussions on above four units

Recommended Books:

1. Ronald E Mickens, Mathematical Methods for the Natural and Engineering Sciences, Series on Advances in Mathematics for Applied Sciences-Vol. 65, World Scientific Publishing Co. Pte. Ltd, Singapore.
2. Robert Weinstock, Calculus of Variations with Applications to Physics and Engineering, Mc-Graw Hill Book Company, Inc., in 1952.
3. Tom M. Apostol, Calculus Vol. II, Second Edition, Wiley India Pvt. Ltd.

Reference Books:

1. Gelfand I. M. and Fomin S. V., Calculus of Variations, Prentice-Hall, Inc., Englewood Cliffs, New Jersey, (1963).

M. A. / M. Sc. Part-I (Mathematics) (Level-8) (Semester II)

(NEP-2020)

Course code	Title of course
CC-201	Real Analysis
CC-202	Algebra
CC-203	Topology
CC-204	Numerical Analysis
CC-205	Partial Differential Equations
OE-206	Any one of the following 1. Operations Research 2. Integral Transforms 3. Any course from other Department

M. A. / M. Sc. Part-I (Mathematics) (Level-8) (Semester II)
(NEP-2020)
(Introduced from Academic Year 2022-23)

Course Code: CC-201
Title of Course: Real Analysis

Course Outcomes: Upon successful completion of this course, the student will be able to:
1. generalize the concept of length of interval.
2. analyze the properties of Lebesgue measurable sets.
3. demonstrate the measurable functions and their properties.
4. understand the concept of Lebesgue integration of measurable functions.
5. characterize Riemann and Lebesgue integrability.
6. prove completeness of L^P Spaces.

UNIT I: σ-algebra and Borel Sets of Real numbers, Lebesgue Outer Measure, The sigma algebra of Lebesgue measurable sets, Outer and Inner approximation of Lebesgue Measurable Sets, Countable Additivity, Continuity and Borel-Cantelli Lemma. **15 Lectures**

UNIT II: Nonmeasurable Sets, Lebesgue Measurable Functions: Sums, Product and Composition of Measurable Functions, Sequential Pointwise Limits and Simple Approximation, Littlewood's Three Principles, Egoroff's Theorem and Lusin's Theorem **15 Lectures**

UNIT III: Lebesgue Integral of a Bounded Measurable Function over a Set of Finite Measure, Lebesgue integral of a Measurable Non-negative Function, The General Lebesgue Integral, Characterizations of Riemann and Lebesgue Integrability. **15 Lectures**

UNIT IV: Differentiability of Monotone Functions, Lebesgue's Theorem, Functions of Bounded Variations, Jordan's theorem (Statement Only), Absolutely Continuous Functions, Integrating Derivatives: Differentiating Indefinite Integrals, The L^P Spaces: Normed Linear Spaces, The Inequalities of Young, Hölder and Minkowski, The Riesz-Fischer Theorem. **15 Lectures**

Seminars, Tutorials, Problem solving session and group discussions on above four units

Recommended Books:

1. H. L. Royden, P.M. Fitzpatrick, Real Analysis, Fourth Edition, PHI Learning Pvt. Ltd., New Delhi, 2010

Reference Books:

1. G. de Barra, Measure Theory and Integration, New Age International (P) Ltd., 1981.
2. I. K. Rana, An Introduction to Measure and Integration, Narosa Book Company, 1997.
3. S. K. Berberian, Measure and Integration, McMillan, New York, 1965.
4. P. K. Jain, V. P. Gupta, Lebesgue measure and Integration, Wiley Easter Limited, 1986.
5. W. Rudin, Principles of Mathematical Analysis, McGraw-Hill Book Co, 1964.
6. P. K. Halmos, Measure Theory, Van Nostrand, 1950.

M. A. / M. Sc. Part-I (Mathematics) (Level-8) (Semester II)
(NEP-2020)
(Introduced from Academic Year 2022-23)

Course Code: CC-202
Title of Course: Algebra
Course Outcomes: Upon successful completion of this course, the student will be able to:
1. study group theory and ring theory in some details.
2. introduce and discuss module structure over a ring.
3. apply Sylow theorems.
4. use homomorphism and isomorphism theorems.
5. check irreducibility of polynomials over Q using Eisenstein criteria.

Unit I: Permutations: Groups of permutations, Examples, The Alternating Groups, Simple groups, simplicity of An (n > 4), Applications, Series of Groups: Subnormal and Normal Series, Jordan-Holder Theorem, The Center and the Ascending Central Series, Isomorphism Theorems: Isomorphism Theorems. **15 Lectures**

Unit II: The Zassenhaus (Butterfly) Lemma, Schreier Theorem, Group action on a set: The Notion of Group Action, fixed sets and isotropy subgroups, Orbits, Applications of G-Sets to Counting: Burnside theorem, Sylow Theorems: p-groups, The Sylow Theorems. **15 Lectures**

Unit III: Applications of the Sylow Theory: Applications to p-Groups and the Class equation, Further Applications, Rings of Polynomials: Polynomial in an Indeterminate, The evaluation Homomorphisms, The New Approach. Factorization of Polynomials over Fields: The Division Algorithm in F[x], Irreducible Polynomials, Eisenstein criteria, Ideal Structure in F[x], Uniqueness of Factorization in F[x]. **15 Lectures**

Unit IV: Unique Factorization Domains: Principal Ideal Domain (PID), Uniqueness of Factorization Domain(UFD), Gauss lemma, Euclidean Domains: Introduction and Definition, Arithmetic in Euclidean Domains. Modules: Definitions and Examples, Direct Sums, Free Modules, sub-modules, Quotient Modules, Homomorphism, Simple Modules, Modules over PID, Schur's Lemma. **15 Lectures**

Seminars, Tutorials, Problem solving session and group discussions on above four units

Recommended Book(s):

1. John B. Fraleigh , A first course in Abstract Algebra (Third Edition), Narosa publishing house, New Delhi.
2. C. Musili, Introduction to Rings and Modules (Second Revised Edition), Narosa Publishing house, New Delhi.

Reference Books:

1. Joseph A. Gallian, Contemporary Abstract Algebra (Fourth Edition), Narosa Publishing house, New Delhi.
2. Bhattacharya, Jain and Nagpal, Basic Abstract Algebra, 2nd edition, Narosa Publishing House, New Delhi.
3. I. N. Herstein, Topics in Algebra, Vikas Publishing House.
4. N. Jacobson, Basic Algebra, Hind Publishing Corporation, 1984.

M. A. / M. Sc. Part-I (Mathematics) (Level-8) (Semester II)
(NEP-2020)
(Introduced from Academic Year 2022-23)

Course Code: CC-203
Title of Course: Topology
Course Outcomes: Upon successful completion of this course, the student will be able to:
1. built foundations for future study in analysis, in geometry, and in algebraic topology.
2. introduce the fundamental concepts in topological spaces.
3. acquire demonstrable knowledge of topological spaces, product spaces, and continuous functions on topological spaces.
4. identify compact and connected sets in topological spaces.
5. use Separation and countability axioms, Urysohn lemma, Urysohn metrization.

Unit I: Topological Spaces, Basis and Subbasis for a Topology, The Order Topology, The Product Topology on $X \times Y$, The Subspace Topology, Closed Sets. **15 Lectures**

Unit II: Closure and Interior of a Set, Limit Points, Hausdorff Spaces, Continuity of Functions, Homeomorphisms, The Product Topology, The Metric Topology. **15 Lectures**

Unit III: Connected Spaces, Connected Subspaces of the Real Line, Components and Local Connectedness, Compact Spaces, Compact Subspaces of the Real Line. **15 Lectures**

Unit IV: The Countability Axioms, The Separation Axioms, Normal Spaces, The Urysohn Lemma, The Urysohn Metrization Theorem (Only statement), The Tietze Extension Theorem (Only statement). **15 Lectures**

Seminars, Tutorials, Problem solving session and group discussions on above four units

Recommended Book:

1. J. R. Munkers, Topology, Second Edition, Pearson Education (Singapore), 2000.

Reference Books:

1. W. J. Pervin, Foundations of General Topology, Academic Press, New York, 1964.
2. J. L. Kelley, General Topology, Springer-Verlag, New York, 1955.
3. S. Willard, General Topology, Addison-Wesley Publishing Company, 1970.
4. K. D. Joshi, Introduction to General Topology, New Age International, 1983.
5. G. F. Simmons, Introduction to Topology and Modern Analysis, McGraw Hill Book Company, New Delhi, 1963.

M. A. / M. Sc. Part-I (Mathematics) (Level-8) (Semester II)
(NEP-2020)
(Introduced from Academic Year 2022-23)

Course Code: CC-204
Title of Course: Numerical Analysis
Course Outcomes: Upon successful completion of this course, the student will be able to:
1) apply the methods to solve linear and nonlinear equations.
2) find numerical integration and analyze error in computation.
3) solve differential equations using various numerical methods.
4) determine eigen values and eigen vectors of a square matrix.
5) construct LU decomposition of a square matrix.

Unit I: Transcendental & polynomial equations: Bisection method, Iteration methods based on First degree equation (Secant method, Regula-Falsi method and Newton-Raphson method). Rate of Convergence, Iterative methods (Birge-Vieta method and Bairstow method). **15 Lectures**

Unit II: System of linear algebraic equations and eigen value problems: Matrix factorization methods (Doolittle's method, Crout's method), Iteration methods (Jacobi iteration method, Gauss-Seidel iteration method), convergence analysis of iterative methods, Eigen values and eigenvectors, Gerschgorin theorem, Brauer theorem, Jacobi method for symmetric matrices, Power method. **15 Lectures**

Unit III: Interpolation, differentiation and integration: Lagrange and Newton interpolations, Truncation error bounds, Newtons divided difference interpolation, finite difference operators, numerical differentiation, methods based on interpolation, numerical integration, methods based on interpolation, error analysis, Newton-Cotes methods, Error estimates for trapezoidal and Simpson's rule. **15 Lectures**

Unit IV: Numerical solution of differential equations: Euler method, analysis of Euler method, Backward Euler method, mid-point method, order of a method, Taylor series method, Explicit Runge-Kutta methods of order two and four, convergence and stability of numerical methods, Truncation error, error analysis. **15 Lectures**

Seminars, Tutorials, Problem solving session and group discussions on above four units

Recommended Books:

1. M. K. Jain, S. R. K. Iyengar, R. K. Jain, Numerical methods for scientific and Engineering Computation (Fifth Edition), New Age International Publishers 2007.

Reference Books:

1. S. S. Sastry, Introductory methods of Numerical Analysis (Fifth Edition), PHI learning Private Limited, New Delhi 2012.
2. D. Kincaid, W. Cheney, Numerical Analysis Mathematics of Scientific Computing (Third Edition), American Mathematical Society.
3. J.C. Butcher, Numerical methods for ordinary differential equations (Second Edition), John Wiley & Sons Ltd, 2008.
4. Kendall E. Atkinson, An Introduction to Numerical Analysis (Second Edition), John Wiley & Sons 1988.

M. A. / M. Sc. Part-I (Mathematics) (Level-8) (Semester II)
(NEP-2020)
(Introduced from Academic Year 2022-23)

Course Code: CC205
Title of Course: Partial Differential Equations
Course Outcomes: Upon successful completion of this course, the student will be able to:
1. classify partial differential equations and transform into canonical form
2. solve linear partial differential equations of both first and second order.
3. solve boundary value problems for Laplace's equation, the heat equation, the wave equation by separation of variables, in Cartesian, polar, spherical and cylindrical coordinates.
4. apply method of characteristics to find the integral surface of a quasi linear partial differential equations.
5. establish uniqueness of solutions of partial differential equations.

Unit I: Curves and surfaces, First order Partial Differential Equations, classification of first order partial differential equations, classifications of Integrals, Linear equations of first order. Pfaffian differential equations, Criteria of Integrability of a Pfaffian differential equation. Compatible systems of first order partial differential equations. **15 Lectures**

Unit II: Charpits method, Jacobi method of solving partial differential equations, Cauchy Problem, Integral surfaces through a given curve for a linear partial differential equations, for a non-linear partial differential equations. Method of characteristics to find the integral surface of a quasi linear partial differential equations. **15 Lectures**

Unit III: Second order Partial Differential Equations. Origin of Partial differential equation, wave equations, Heat equation. Classification of second order partial differential equation, Vibration of an infinite string (both ends are not fixed), Physical Meaning of the solution of the wave equation. Vibration of an semi infinite string, Vibration of a string of finite length, Method of separation of variables, Uniqueness of solution of wave equation. Heat conduction Problems with finite rod and infinite rod. **15 Lectures**

Unit IV: Families to equipotential surfaces, Laplace equation, Solution of Laplace equation, Laplace equation in polar form, Laplace equation in spherical polar coordinates. Kelvin's inversion theorem. Boundary Value Problems: Dirichlets problems and Neumann problems, Maximum and minimum principles, Stability theorem. Dirichlet Problems and Neumann problems for a circle, for a rectangle and for a upper half plane, Duhamel's Principle. **15 Lectures**

Seminars, Tutorials, Problem solving session and group discussions on above four units

Recommended Book:

1. T. Amarnath: An elementary course in Partial differential equations, 2nd edition, Narosa publishing House(2012).

Reference Books:

1. Mark Pinsky: Partial differential equations and boundary-value problems with applications, AMS,3rd edition(2011).
2. I. N. Sneddon: Elements of Partial Differential Equations, McGraw Hill Int.
3. Fritz John: Partial Differential Equations, Springer(1952).

M. A. / M. Sc. Part-I (Mathematics) (Level-8) (Semester II)
(NEP-2020)
(Introduced from Academic Year 2022-23)

Course Code: OE-206
Title of Course: Operation Research
Course outcomes: Upon successful completion of this course, the student will be able to --

1. Recognize convex sets and convex functions.
2. Calculate maximum and minimum value of a function of several variables.
3. Solve LPP by simplex and dual simplex methods.
4. Construct codes, efficiency and redundancy in Encoding

Unit – I Convex sets and their properties: Lines and hyper planes, convex sets, Extreme points of convex set, convex combination of vectors, Convex hull, Convex polyhedron, convex cone, simplex and convex function, General formulation of linear programming problem, Matrix form of LP problem. **15 lectures**

Unit- II Definitions of standard LPP, Fundamental Theorem of linear programming.
Simplex method, Computational procedure of simplex method, Artificial variable techniques, two phase simplex method, problem of degeneracy and method to resolve degeneracy. Duality in linear programming, Concept of duality, definition of primal dual problems, General rules for converting any primal into its dual. **15 lectures**

Unit – III Duality theorems, Primal and dual correspondence, Duality and simplex method.
Dual simplex method , Computational procedure of dual simplex method, Integer linear programming, Gomory's constraint, Gomory's cutting plane, Computational demonstration of Gomory's algorith , Gomory's cutting plane method, Branch and Bound method, Computational demonstration of Branch and Bound method, Applications of integer programming **15 lectures**

Unit – IV Information Theory : Communication process, Model for communication system,, Fundamental theorem of information theory, Statistical nature of communication systems, measure of information, A binary unit of information, measure of uncertainty of entropy, basic properties of entropy function (H), Joint and conditional entropies, Uniqueness theorem, Chanel capacity, efficiency and redundancy, Encoding, The problem of unique Decipherability, Shannon Fano encoding procedure. **15 lectures**

Recommended Books:
1 S.D. Sharma: Operations Research, Kedar Nath Ram Noth and co. 15^{th} edition reprint 2009

Reference Books:
1.J.K.Sharma : Operations research
2. Kanti Swarup ,P.K.Gupta and Manmohan : Operations research, S.Chand& Co.
3. Hamady Taha : Operations Research :Mac Millan Co.
4. R.K.Gupta : Operations Research Krishna Prakashan Mandir, Meeru
5. G.Hadley : Linear programming, Oxford and IBH Publishing Co. 6. S.I.Gass : Linear Programming, Mc Graw Hill Book Co

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(NEP-2020)
(Introduced from Academic Year 2022-23)

Course Code: OE-206
Title of Course: Integral Transforms
Course Outcomes: Upon successful completion of this course, the student will be able to:

1. describe the ideas of different types of integral transforms
2. evaluate the integral transfoems of various functions.
3. apply technique of Fourier and Laplace transforms to solve ordinary and partial differential equations.
4. analyze the properties of Fourier transforms and Laplace transforms
5. apply Z- transform to solve difference equations

UNIT 1: The Laplace Transform, The Transforms of Some Typical Functions, Basic Operational Properties, The inverse Laplace Transform, Applications Involving Laplace Transforms, Evaluating Integrals, Solutions of ODEs, Solutions of PDEs **15 Lectures**

UNIT 2: Fourier Integrals and Fourier Transforms: Fourier Integral Representations, Proof of the Fourier Integral Theorem, Fourier Transform Pairs, Properties of the Fourier Transform, The Convolution Integrals of Fourier. **15 Lectures**

UNIT 3: Applications Involving Fourier Transforms: Boundary Value Problems , Heat Conduction in Solids , Mechanical Vibrations, Mellin Transform: Evaluation of Mellin transforms, Complex variable method and Applications. **15 Lectures**

UNIT 4: The Henkel Transforms: Evaluation of Henkel transforms, Applications of transform.
Finite Transforms: Finite Fourier transform, Z- transform, Solutions of difference equations using Z Transform. **15 Lectures**

Seminars, Tutorials, Problem solving session and group discussions on above four units

Recommended Book:

1. Larry Andrews, Bhimsen Shivamoggi, Integral Transforms for Engineers, Prentice Hall of India, New Delhi, 2005.

Reference Books:

1. Lokenath Debnath & Damba Bhatta, Integral Fransforms and their applicaton (2nd Ed), Chapman & Hall/CRC (2007).
2. I. N. Sneddon, Fourier Transforms, McGraw Hill, 1951.
3. Bracemell, Fourier Transforms and Its Applications, McGraw-Hill, 3rd Edition, 1999.

Nature of the Theory Question Papers:

1. There shall be 7 questions each carrying 16 marks
2. Question No.1 is compulsory. It consists of objective type questions.
3. Students have to attempt any four questions from Question No. 2 to Question No.7.
4. Question No.2 to Question No.7 shall consist of short/ descriptive-answer type sub-questions.