Rayat Shikshan Sanstha's

Karmaveer Bhaurao Patil College Vashi, Navi Mumbai

Autonomous College

[Affiliated to University of Mumbai]

Syllabus for Approval

Sr. No.	Heading	Particulars
1	Title of Course	M.Sc. I Mathematics (CBCS)
2	Eligibility for Admission	T.Y.B.Sc. (Mathematics), From a recognized university
3	Passing Marks	40%
4	Ordinances/Regulations (if any)	
5	No. of Years/Semesters	One year/Two semester
6	Level	P.G.
7	Pattern	Semester
8	Status	New
9	To be implemented from Academic year	2021-2022

AC- 25 /10 /2021

Item No-8.5

Rayat Shikshan Sanstha's

KARMAVEER BHAURAO PATIL COLLEGE, VASHI.

NAVI MUMBAI

(AUTONOMOUS COLLEGE)

Sector-15- A, Vashi, Navi Mumbai - 400 703

Syllabus for M.Sc. I Mathematics

Program: M.Sc.

Course: M.Sc. I Mathematics

(Choice Based Credit System
with effect from the academic year 2021-2022)

Preamble of the Syllabus:

Master of Science (M.Sc.) in Mathematics is a post-graduation programme of Department of Mathematics, Karmaveer Bhaurao Patil College Vashi, Navi Mumbai [Autonomous College]

The Choice Based Credit System to be implemented through this curriculum, would allow students to develop a strong footing in the fundamentals and specialize in the disciplines of his/her liking and abilities. The students pursuing this course would have to develop understanding of various aspects of the mathematics. The conceptual understanding, development of experimental skills, developing the aptitude for academic and professional skills, acquiring basic concepts and understanding of hyphenated techniques are among such important aspects.

Rayat Shikshan Sanstha's

KARMAVEER BHAURAO PATIL COLLEGE, VASHI, NAVI MUMBAI

(Autonomous)

Department of Mathematics

M. Sc. Mathematics

Program Outcomes (POs)

Learners are able to:

PO-1	**Disciplinary Knowledge and Skills**	Acquire the comprehensive and in-depth knowledge of various subjects in sciences such as Physics, Chemistry, Mathematics, Microbiology, Bio-analytical Science, Computer Science, Data Science, Information Technology and disciplinary skills and ability to apply these skills in the field of science, technology and its allied branches.
PO-2	**Communication and Presentation Skills**	Develop various communication skills including presentation to express ideas evidently to achieve common goals of the organization.
PO-3	**Creativity and Critical Judgement**	Facilitate solutions to current issues based on investigations, evaluation and justification using evidence-based approach.
PO-4	**Analytical Reasoning and Problem Solving**	Build critical and analytical attitude in handling the problems and situations.
PO-5	**Sense of Inquiry**	Curiously raise relevant questions based on highly developed ideas, scientific theories and its applications including research.

PO-6	**Use of Modern Tools**	Use various digital technologies to explore information/data for business, scientific research and related purposes.
PO-7	**Research Skills**	Construct, collect, investigates, evaluate and interpret information/data relevant to science and technology to adapt, evolve and shape the future.
PO-8	**Application of Knowledge**	Develop scientific outlook to create consciousness against the social myths and blind faith.
PO-9	**Moral and Ethical Reasoning**	Imbibe ethical, moral and social values to develop virtues such as justice, generosity and charity as beneficial to individuals and society at large.
PO-10	**Leadership and Teamwork**	Work cooperatively and lead proactively to achieve the goals of the organization by implementing the plans and projects in various field-based situations related to science, technology and society at large.
PO-11	**Environment and Sustainability**	Create social awareness about environment and develop sustainability for betterment of future.
PO-12	**Lifelong Learning**	Realize that pursuit of knowledge is a lifelong activity and in combination with determined efforts, positive attitude and other qualities to lead a successful life.

Program Specific Outcomes (PSO)

PSO1	Recalling the concepts of mathematics and applying them to the various courses like algebra, analysis, Differential equations, statistics, etc to form mathematical models.
PSO2	Apply Mathematics to interdisciplinary ways like statistician, mathematical finance, industry expertise and interpret quantitative ideas.
PSO3	Apply knowledge of Mathematics for research and engineering.

[AUTONOMOUS COLLEGE]

Department of Mathematics

M.Sc. Mathematics

Choice Based Credit System (CBCS)

Programme	**SEM**	**Core Course (CC)** (6 credits per course)	**Discipline Specific Elective (DSE)** (6 credits per course)	**SEC** (4 credits per course)
MSC-I Mathematics	I	Algebra-I Analysis-I Complex Analysis	Discrete Mathematics **Or** Elementary Probability Theory and Statistics	Introduction to R Programming-I
	II	Algebra-II Topology Research Methodology	Differential Equation **Or** Optimization Techniques	Introduction to R Programming-II
MSC-II Mathematics	III	Algebra-III Analysis-II Differential Geometry	Numerical Methods **Or** Graph Theory **Or** Design Theory	Integral Transform
	IV	Field Theory Functional Analysis Partial Differential Equations	Fourier Analysis **Or** Mathematical Modelling **Or** Calculus on Manifolds	Project

CC: Core Course (these courses are compulsory to the students),

DSE: Discipline Specific Elective (Students can choose anyone)

SEC: Skill Enhanced Course (Compulsory Skill Based Course)

Credits: Part-I (28+28), Part-II (28+28), Total Credits: 112

Teaching - Evaluation Scheme

Semester-I

Course Code	Course Name	Teaching Scheme (Hours/Week)			Examination Scheme and Marks						Credit Scheme			
		Lecture	Practical	Tutorial	CIE	Sem End-Exam	Term work	Practical		Total	Lecture	Practical	Tutorial	Total
PGMT101	Algebra-I	06	-	-	40	60	-	-	-	100	06	-	-	06
PGMT102	Analysis-I	06	-	-	40	60	-	-	-	100	06	-	-	06
PGMT103	Complex Analysis	06	-	-	40	60	-	-	-	100	06	-	-	06
PGMT104A Or PGMT104B	Discrete Mathematics **Or** Elementary Probability Theory and Statistics	06	-	-	40	60	-	-	-	100	06	-	-	06
PGMT105	Introduction to R Programming-I	03	01	-	40	60	-	-	-	100	04	-	-	04
	Total	**27**	**01**	**-**	**200**	**300**	**-**	**-**	**-**	**500**	**28**	**-**	**-**	**28**
										Total Credit	**28**	**-**	**-**	**28**

Semester-II

Course Code	Course Name	Teaching Scheme (Hours/Week)			Examination Scheme and Marks						Credit Scheme			
		Lecture	Practical	Tutorial	CIE	Sem End-Exam	Term work	Practical		Total	Lectu	Practical	Tutori	Total

											re		al	
PGMT201	Calculus-II	06	-	-	40	60	-	-	-	100	06	-	-	06
PGMT202	Algebra-II	06	-	-	40	60	-	-	-	100	06	-	-	06
PGMT203	Topology	06	-	-	40	60	-	-	-	100	06	-	-	06
PGMT204A Or PGMT204A	Differential Equations Or Optimization Techniques	06	-	-	40	60	-	-	-	100	06	-	-	06
PGMT205	Introduction to R Programming-II	03	01	-	40	60	-	-	-	100	04	-	-	04
Total		**27**	**01**	**-**	**200**	**300**	**-**	**-**	**-**	**500**	**28**	**-**	**-**	**28**
Total Credit											**28**	**-**	**-**	**28**

COURSE STUCTURE FOR M.Sc. I MATHEMATICS

SEMESTER I

	Course Code	Unit	Topic	Credit	L/W
CORE COURSE	**Algebra I**				
	PGMT101	I	Dual spaces	6	6
		II	Homogeneous Linear Differential Equations with Constant Coefficients and Determinants		
		III	Invariant Subspaces		
		IV	Bilinear forms		
CORE COURSE	**Analysis I**				
	PGMT102	I	Euclidean space R^n	6	6
		II	Riemann integration		

		III	Differentiable functions		
		IV	Inverse function theorem, Implicit		
CORE COURSE	**Complex Analysis**				
	PGMT103	I	Holomorphic functions	6	6
		II	Contour integration, Cauchy-Goursat theorem		
		III	Holomorphic functions and their properties		
		IV	Singularities, Conformal Mappings and multivalued Functions		
DISIPLINE SPECIFIC ELECTIVE (DSE-A)	**Discrete Mathematics**				
	PGMT104 A	I	Number Theory	6	6
		II	Advanced Counting		
		III	Recurrence relations		
		IV	Polya's theory of counting		
DISIPLINE SPECIFIC ELECTIVE (DSE-B)	**Elementary probability Theory and Statistics**				
	PGMT104 B	I	Basics of Probability	6	6
		II	Probability measure		
		III	Random variables		
		IV	Statistics		
SKILL ENHANCEMENT COURSE (SEC)	**Introduction to R Programming-I**				
	PGMT105	I	Introduction to R	4	4
		II	R Function		
		III	Data Frames		
		IV	Practical		

SEMESTER II

	Course Code	Unit	Topic	Credit	L/W

CORE COURSE	**Algebra II**				
	PGMT201	I	Groups, group homomorphisms	6	6
		II	Groups acting on sets and Sylow's theorems		
		III	Rings, Fields		
		IV	Divisibility in integral domains, finite fields		
CORE COURSE	**Topology**				
	PGMT202	I	Topological spaces	6	6
		II	Connected and Compact topological spaces		
		III	Countability and Separation Axioms		
		IV	Complete metric spaces		
CORE COURSE	**Research Methodology**				
	PGMT203	I	Fundamentals of Research	6	6
		II	Data Collection		
		III	Data Analysis and Reporting		
		IV	Intellectual Property Rights		
DISIPLINE SPECIFIC ELECTIVE (DSE-A)	**Differential Equations**				
	PGMT204 A	I	Picard's theorem	6	6
		II	Linear Ordinary Differential Equations		
		III	Series solutions and Sturm Liouville's theory		
		IV	Fourier series		

DISIPLINE SPECIFIC ELECTIVE (DSE-B)	**Optimization Techniques**				
	PGMT204 B	I	Linear Programming	6	6
		II	Unconstrained Optimization I		
		III	Unconstrained Optimization II		
		IV	Constrained Optimization Problems		
SKILL ENHANCEMENT COURSE(SEC)	**Introduction to R Programming-II**				
	PGMT205	I	Loading and handling Data in R	4	4
		II	Descriptive Statistic		
		III	Machine Learning		
		IV	Practical-I		

Note: 1. Blue Highlighted Topic / Course has focused on employability/ entrepreneurship/skill development

2. Yellow Highlighted Topic / Course is related to professional ethics, gender, human values, Environment & sustainability
3. Green Highlighted Topic / Course is related to local/national/regional & global development needs.

Teaching Pattern for Semester I and II:

1. Six lectures per week per course. Each lecture is of 60 minutes duration.
2. For SEC four lectures per week per course and practical sessions for 2Hrs. Each lecture is of 60 minutes duration.
3. In addition, there shall be tutorials, seminars as necessary for each of the five courses.

Objective:

1. Giving an adequate knowledge of basic with fundamental principles to understand the numerous powers of mathematical ideas and tools for modelling, solving and interpreting.

2. Developing analytical methods mathematical tools for continuing further study in various fields of science.

3. Enhancing students' overall development and to equip them with mathematical modeling abilities, problem solving skills, creative talent and power of communication necessary for various kinds of employment.

4. A student should get adequate exposure to global and local concerns that explore them many aspects
of Mathematical Sciences.

5. The main objective of this course is to introduce mathematics and statistics to students of science, so that they can use them in the field of commerce and industry to solve the real life problems.

SEMESTER I

PGMT101: ALGEBRA I

Course Outcome of Algebra I:
Students will be able to:

1. Define dual space and calculate the dual basis of a finite-dimensional vector space.
2. Explain the relation between matrices representing a linear transformation and its transpose.
3. Explain different operators like normal, self-adjoint, and symmetric operators.
4. Compute the Eigenvalue and Eigenvectors and minimal polynomial of a matrix.
5. Compute Jordan Canonical form of a matrix.

(All Results have to be done with proof unless otherwise stated).

Unit I. Dual spaces (15 Lectures)

(Review) Vector spaces over a field, linear independence, basis and dimension, infinite dimensional vector spaces. Linear transformations, kernel and image, relationship of linear transformations with matrices, invertible linear transformations, rank-nullity theorem (for finite dimensional vector spaces), application: characterization of an isomorphism from a finite-dimensional vector space to itself. (No question be asked)

Dual spaces of a vector space, dual basis (for finite dimensional vector spaces), Double dual V^{**} of a Vector space V and canonical embedding of V into V^{**}. Isomorphism of V and its double dual in the

finite-dimensional case. Transpose T^t of a linear transformation T, relation between matrices representing T and T^t.

Unit II. Determinants, Eigen values and Eigenvectors (15 Lectures)

Determinants as an alternating multilinear map, existence and uniqueness, Laplace expansion of determinant, determinants of products and transposes, determinants and invertible linear transformations, determinant of a linear transformation.

Eigen values and Eigen vectors, Characteristic polynomial, Minimal polynomial, Triangulable and diagonalizable linear operators. Matrix limits and Markov chains. Application of Stochastic Matrices: Google Page Rank Algorithm

Unit III. Invariant Subspaces and Applications (15 Lectures)

Invariant subspaces and Cayley-Hamilton theorem. Nilpotent linear transformations on finite dimensional vector spaces, computations of Minimum polynomials and Jordan Canonical Forms for nilpotent matrices, Jordan canonical forms in general through examples.

The derivative operator on C^∞, the space of infinitely differentiable functions, polynomial operators, solution space as a subspace of C^∞, Solution to an equation of order 1, the general case and connection with the auxiliary polynomial.

Application of Jordan Canonical Form in solving system of linear differentiable equations.

Unit IV: Bilinear forms (15 Lectures)

(Review) Inner product spaces, orthonormal basis. (No question be asked)
Adjoint of a linear operator, normal and self-adjoint operators, unitary operators and orthogonal operators and their matrices, orthogonal projections and the spectral theorem.
Applications: Singular Value Decomposition. Bilinear and quadratic forms, Sylvester's Law.
Least squares method as an application of orthogonal projection. Application of SVD to least square solutions and Image Compression.

Recommended Text Books:

1. S.H.Friedberg, A. J. Insel, L.E.Spence: Linear Algebra, 4th Ed. Prentice-Hall.
2. S. Kumaresan: Linear Algebra, a Geometric Approach, Prentice-Hall.
3. David Lay: Linear Algebra and Applications.
4. Gilbert Strang: Introduction to Linear Algebra, Wellesley-Cambridge Pres.
5. Steven G. Krantz: Jordan Canonical Form Theory and Practice.
6. Serge Lang: Linear Algebra, Springer-Verlag Undergraduate Text in Mathematics.

PGMT101 - Algebra I

Course Outcomes: After successful completion of this course, students will be able to:

CO-1: Define dual space and calculate the dual basis of a finite dimensional vector space.

CO-2: Explain the relation between matrices representing a linear transformation and its transpose.

CO-3: Explain different operators like normal, self-adjoint and symmetric operators.

CO4: Compute the Eigenvalue and Eigenvectors and minimal polynomials of a matrix.

CO5: Compute Jordan Canonical form of a matrix.

ICT Tools Used: Videos, PPT, Pen-Tablet

Students Centric Methods: Problem Solving and Participative
(Experimental, Participative, Problem Solving)

Links: SWAYAM / MOOCS:

1. https://onlinecourses.nptel.ac.in/noc20_ma34/preview
2. https://onlinecourses.nptel.ac.in/noc19_ma23/preview
3. https://onlinecourses.nptel.ac.in/noc21_ma50/preview

The CO-PO Mapping Matrix

CO\PO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	1	-	-	1	-	-	-	-	-	-	-	-
CO2	1	1	-	1	-	-	-	-	-	-	-	-
CO3	2	1	-	1	-	-	-	-	-	-	-	-
CO4	3	-	-	2	-	-	-	-	-	-	-	-
CO5	1	-	-	2	-	-	-	-	-	-	-	-

***In CO-PO Mapping Matrix:** a correlation is established between COs and POs in the scale of 1 to 3, 1 being the slight (low), 2 being moderate (medium), 3 being substantial (high), and '-' indicate there is no correlation in respective CO and PO.

PGMT102: ANALYSIS I

Course Outcome of Analysis I:

Students will be able to:

1. Recall Inner product space, norm linear space and vector space.
2. Distinguish among open and closed sets on different topologies of R^n.
3. Determine whether a function is Riemann integrable using definition and Riemann criteria.
4. List the results on total derivative.
5. Compare Taylor's theorem for one and more variables.
6. Apply second derivative to find maxima and minima of a differentiable functions.

Unit I. Euclidean space R^n (15 Lectures)

Euclidean space R^n : inner product $\langle x, y\rangle = \sum_{j=1}^{n} xjyj$ of $x = (x_1, x_2, \dots \dots x_n)$ $y = (y_1, y_2, \dots \dots y_n) \in R^n$
and properties, norm $\|x\| = \sqrt{\sum_{j=1}^{n} x_j^2}$ of $x = (x_1, x_2, \dots \dots x_n) \in R^n$, Cauchy-Schwarz inequality, properties of the norm function $\|x\|$ of R^n (ref: [4] W. Rudin or [5] M. Spivak)

Standard topology on R^n: open subsets of R^n, closed subsets of R^n, interior A^0 and boundary ∂A of a subset A of R^n: (ref: [5] M. Spivak)

Operator norm $\|T\|$of a linear transformation T : $R^n \to R^m$ ($\|T\| = sup\{\|T(v)\|: v \in R^n \ \& \ \|v\| \leq 1\}$) and its properties such as: For all linear maps S, T : $R^n \to R^m$ and R : $R^m \to R^k$

1. $\|S + T\| \leq \ \|S\| + \|T\|$

2. $\|RoS\| \leq \ \|R\|\|S\|$

3. $\|cT\| = |c|\|T\|, c \in R$

(Ref: [1] C.C. Pugh or [2] A. Browder)
Compactness: Open cover of a subset of R^n, Compact subsets of R^n (A subset K of R^n is compact if every open cover of K contains a finite subcover), Heine-Borel theorem (statement only), the Cartesian product of two compact subsets of R^n is compact (statement only), every closed and bounded subset of R^n is compact. Bolzano-Weierstrass theorem: Any bounded sequence in R^n has a converging subsequence.

Brief review of following three topics:

1. Functions and Continuity: Notation: A $\subset R^n$ arbitrary non-empty set. A function $f: A \to R^m$ and its component functions, continuity of a function ($\in -\delta$; definition). A function $f: A \to R^m$ is continuous if and only if for every open subset V$\subset R^m$there is an open subset U of R^n such that $f^{-1}(V) = A \cap U$.
2. Continuity and compactness: Let K$\subset R^n$ be a compact subset and f: K$\to R^m$ be any continuous function. Then f is uniformly continuous, and f(K) is a compact subset of R^m
3. Continuity and connectedness: Connected subsets of are intervals. If f:E$\to R$ is continuous where E$\subset$ R^n and E is connected , then f(E) $\subset R$ is connected.

Unit II: Riemann Integration (15 Lectures)

Riemann Integration over a rectangle in R^n ; Riemann Integrable functions, Continuous functions are Riemann integrable, Measure zero sets, Lebesgues Theorem (statement only), Fubini's Theorem and applications.
Reference for Unit II: M. Spivak, Calculus on Manifolds.

Unit III: Differentiable functions (15 Lectures)
Differentiable functions on R^n, the total derivative $(Df)_p$ of a differentiable function f : U$\to R^m$ at p $\in$ U where U is open inR^n; uniqueness of total derivative, differentiability implies continuity. (ref: [1] C.C. Pugh or [2] A. Browder)

Chain rule, Applications of chain rule such as:

1. Let γ be a differentiable curve in an open subset U of R^n: Let f : U U$\to R$ be a differentiable function and let g(t) = f(γ (t)). Then g′(t) = $\langle(\nabla f(\gamma(t), \gamma'(t)\rangle$.
2. Computation of total derivatives of real valued functions such as
   (a) the determinant function det(X), X $\in M_n(R)$.
   (b) the Euclidean inner product function $\langle x, y\rangle$, (x, y) $\in R^n \times R^n$

(ref: [5] M. Spivak & [4] W. Rudin)

Results on total derivative:

1. If f : $R^n \to R^m$ is a constant function, then $(Df)_p = 0 \ \forall \ p \in R^n$
2. If f : $R^n \to R^m$ is a linear map, then $(Df)_p = f \ \forall \ p \in R^n$
3. A function $f = (f_1, f_2, \ldots, f_m) : R^n \to R^m$ is differentiable at $p \in R^n$ if and only if each f_j is differentiable at $p \in R^n$; and $(Df)_p = ((Df_1)_p, (Df_2)_p, \ldots, (Df_m)_p)$.

(ref: [5] M. Spivak)

Partial derivatives, directional derivative $(D_u f)(p)$ of a function f at p in the direction of the unit vector, Jacobian matrix, Jacobian determinant. Results:

1. If the total derivative of a map $f = (f_1, \ldots, f_m) : U \to R^m$ (U open subset of R^n) exists at $p \in U$; then all the partial derivatives $\frac{\partial f_j}{\partial x_j}$ exist at p
2. If all the partial derivatives $\frac{\partial f_j}{\partial x_j}$ of a map $f = (f_1, f_2, \ldots, f_m) : U \to R^m$ (U open subset of R^n) exist and are continuous on U, then f is differentiable. (ref:[4] W. Rudin)

Derivatives of higher order, C^k-functions, C^∞-functions. (ref: [3] T. Apostol)

Unit IV: Inverse function theorem, Implicit function theorem (15 Lectures)

Theorem (Mean Value Inequality): Suppose $f : U \to R^m$ is differentiable on an open subset U of R^n and there is a real number such that $\|(Df)_x\| \leq M \ \forall \ x \in U$. If the segment [p, q] is contained in U; then $\|f(q) - f(p)\| \leq M\|q - p\|$ (ref: [1] C.C. Pugh or [2] A. Browder)

Mean Value Theorem: Let $f : U \to R^m$ is differentiable on an open subset U of R^n. Let $p, q \in U$ such that the segment [p; q] is contained in U. Then for every vector $v \in R^n$ there is a point $x \in [p, q]$ such that $\langle v, f(q) - f(p)\rangle = \langle v, (Df)_x(q - p))\rangle$. (ref: [3] T. Apostol)

If $f : U \to R^m$ is differentiable on a connected open subset U of R^n and $(Df)_x = 0 \ \forall \ x \in U$, then f is a constant map.

Taylor expansion for a real valued C^m-function defined on an open subset of R^n, stationary points (critical points), maxima, minima, saddle points, second derivative test for extrema at a stationary point of a real valued C^2-function defined on an open subset of R^n. (ref: [3] T. Apostol)

Contraction mapping theorem. Inverse function theorem , Implicit function theorem. (ref: [2] A. Browder)

Recommended Text Books

1. C.C. Pugh: Real mathematical analysis, Springer UTM.
2. A. Browder: Mathematical Analysis, An Introduction, Springer.
3. T. Apostol: Mathematical Analysis, Narosa.
4. W. Rudin: Principles of Mathematical Analysis, Mcgraw-Hill India.
5. M. Spivak: Calculus on Manifolds, Harper-Collins Publishers.

PGMT102- Analysis I

Course Outcomes: After successful completion of this course, students will be able to:

CO-1: Recall Inner product space, norm linear space and vector space.

CO-2: Distinguish among open and closed sets on different topologies of R^n.

CO-3: Determine whether a function is Riemann integrable using definition and Riemann criteria.

CO4: Demonstrate a working knowledge of Taylor's theorem, mean value inequality and mean value theorem.

CO5: Find stationary points, saddle points, maxima and minima of a differentiable function by applying a second derivative test.

ICT Tools Used: Videos, PPT, Pen-Tablet

Students Centric Methods: Problem Solving and Participative
(Experimental, Participative, Problem Solving)

Links: SWAYAM / MOOCS:

1) Basic Calculus-1 - Course https://onlinecourses.nptel.ac.in/noc20_ma34/preview
2) Basic real analysis - Course https://onlinecourses.nptel.ac.in/noc19_ma23/preview
3) Multivariable calculus - Course https://onlinecourses.nptel.ac.in/noc21_ma50/preview

The CO-PO Mapping Matrix

CO\PO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	3	-	-		-	-	-	-	-	-	-	-
CO2	-	-	2	1	-	-	-	-	-	-	-	-
CO3	-	-	1	2	-	-	-	-	-	-	-	-
CO4	1	-	-	2	1	-	-	-	-	-	-	-
CO5	2	-	-	2	2	-	-	-	-	-	-	-

*In CO-PO Mapping Matrix: a correlation is established between COs and POs in the scale of 1 to 3, 1 being the slight (low), 2 being moderate (medium), 3 being substantial (high), and '-' indicate there is no correlation in respective CO and PO.

PGMT103: COMPLEX ANALYSIS

Course Outcome of Complex Analysis:

Students will be able to:

1. Represent complex numbers algebraically and geometrically.
2. Define and analyse limits and continuity for complex functions as well as consequences of continuity.
3. Apply the Cauchy-Riemann equations and results on harmonic and entire functions including the fundamental theorem of algebra.
4. Analyse sequences and series of analytic functions and types of convergence.
5. Evaluate complex contour integrals directly and by the fundamental theorem, apply the Cauchy integral theorem in its various versions.
6. Represent functions as Taylor, power and Laurent series, classify singularities and poles, find residues and evaluate complex integrals using the residue theorem.

Unit I: Holomorphic functions (15 Lectures)

Review: Complex Numbers, Geometry of the complex plane, Riemann sphere, Complex sequences and series, Sequences and series of functions in C , Weierstrass's M-test, Uniform convergence, (no questions be asked).

Complex differentiable functions, Cauchy-Riemann equations, A complex differentiable function defined on an open subset of C is called a Holomorphic function.

Ratio test and root test for convergence of a series of complex numbers. Complex Power series, radius of convergence of a power series, Cauchy-Hadamard formula for radius of convergence of a power series. Examples of convergent power series such as exponential series, cosine series and sine series, and the basic properties of the functions e^z, cos z, sin z.

Abel's theorem: Let $\sum_{n\geq 0} \quad a_n(z-z_0)^n$ be a power series, of radius of convergence R > 0. Then the function f defined by f(z) =$\sum \quad a_n(z-z_0)^n$ is holomorphic on the open ball $|z-z_0| < R$ and $f'(z) = \sum_{n\geq 1} \quad na_n(z-z_0)^{n-1} \; \forall |z-z_0| < R$.

Applications of Abel's theorem such as$exp'(z) = exp\, z,\ cos'(z) = -\sin z, sin'(z) = cos\, z$ $(z \in C)$

Chain Rule. A basic result: Let Ω_1, Ω_2 be open subsets of C. Suppose $f : \Omega_1 \to C$ is a Holomorphic function with $f'(z) \neq 0 \; \forall \; z \in \Omega_1$ and $g : \Omega_2 \to C$ be a continuous function such that $g(\Omega \quad _2) \subset \Omega_1$ and $f\big(g(w)\big) = w \; \forall \; w \in \Omega_2$. Then g is a holomorphic function on $\Omega_2$and $g'(w) = \frac{1}{f'(g(w))} \; \forall \; w \in \Omega_2$.

Unit II: Contour integration, Cauchy-Goursat theorem (15 Lectures)

Contour integration, Cauchy-Goursat Theorem for a rectangular region or a triangular region. Primitives. Existence of primitives: If f is Holomorphic on a disc U, then it has a primitive on U and the integral of f along any closed contour in U is 0. Local Cauchy's Formula for discs, Power series representation of Holomorphic functions, Cauchy's estimates, Cauchy's theorem (homotopy version)

Unit III: Holomorphic functions and their properties (15 Lectures)

Entire functions, Liouville's theorem, Morera's theorem, the Fundamental theorem of Algebra.

The index (winding number) of a closed curve, Cauchy integral formula. Zeros of Holomorphic functions, Identity theorem. Counting zeros; Open Mapping Theorem, Maximum modulus theorem.

Unit IV: Isolated singularities, Conformal Mappings and multivalved Functions (15 Lectures)

Isolated singularities: removable singularities and Removable singularity theorem, poles and essential singularities. Laurent Series development. Casorati-Weierstrass's theorem

Residue Theorem and evaluation of standard types of integrals by the residue calculus method.

Conformal mappings. If $f : G \to C$ is a holomorphic function on the open subset G of C and $f'(z) \neq 0 \; \forall \; z \in G$. then f is a conformal map. Mobius transformations (fractional linear transformation or linear transformation). Any Mobius transformation which fixes three distinct points is necessarily the identity map. Cross ratio (z_1, z_2, z_3, z_4) of four points z_1, z_2, z_3, z_4. Cross ratio (z_1, z_2, z_3, z_4) is real if and only if the four points z_1, z_2, z_3, z_4 lie on a circle.

Multivalved Functions: $\sqrt{Z}$, the logarithm as the inverse of exponential, branches of logarithm, the principal branch ln(z) of the logarithmic function on $C - \{z \in C : z \leq 0\}$ is a Holomorphic function and $ln'(z) = \frac{1}{z}$.

Recommended Text Books:

1. J. B. Conway, Functions of one Complex variable, Springer.
2. R. Remmert: Theory of complex functions, Springer.
3. A. R. Shastri: An introduction to complex analysis, Macmillan.
4. J. W. Brown and R. V. Churchill : Complex variables and applications
5. L. V. Ahlfors: Complex analysis, McGraw Hill .
6. Donold Sarason: Notes on Complex function theory, Hindustan book agency
7. Steven Krantz: Complex analysis: The geometric view point, second edition, carus mathematical monographs.
8. Introduction to Complex Analysis, Kumarsenan.

PGMT103 - Complex Analysis

Course Outcomes: After successful completion of this course, students will be able to:

CO-1 : Represent complex numbers algebraically and geometrically.

CO-2 : Define and analyze limits, continuity for complex functions as well as consequences of continuity.

CO-3 : Apply the Cauchy-Riemann equations and results on harmonic and entire functions including the fundamental theorem of algebra.

CO-4 : Analyze sequences and series of analytic functions and types of convergence.

CO-5 : Evaluate complex contour integrals directly and by the fundamental theorem, apply the Cauchy integral theorem in its various versions.

CO-6 : Represent functions as Taylor, power and Laurent series, classify singularities and poles, find residues and evaluate complex integrals using the residue theorem.

ICT Tools Used: Videos, PPT, Pen-Tablet

Students Centric Methods: Problem Solving and Participative (Experimental, Participative, problem Solving)

Links: SWAYAM / MOOCS:

1. NOC:Complex Analysis https://nptel.ac.in/courses/111/106/111106141/
2. Complex Analysis https://nptel.ac.in/courses/111/107/111107056/
3. Advanced Complex Analysis https://nptel.ac.in/courses/111/106/111106084/

The CO-PO Mapping Matrix

CO\PO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	1	1	-		-	-	-	-	-	-	-	-
CO2	1	-	-	2	-	-	-	-	-	-	-	-
CO3	1	-	2	3	1	-	-	-	-	-	-	-
CO4	2	-	-	2	-	-	-	-	-	-	-	-
CO5	1	-	2	1	1	-	-	-	-	-	-	-
CO6	1	1	2	-	-	-	-	-	-	-	-	-

*In CO-PO Mapping Matrix: a correlation is established between COs and POs in the scale of 1 to 3, 1 being the slight (low), 2 being moderate (medium), 3 being substantial (high), and '-' indicate there is no correlation in respective CO and PO.

PGMT 104 A: DISCRETE MATHEMATICS

Course Outcome of Discrete Mathematics:
Students will be able to:

1. Solve discrete mathematics problems that involve computing permutations and combinations of a set.
2. Explain Polya's theory of counting, Orbit stabilizer theorem, Burnside lemma and its applications, applications of Polya's formula.
3. Apply the knowledge of Number theory to attain specific maturity.
4. Apply fundamental enumeration principles to solve appropriate problems.

Unit I. Number theory (15 Lectures)
Divisibility, Linear Diophantine equations, Cardano's Method, Congruences, Quadratic residues, Arithmetic functions,
Types of occupancy problems, distribution of distinguishable and indistinguishable objects into distinguishable and indistinguishable boxes (with condition on distribution) Stirling numbers of second and first kind. Selections with Repetitions.

Unit II. Advanced counting (15 Lectures)
Pigeon-hole principle, generalized pigeon-hole principle and its applications, Erdos- Szekers theorem on monotone subsequences, A theorem of Ramsey. Inclusion-Exclusion Principle and its applications. Derangement. Permutations with Forbidden Positions, Restricted Positions and Rook Polynomials.

Unit III. Recurrence Relations (15 Lectures)
The Fibonacci sequence, Linear homogeneous recurrence relations with constant coefficient. Proof of the solution in case of distinct roots and statement of the theorem giving a general solution (in case of repeated roots), Iteration and Induction. Ordinary generating Functions, Exponential Generating Functions, algebraic manipulations with power series, generating functions for counting combinations with and without repetitions, exponential generating function for bell numbers, applications to counting, use of generating functions for solving recurrence relations.

Unit IV. Polyas Theory of counting (15 Lectures)
Equivalence relations and orbits under a permutation group action. Orbit stabiliser theorem, Burnside Lemma and its applications, Cycle index, Polyas Formula, Applications of Polyas Formula.

Recommended Text Books

1. D. M. Burton, Introduction to Number Theory, McGraw-Hill.
2. Nadkarni and Telang, Introduction to Number Theory
3. V. Krishnamurthy:Combinatorics: Theory and applications, A liated East-West Press.
4. Richard A. Brualdi: Introductory Combinatorics, Pearson.
5. A. Tucker: Applied Combinatorics, John Wiley & Sons.
6. Norman L. Biggs: Discrete Mathematics, Oxford University Press.
7. Kenneth Rosen: Discrete Mathematics and its applications, Tata McGraw Hills.
8. Sharad S. Sane, Combinatorial Techniques, Hindustan Book Agency, 2013.

PGMT104A - Discrete Mathematics

Course Outcomes: After successful completion of this course, students will be able to:

CO-1: Solve discrete mathematics problems that involve computing permutations and combinations of a set.

CO-2: Explain Polya's theory of counting, Orbit stabilizer theorem, Burnside lemma and its applications, applications of Polya's formula.

CO-3: Apply the knowledge of Number theory to attain specific maturity.

CO4: Apply fundamental enumeration principles to solve appropriate problems.

ICT Tools Used: Videos, PPT, Pen-Tablet

Students Centric Methods: Problem Solving and Participative (Experimental, Participative, Problem Solving)

Links: SWAYAM / MOOCS:

Mathematics - Discrete Mathematics https://nptel.ac.in/courses/111/107/111107058/

Mathematics - Number Theory https://nptel.ac.in/courses/111/103/111103020/

The CO-PO Mapping Matrix

CO\PO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	1	-	-	2	-	-	-	-	-	-	-	-
CO2	1	1	-	1	-	-	-	-	-	-	-	-
CO3	2	-	-	2	-	-	-	-	-	-	-	-
CO4	1	-	1	3	-	-	-	-	-	-	-	-

*In CO-PO Mapping Matrix: a correlation is established between COs and POs in the scale of 1 to 3, 1 being the slight (low), 2 being moderate (medium), 3 being substantial (high), and '-' indicate there is no correlation in respective CO and PO.

PGMT104 B: ELEMENTARY PROBABLITY THEORY AND STATISTICS

Course Outcome of Elementary Probability theory and Statistics:

Students will be able to:

1. Define the principle concepts about probability.
2. Express the concept of probability with the concept of random variable and the probability distributions.
3. Calculate the expected value and the moments.
4. Derive the probability density function of transformation of random variables.
5. Find basic theoretical and applied principles of statistics.

Unit I: Probability basics (15 Lectures)

Modelling Random Experiments: Introduction to probability, probability space, events.

Classical probability spaces: uniform probability measure, fields, finite fields, finitely additive probability, Inclusion-exclusion principle,σ - fields, σ - fields generated by a family of sets, σ- field of Borel sets, Limit superior and limit inferior for a sequence of events.

Unit II: Probability measure (15 Lectures)

Probability measure, Continuity of probabilities, First Borel-Cantelli lemma, Discussion of Lebesgue measure on σ - field of Borel subsets of assuming its existence, Discussion of Lebesgue integral for non-negative Borel functions assuming its construction.

Discrete and absolutely continuous probability measures, conditional probability, total probability formula, Bayes formula, Independent events.

Unit III. Random variables (15 Lectures)

Random variables, simple random variables, discrete and absolutely continuous random variables, distribution of a random variable, distribution function of a random variable, Bernoulli, Binomial, Poisson and Normal distributions, Independent random variables, Expectation and variance of random variables both discrete and absolutely continuous.

Unit IV. Statistics (15 Lectures)

Measures of central tendency, Measures of dispersion, Coefficient of variation, Moments, Skewness and Kurtosis, Curve fitting: fitting of straight line, parabola and related curves, Correlation and Regression, Reliability of Regression Estimates

Recommended Text Books:

1. M. Capinski, Tomasz Zastawniak: Probability Through Problems.
2. J. F. Rosenthal: A First Look at Rigorous Probability Theory, World Scientific.
3. Kai Lai Chung, Farid Ait Sahlia: Elementary Probability Theory, Springer Verlag.

PGMT104B - ELEMENTARY PROBABILITY THEORY AND STATISTICS

Course Outcomes: After successful completion of this course, students will be able to:

CO-1: Define the principle concepts about probability.

CO-2: Express the concept of probability with the concept of random variable and the probability distributions.

CO-3: Calculate the expected value and the moments.

CO4: Derive the probability density function of transformation of random variables.

CO5: Find basic theoretical and applied principles of statistics.

ICT Tools Used: Videos, PPT, Pen-Tablet

Students Centric Methods: Problem Solving and Participative (Experimental, Participative, Problem Solving)

Links: SWAYAM / MOOCS:

1. https://nptel.ac.in/courses/111/105/111105090/
2. https://nptel.ac.in/courses/111/105/111105041/

The CO-PO Mapping Matrix												
CO\PO	**PO1**	**PO2**	**PO3**	**PO4**	**PO5**	**PO6**	**PO7**	**PO8**	**PO9**	**PO10**	**PO11**	**PO12**
CO1	1	-	-	-	-	-	-	-	-	-	-	-
CO2	1	1	-	1	-	-	-	-	-	-	-	-
CO3	1	-	2	2	-	-	-	-	-	-	-	-
CO4	1	-	1	3	-	-	-	-	-	-	-	-
CO5	1	-	2	2	-	-	-	-	-	-	-	-

*In CO-PO Mapping Matrix: a correlation is established between COs and POs in the scale of 1 to 3, 1 being the slight (low), 2 being moderate (medium), 3 being substantial (high), and '-' indicate there is no correlation in respective CO and PO.

PGMT105: INTRODUCTION TO R PROGRAMMING -I

(Theory & Practical: 30 Lectures; Practicals:30 Hrs **)**

COURSE OBJECTIVES:

1. Study of fundamentals of R.
2. Use different functions, variables and operators in R
3. Write and execute programming in R by using loop and string
4. Analysed and visualized mathematical statistical functions using R.

UNIT I. Introduction to R: What is R? Advantages of R over Other Programming Languages - **R Studio:** R command Prompt, R script file, comments – **Handling Packages in R:** Installing a R Package, Few commands to get started: installed. packages(), packageDescription(), help(), find.package(), library() - Input and Output – Entering Data from keyboard – Printing fewer digits or more digits – Special Values functions : NA, Inf and –inf. **R Data Types:** Vectors, Lists, Matrices, Arrays, Factors, Data Frame. **R-Variables:** Variable assignment, Data types of Variable, Finding Variable ls(), Deleting Variables - **R Operators:** Arithmetic Operators, Relational Operators, Logical Operator, Assignment Operators, Miscellaneous Operators - **R Decision Making:** if statement, if – else statement, if – else if statement, switch statement – **R Loops:** repeat loop, while loop, for loop - Loop control statement: break statement, next statement.

UNIT II. R-Function: function definition, Built in functions: mean(), paste(), sum(), min(), max(), seq(), user-defined function, calling a function, calling a function without an argument, calling a function with argument values. **R-Strings** – Manipulating Text in Data: substr(), strsplit(), paste(), grep(), toupper(), tolower(), **R Vectors** – Sequence vector, rep function, vector access, vector names, vector math, vector recycling, vector element sorting - **R List** Creating a List, List Tags and Values, Add/Delete Element to or from a List, Size of List, Merging Lists, Converting List to Vector - **R**

Matrices – Accessing Elements of a Matrix, Matrix Computations: Addition, subtraction, Multiplication and Division- **R Arrays:** Naming Columns and Rows, Accessing Array Elements, Manipulating Array Elements, Calculation Across Array Elements - **R Factors** –creating factors, generating factor levels gl().

UNIT III. Data Frames –Create Data Frame, Data Frame Access, Understanding Data in Data Frames: dim(), nrow(), ncol(), str(), Summary(), names(), head(), tail(), edit() functions - Extract Data from Data Frame, Expand Data Frame: Add Column, Add Row - Joining columns and rows in a Data frame rbind() and cbind() – Merging Data frames merge() – Melting and Casting data melt(), cast().

Unit-IV. Practical (Lab Sessions)

Recommended Text Books:

1. Sandip Rakshit, R Programming for Beginners, McGraw Hill Education (India), 2017, ISBN : 978-93-5260-455-5. 2. Seema Acharya, Data Analytics using R, McGrawHill Education (India), 2018, ISBN: 978-93-5260-524-8.
3.Hands-On Programming with R, O'Reilly (Pub.)
4. Andrie de Vries, Joris Meys, R for Dummies A Wiley Brand, 2nd Edition, John Wiley and Sons, Inc, 2015, ISBN: 978-1-119-05580-8.
5. Tutorials Point (I) simply easy learning, Online Tutorial Library (2018), R Programming, Retrieved from https://www.tutorialspoint.com/r/r_tutorial.pdf.
6. https://nptel.ac.in/courses/111/104/111104100/

PGMT105: INTRODUCTION TO R PROGRAMMING -I

Course Outcomes: After successful completion of this course, students will be able to:

CO-1: Study of fundamentals of R.

CO-2: Use different functions, variables and operators in R

CO-3: Write and execute programming in R by using loop and string

CO-4: Analysed and visualized mathematical statistical functions using R.

ICT Tools Used: Videos, PPT, Pen-Tablet

Students Centric Methods: Problem Solving and Participative
(Experimental, Participative, Problem Solving)

Links: SWAYAM / MOOCS:

1. https://nptel.ac.in/courses/111/104/111104100/
2. https://nptel.ac.in/courses/111/104/111104120/
3. https://nptel.ac.in/courses/111/104/111104146/

The CO-PO Mapping Matrix

CO\PO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	3	-	-	1	-	1	-	-	-	-	-	-

CO2	2	-	-	1	-	2	-	-	-	-	-	-
CO3	2	1	1	-	-	1	-	-	-	-	-	-
CO4	1	-	-	2	-	-	-	1	-	-	-	-

SEMESTER II

PGMT201: ALGEBRA II

(All results have to be done with proof unless otherwise stated.)

Course Outcome of Algebra-II:
Students will be able to:

1. Understand the concept of group homomorphism, isomorphism and automorphism and apply it for constructing groups.
2. Analyze Class equation, Sylow's theorems and apply them for describing structures of finite groups.
3. Demonstrate the knowledge of Rings, ideals of Rings and Quotient rings, Polynomial ring over field and its extension.
4. Learn Fundamental theorem of algebra, Burnside theorem and Kronecker's theorem and solve the problems.
5. Derive and apply Gauss Lemma, and Eisenstein criterion for irreducibility of Polynomials.
6. Demonstrate Field extensions and characterization of finite fields.

Unit I. Groups, group Homomorphisms (15 lectures)

Review: Groups, subgroups, normal subgroups, products of subgroups H and K, various cases depending on normality of H and K, center Z(G) of a group. Homomorphisms and kernels. Cyclic groups, Permutation groups, Dihedral groups, Matrix groups, the group of units U_n of Z_n, Lagrange's theorem. (No questions to be asked).

Quotient groups. First isomorphism theorem and examples: quotients of groups of non-zero complex numbers, $Gl_n(R)$, real numbers by integers. Second and third isomorphism theorems for groups, applications. Automorphisms of a group. Automorphisms of cyclic groups. Inner automorphisms of a group. Product of groups. Z_{mn} as a product, Structure theorem of abelian groups and applications.

Unit II. Groups acting on sets, Sylow theorems (15 lectures)

Center of a group, centralizer or normalizer of an element, conjugacy class C(a) of a in G.

Groups acting on sets, Examples: action of G on itself by conjugation, and by left multiplication on itself, and on the set of the left cosets of a subgroup. Centralizers, Normalizers, Orbits and Stabilizers, Cayley's Theorem, Class equation, Cauchy's theorem, p-groups, Commutativity of groups of order p^2, centre of a group of order p^n, Sylow's theorems and applications. Groups of order 15, 6. Semi-direct products, groups of order 12. Classification of Groups of small orders. Burnside Counting as an application of group action.

Unit III. Rings, Fields (15 lectures)

Review: Rings (with unity), ideals, quotient rings, prime ideals, maximal ideals, ring homomorphisms, characteristic of a ring, isomorphism theorems for rings, relation between ideals in the ring and a quotient ring. Integral domains and their quotient fields. (no questions be asked).

Definition of field, characteristic of a field, subfields and prime subfields. Polynomial rings over a field F, irreducible polynomials over F. Prime, and maximal ideals in F[X], and their generators, unique factorization for polynomials over a field.

Definition of field extension, algebraic elements, minimal polynomial of an algebraic element, extension of a field obtained by adjoining one algebraic element. Kronecker's theorem, an application of Kronecker's theorem: Existence of a splitting field of a polynomial.

Unit IV. Divisibility in integral domains, finite fields (15 lectures)

Prime elements, irreducible elements, Unique Factorization Domains, Principle Ideal Domains, Gauss's lemma, Z, F[X] are UFD, irreducibility criterion, Eisenstein's criterion, Euclidean domains. Examples of: domain but not a UFD, UFD but not a PID, PID but not a Euclidean domain.

Finite integral domains are fields, Finite fields, order, existence of polynomials with no roots. Existence of a field of characteristic p with p^n elements for and prime p and positive integer n.

Recommended Text Books

1. Michael Artin: Algebra, Prentice-Hall India.
2. David Dummit, Richard Foote: Abstract Algebra, Wiley-India.
3. R.B.J.T. Allenby: Rings, Fields and Groups, An Introduction to Abstract Algebra, Elsevier (Indian edition).
4. J. B. Fraleigh, A first Course in Abstract Algebra, Narosa.
5. G. Santhanam, Algebra, Narosa.

PGMT201 - ALGEBRA II

Course Outcomes: After successful completion of this course, students will be able to:

CO-1 : Understand the concept of group homomorphism, isomorphism and automorphism and apply it for constructing groups.

CO-2 : Analyze Class equation, Sylow's theorems and apply them for describing structures of finite groups.

CO-3 : Demonstrate the knowledge of Rings, ideals of Rings and Quotient rings, Polynomial ring over field and its extension.

CO-4 : Learn Fundamental theorem of algebra, Burnside theorem and Kronecker's theorem and solve the problems.

CO-5 : Derive and apply Gauss Lemma, and Eisenstein criterion for irreducibility of Polynomials.

CO-6 : Demonstrate Field extensions and characterization of finite fields.

ICT Tools Used: Videos, PPT, Pen-Tablet

Students Centric Methods: Problem Solving and Participative (Experimental, Participative, Problem Solving)

Links: SWAYAM / MOOCS:

1.
2. NOC:Algebra II https://nptel.ac.in/courses/111/106/111106151/
3. Basic Algebraic Geometry https://nptel.ac.in/courses/111/106/111106097/

The CO-PO Mapping Matrix

CO\PO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	1	-	-	3	1	-	-	-	-	-	-	-
CO2	2	-	1	2	-	-	-	-	-	-	-	-

CO3	2	1	2	1	-	-	-	-	-	-	-	-
CO4	3	-	2	-	-	-	-	-	-	-	-	-
CO5	1	-	3	1	-	-	-	-	-	-	-	-
CO6	3	1	2	-	-	-	-	-	-	-	-	-

*In CO-PO Mapping Matrix: a correlation is established between COs and POs in the scale of 1 to 3, 1 being the slight (low), 2 being moderate (medium), 3 being substantial (high), and '-' indicate there is no correlation in respective CO and PO.

PGMT202: TOPOLOGY

Course Outcome of Topology:
Students will be able to:

1. Identify topologies and form a topological space using basis and sub-basis.
2. Define connected space and find its components and path components of a topological space.
3. Study of theorems on connectedness, compactness and completeness.
4. State the first, second countability and separable axioms. List the results based on first and second countability.
5. Apply metric space concept to compactness and completeness.

Unit I. Topological spaces (15 Lectures)
Topological spaces, basis, sub-basis, product topology (finite factors only), subspace topology, closure, interior, continuous functions, T_1, T_2 spaces, quotient topology.

Unit II. Connected and Compact topological spaces (15 Lectures)
Connected topological spaces, path-connected topological spaces, continuity and connectedness, Connected components of a topological space, Path components of a topological space.
Compact spaces, limit point compact spaces, continuity and compactness, tube lemma, compactness and product topology (finite factors only), local compactness, one point compactification.

Unit III. Countability and Separation Axioms (15 Lectures)
Countability Axioms, Separation Axioms, Separable spaces, Lindeloff spaces, Second countable spaces. A compact T_2 space is regular and normal space.

Unit IV. Complete metric spaces (15 Lectures)
Complete metric spaces, Completion of a metric space, total boundedness , compactness in Metric spaces, sequentially compact metric spaces, uniform continuity, Lebesgue covering lemma, Arzela-Ascoli theorem.

Recommended Text Books

1. James Munkres: Topology, Pearson.
2. George Simmons: Topology and Modern Analysis, Tata Mcgraw-Hill.
3. M.A.Armstrong: Basic Topology, Springer UTM.

4. K.D.Joshi: General Topology.

PGMT202– Topology

Course Outcomes: After successful completion of this course, students will be able to:

CO-1: Identify topologies and form a topological space using basis and sub-basis.

CO-2: Define connected space and find its components and path components of a topological space.

CO-3: Study of theorems on connectedness, compactness and completeness.

CO-4: State the first, second countability and separable axioms. List the results based on first and second countability.

CO-5: Apply metric space concept to compactness and completeness.

ICT Tools Used: Videos, PPT, Pen-Tablet

Students Centric Methods: Problem Solving and Participative
(Experimental, Participative, Problem Solving)

Links: SWAYAM / MOOCS:

1. https://nptel.ac.in/courses/111/106/111106054/#
2. https://nptel.ac.in/courses/111/106/111106053/#

The CO-PO Mapping Matrix

CO\PO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	3	-	-	-	-	-	-	-	-	-	-	-
CO2	2	2	-	1	-	-	-	-	-	-	-	-
CO3	2	-	-	-	-	-	1	1	-	-	-	-
CO4	3	-	2	-	-	-	-	-	-	-	-	-
CO5	-	-	-	-	-	-	-	-	-	-	-	-

*__In CO-PO Mapping Matrix:__ a correlation is established between COs and POs in the scale of 1 to 3, 1 being the slight (low), 2 being moderate (medium), 3 being substantial (high), and '-' indicate there is no correlation in respective CO and PO.

PGMT203: RESEARCH METHODOLOGY

Course Outcome of Research Methodology:
Students will be able to:

1. Understand fundamental concept of research and define appropriate hypothesis.
2. Collect data and apply different methods for sampling data
3. Analyse data and form report
4. Understand Intellectual Property Rights, patenting and copy right to develop research skill
5. Construct project research report

Unit –I: Fundamentals of Research Methodology

Introduction to Research Methodology: Meaning and objectives of research, Terminology, Features of a good research study, Ethics in research

Study designs: basic, applied, historical, exploratory, experimental, ex-post-facto, case study, diagnostic research, crossover design, case control design, cohort study design, multifactorial design.

Hypothesis: Meaning, significance and characteristics of hypothesis, Basic concepts concerning testing of hypotheses, Hypothesis development, Steps in formulation of hypothesis, Statistical hypothesis testing – type 1, type 2 errors, levels of significance

Unit – II: Data Collection

Experimental data collection: Types of data**,** Methods of primary data collection (observation, experimentation, questionnaire, schedules, interviewing, case, pilot study)**,** Methods of secondary data collection (internal, external)**,** Selection of appropriate method for data collection.

Sampling: Terminology, Need for sampling**,** Types of Sampling (probability sampling and non-probability sampling)

Variable: Dependent, Independent, Intervening, Moderator, Control variables, Extraneous variables.

Unit –III: Data Analysis and Reporting

Data processing and processing operations: Problems in processing, Elements of analysis in data processing, Software for data processing e.g. SPSS & SAS

Scientific writing and publishing: Report Writing, Writing a Research Paper, Writing a Review Article.

Unit –IV: Intellectual Property Rights

General Regime of Intellectual Property Rights: Concept of Property vis-à-vis Intellectual Property, Types of Intellectual Property- Origin and Development- An Overview, Intellectual Property Rights as Human Right, Role of International Institutions

Patent Law Introduction to Patent Law, Paris Convention, Patent Cooperation Treaty, WTO- TRIPS, Harmonization of CBD and TRIPs

Indian Patent Law: Patentable Subject Matter, Patentability Criteria, Procedure for Filing Patent Applications, Patent Granting Procedure, Revocation, Patent Infringement and Remedies Relevant Provisions of the Biological Diversity Act, 2002

Copyright and Neighbouring Rights: Introduction to Copyright, Conceptual Basis, International Protection of Copyright and Related rights- An Overview (International Convention/Treaties on Copyright), Indian Copyright Law

Trademarks Introduction to Trademarks, Need for Protection of Trademarks Kinds of Trademarks, International Legal Instruments on Trademarks, Indian Trademarks Law

Text & References:

1. Research Methodology: C.R. Kothari Second edition

2. http://linguistics.byu.edu/faculty/henrichsenl/ResearchMethods/RM_2_14.html
3. http://linguistics.byu.edu/faculty/henrichsenl/ResearchMethods/RM_2_14.html

PGMT203– RESEARCH METHODOLOGY

Course Outcomes: After successful completion of this course, students will be able to:

CO-1: Understand fundamental concept of research and define appropriate hypothesis.
CO-2: Collect data and apply different methods for sampling data
CO-3: Analyse data and form report
CO-4: Understand Intellectual Property Rights, patenting and copy right to develop research skill
CO-5: Construct project research report

ICT Tools Used: Videos, PPT, Sampling Data Analysis

Students Centric Methods: Problem Solving and Participative
(Experimental, Participative, Problem Solving)

Links: SWAYAM / MOOCS:

1. https://nptel.ac.in/courses/121/106/121106007/
2. https://nptel.ac.in/courses/107/108/107108011/
3. https://nptel.ac.in/courses/127/105/127105008/
4. https://nptel.ac.in/courses/110/105/110105139/

The CO-PO Mapping Matrix

CO\PO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	3	2	-	1	1	1	-	-	-	-	-	-
CO2	2	-	-	2	1	1	1	1	-	-	-	-
CO3	2	1	-	-	-	1	1	-	-	-	-	-
CO4	2	2	-	-	-	-	-	-	-	-	-	-
CO5	2	3	-	-	-	1	1	-	-	-	-	1

PGMT204A: DIFFERENTIAL EQUATIONS

Course Outcome of Differential Equation:

Students will be able to:

1. Apply Picard's method for finding solutions of first order differential equations.
2. Expresses the existence and uniqueness results for an n^{th}order linear Ordinary Differential Equations.
3. Apply the method of 'variation of parameters' to find solution of higher order linear differential equations with variable coefficients.
4. Define Fourier series and apply for periodic functions.
5. Construct Fourier analysis of daily life periodic functions.

Unit I. Picard's Theorem (15 Lectures)

Existence and Uniqueness of solutions to initial value problem of first order ODE- both autonomous, non-autonomous (Picard's Theorem), Approximations, system of first order Picard's scheme of successive linear ODE with constant coefficients and variable coefficients, reduction of an n-th order linear ODE to a system of first order ODE.

Unit II. Linear Ordinary Differential Equations (15 Lectures)

Existence and uniqueness results for an **n-th** order linear ODE with constant coefficients and variable coefficients, linear dependence and independence of solutions of a homogeneous n-th order linear ODE, Wronskian matrix, Lagrange's Method (variation of parameters), algebraic properties of the space of solutions of a non-homogeneous n-th order linear ODE.

Unit III. Series solutions and Sturm Liouville theory (15 Lectures)

Solutions in the form of power series for second order linear equations of Legendre and Bessel, Legendre polynomials, Bessel functions. Sturm- Liouville Theory: Sturm- Liouville Separation and comparison Theorems, Oscillation properties of solutions.

Unit IV: Fourier series (15 lectures)

Eigenvalues and eigenfunctions of Sturm-Liouville Boundary Value Problem, the vibrating string. Orthogonality of eigen functions, Dirichlet's conditions, Fourier series expansion of periodic functions (period 2pi & arbitrary period), Complex form of Fourier series, Half range Fourier series, Nth partial sum of Fourier series, Bessel's inequality, Parseval's identity (over complex field).

Note: ODE stands for Ordinary Differential Equations and PDE stands for Partial Differential Equations.

Recommended Text Books:

1. Units I and II:

(a) E.A. Coddington, An introduction to Ordinary Differential Equations, Dover Publication INC.
(b) E.A. Coddington, N. Levinson, Theory of Ordinary differential Equations, Tata McGraw-Hill, India.
(c) Hurewicz W., Lectures on ordinary differential equations, M.I.T. Press.
(d) Morris W. Hirsch and Stephen Smale, Differential Equations, Dynamical Systems, Linear Algebra, Elsevier.

2. Unit III and Unit IV:

(a) G.F. Simmons, Differential equations with applications and historical notes, McGraw-Hill international edition.
(b) G.F. Simmons, S.G. Krantz, Differential equations, Theory, Technique and Practice,
Walter Rudin series in advanced mathematics, 1st edition.
(c) G. B. Folland, Fourier series and its applications, AMS.

PGMT204A– Differential equations

Course Outcomes: After successful completion of this course, students will be able to:

CO-1: Apply Picard's method for finding solutions of first order differential equations.

CO-2: Expresses the existence and uniqueness results for an n^{th} order linear Ordinary Differential Equations.

CO-3: Apply the method of 'variation of parameters' to find solution of higher order linear differential equations with variable coefficients.

CO-4: Define Fourier series and apply for periodic functions.

CO-5: Construct Fourier analysis of daily life periodic functions.

ICT Tools Used: Videos, PPT, Pen-Tablet

Students Centric Methods: Problem Solving and Participative (Experimental, Participative, Problem Solving)

Links: SWAYAM / MOOCS:

1. https://nptel.ac.in/courses/111/108/111108081/ .
2. https://nptel.ac.in/courses/111/106/111106046/
3. https://nptel.ac.in/courses/111/104/111104031/

The CO-PO Mapping Matrix

CO\PO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	2	-	-	-	1	-	-	1	-	-	-	-
CO2	2	-	-	3	-	-	1	-	-	-	-	-
CO3	2	-	1	1	-	-	2	-	-	-	-	-
CO4	-	-	-	2	1	-	-	-	-	-	-	-
CO5	-	-	1	2	-	-	-	-	-	-	-	-

*In CO-PO Mapping Matrix: a correlation is established between COs and POs in the scale of 1 to 3, 1 being the slight (low), 2 being moderate (medium), 3 being substantial (high), and '-' indicate there is no correlation in respective CO and PO.

PGMT204 B: Optimization Techniques

Course Outcome of Optimisation Techniques:

Students will be able to:

1. Formulate linear programming problems to determine the feasible solutions.
2. Explain first and second order conditions for local optima.
3. Use various methods such as one-dimensional search method, Golden section search, Fibonacci search etc
4. Apply operation research to handle data in industry.

Unit I. Linear Programming (15 Lectures)

Operations research and its scope, Necessity of operations research in industry, Linear programming problems, convex sets, Simplex method, Theory of simplex method, Duality theory and sensitivity analysis, Dual simplex method.

Unit II. Unconstrained Optimization I (15 Lectures)

First and second order conditions for local optima, One-Dimensional Search Methods: Golden Section Search, Fibonacci Search, Newtons Method, Secant Method

Unit III. Unconstrained Optimization II (15 Lectures)

Powell's Method, Nelder-Mead (Simplex Method), Gradient Methods: Steepest Descent Methods, Newton's method, Conjugate gradient methods.

Unit IV. Constrained Optimization Problems (15 Lectures)

Problems with equality constraints, Tangent and normal spaces, Lagrange Multiplier Theorem, Second order conditions for equality constraints problems, Problems with inequality constraints, Karush-Kuhn-Tucker Theorem, Second order necessary conditions for inequality constraint problems.

Recommended Books:

1. H.A. Taha, Operations Research-An introduction, Macmillan Publishing Co. Inc., NY.
2. K. Swarup, P. K. Gupta and Man Mohan, Operations Research, S. Chand and sons, New Delhi.
3. S.S. Rao, Optimization Theory and Applications, Wiley Eastern Ltd, New Delhi.
4. G. Hadley, Linear Programming, Narosa Publishing House, 1995.
5. F.S. Hillier and G.J. Lieberman, Introduction to Operations Research (Sixth Edition), McGraw Hill.

PGMT204B– Optimization Techniques

Course Outcomes: After successful completion of this course, students will be able to:

CO-1: Formulate linear programming problems to determine the feasible solutions.

CO-2: Explain first and second order conditions for local optima.

CO-3: Use various methods such as one-dimensional search method, Golden section search, Fibonacci search etc.

CO-4: Apply operation research to handle data in industry.

ICT Tools Used: Videos, PPT, Pen-Tablet

Students Centric Methods: Problem Solving and Participative (Experimental, Participative, Problem Solving)

Links: SWAYAM / MOOCS:

1. https://nptel.ac.in/courses/111/105/111105039/
2. https://nptel.ac.in/courses/111/102/111102012/

The CO-PO Mapping Matrix

CO\PO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	2	1	-	-	-	-	-	-	c	-	-	-
CO2	3	-	1	-	-	-	-	-	-	-	-	-
CO3	2	2	-	-	-	-	-	-	-	-	-	-
CO4	-	-	-	2				1	-	-	-	-

CO5									-	-	-	-

PGMT 205: INTRODUCTION TO R PROGRAMMING-II

Course Outcomes:

1. Create different types of data frames in R
2. Handel and analyse various files in R
3. Analyse and visualize statistical functions using R.
4. Apply R programming to machine learning and big data analysis.

UNIT I: Loading and handling Data in R

Getting and Setting the Working Directory – getwd(), setwd(), dir() - R-CSV Files - Input as a CSV file, Reading a CSV File, Analyzing the CSV File: summary(), min(), max(), range(), mean(), median(), apply() - Writing into a CSV File – R -Excel File – Reading the Excel file. Descriptive Statistics: Data Range, Frequencies, Mode, Mean and Median: Mean Applying Trim Option, Applying NA Option, Median - Mode - Standard Deviation – Correlation - Spotting Problems in Data with Visualization: visually Checking Distributions for a single Variable - R –Pie Charts: Pie Chart title and Colors – Slice Percentages and Chart Legend, 3D Pie Chart – R Histograms – Density Plot - R – Bar Charts: Bar Chart Labels, Title and Colors.

UNIT II: Descriptive Statistics

Data Range, Frequencies, Mode, Mean and Median: Mean Applying Trim Option, Applying NA Option, Median - Mode - Standard Deviation – Correlation - Spotting Problems in Data with Visualization: visually Checking Distributions for a single Variable - R –Pie Charts: Pie Chart title and Colors – Slice Percentages and Chart Legend, 3D Pie Chart – R Histograms – Density Plot - R – Bar Charts: Bar Chart Labels, Title and Colors.

UNIT III: Machine Learning

Introduction to Machine Learning in R, Setting up Environment for Machine Learning with R Programming, Supervised and Unsupervised Learning in R Programming, Regression and its Types in R Programming, Classification in R Programming , Naive Bayes Classifier in R Programming , K-NN Classifier in R Programming , Clustering in R Programming , Decision Tree in R Programming., Random Forest Approach in R Programming , Hierarchical Clustering in R Programming , DBScan Clustering in R Programming, Deep Learning in R Programming.

Unit-IV: Practical (Lab Sessions)

REFERENCES:

1. Sandip Rakshit, R Programming for Beginners, McGraw Hill Education (India), 2017, ISBN : 978-93-5260-455-5.

2. Seema Acharya, Data Analytics using R, McGrawHill Education (India), 2018, ISBN: 978-93-5260-524-8.

3. Andrie de Vries, Joris Meys, R for Dummies A Wiley Brand, 2nd Edition, John Wiley and Sons, Inc, 2015, ISBN: 978-1-119-0558-8.

4. Tutorials Point (I) simply easy learning, Online Tutorial Library (2018), R Programming, Retrieved from https://www.tutorialspoint.com/r/r_tutorial.pdf.

5. https://nptel.ac.in/courses/111/104/111104100/

PGMT204A– INTRODUCTION TO R PROGRAMMING-II

Course Outcomes: After successful completion of this course, students will be able to:

CO-1: Create different types of data frames in R

CO-2: Handel and analyse various files in R

CO-3: Analyse and visualize statistical functions using R.

CO-4: Apply R programming to machine learning and big data analysis.

ICT Tools Used: Videos, PPT, Pen-Tablet

Students Centric Methods: Problem Solving and Participative (Experimental, Participative, Problem Solving)

Links: SWAYAM / MOOCS:

1. https://nptel.ac.in/courses/111/104/111104100/
2. https://nptel.ac.in/courses/110/105/110105142/
3. https://nptel.ac.in/courses/111/104/111104120/
4. https://nptel.ac.in/courses/111/104/111104146/

The CO-PO Mapping Matrix

CO\PO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	3	-	-	1	-	1	-		-	-	-	-
CO2	2	-	-	1	-	2	-	1	-	-	-	-
CO3	2	1	1	-	-	-	-	1	-	-	-	-
CO4	1	-	-	2	-	-	-	1	-	-	-	-

Scheme of Examination

In each semester, the performance of the learners shall be evaluated into two parts. The learner's performance in each course shall be assessed by Continuous Internal Assessment **(CIE)** with 40 marks and conducting the **Semester End Examinations (SEE)** with 60 marks.

Continuous Internal Assessment of 40 marks:

Paper Code	**CIE**	**Unit Tests/Seminar**	**Total**
PGMT101 to PGMT104 and PGMT201 TO PGMT204	20 Marks	20 Marks	40 Marks
PGMT105 and PGMT205 (SEC)	Practical based on each unit		40 Marks

Project Work:

Evaluation of Project work: The evaluation of the Project submitted by a student shall be made by a Committee appointed by the Head of the Department of Mathematics of the college. The presentation of the project is to be made by the student in front of the committee appointed by the Head of the Department of Mathematics. This committee shall have two members, possibly with one external referee.

The Marks for the project are detailed below:

1. Monthly Project Report & Development: 30 Marks.
2. Power Point presentation: 10 Marks.
3. Viva- voce: 20 Marks.
4. Usage of modern tools/ technology: 10 Marks.
5. Innovativeness: 10 Marks.
6. Individual Contribution: 10 Marks.
7. Group activity: 10 Marks.

Semester End Examination of 60 marks:

(i) Duration: - Examination shall be of **Two and Half hours** duration.

(ii) Theory Question Paper Pattern: -

1. There shall be five questions each of 12 marks.
2. On each unit there will be one question and the fifth one will be based on entire syllabus.
3. All questions shall be compulsory with internal choice within each question.
4. Each question may be subdivided into sub-questions a, b, c, d and the allocation of marks depend on the weightage of the topic.
5. Each question will be of 24 marks when marks of all the sub-questions are added (including the options) in that question.

Questions		Marks
Q 1	Based on Unit I	12
Q 2	Based on Unit II	12
Q 3	Based on Unit III	12
Q 4	Based on Unit IV	12
Q 5	Based on All Units (I to IV)	12
	Total Marks	60