BABU BANARASI DAS UNIVERSITY, LUCKNOW
Department of Mathematics & Computer Science
School of Basic Sciences

Program Structure

B.Sc. (Hons./ Hons. with Research) Mathematics
(As per National Education Policy 2020)

For Academic Session 2026-27 and After

Semester	Major Core Course (DSC) - 4 Credits	Major Elective Course (DSE) - 4 Cr	Minor Course (GE) 4 Credits	Skill Enhancement Course (SEC) - 3 Credits	Ability Enhancement Course (AEC) - 3 Credits	/Comprehensive Viva Voce / Value Added Course (VAC)/ Seminar /Project/ Internship / MOOC - 2 Credits	Academic Project Total 12 Credits	General Proficiency (GP) 1 Credit	Total Credit
I	DSC1 DSC2 DSC3		GE1	SEC1	AEC1			GP (RBMGP1)	23
II	DSC4 DSC5 DSC6		GE2	SEC2	AEC2			GP (RBMGP2)	23
III	DSC7 DSC8 DSC9		GE3	SEC3		VAC1/ MOOCS		GP (RBMGP3)	22
IV	DSC10 DSC11 DSC12		GE4	SEC4		VAC2 / MOOCS		GP (RBMGP4)	22
V	DSC13 DSC14 DSC15	DSE1	GE5			VAC3/ Seminar (RBMS5)/ MOOCS			22
VI	DSC16 DSC17 DSC18	DSE2	GE6			Dissertation (RBMD6) / Project (RBMP6)/ Internship (RBMI6)			22
VII	DSC19	Two DSE3 or One DSE3 and One GE7				MOOCS	Research Project (RBMR7) 4 Credit		18
VIII		Two DSE4 or One DSE4 and One GE8				Comprehensive Viva Voce (RBMV8)	Research Project (RBMR8) 8 Credit		18

*MOOCS code will be decided at the time of announcements at the commencement of the semester.

Credit Distribution & Evaluation Scheme

B.Sc. (Hons./ Hons. with Research) Mathematics
(As per National Education Policy 2020)

For Academic Session 2026-27 and After

Sem	Course Type	Contact Hours			Marks			Cr	Exam Hrs.
		L	T	P	CIA	ESE	Total		
1	DSC1	3	1	-	40	60	100	4	3
	DSC2	3	1	-	40	60	100	4	3
	DSC3	3	1	-	40	60	100	4	3
	One Course from GE1	3	-	-	40	60	100	3	3
		-	-	2	40	60	100	1	3
		Or							
		3	1	-	40	60	100	4	3
	SEC1	2	1	-	40	60	100	3	3
	AEC1	3	-	-	40	60	100	3	3
	GP	-	-	-	100	-	100	1	-
							Total	23	
2	DSC3	3	1	-	40	60	100	4	3
	DSC4	3	1	-	40	60	100	4	3
	DSC5	3	1	-	40	60	100	4	3
	One Course from GE2	3	-	-	40	60	100	3	3
		-	-	2	40	60	100	1	3
		Or							
		3	1	-	40	60	100	4	3
	SEC2	2	1	-	40	60	100	3	3

	AEC2	3	-	-	40	60	100	3	3
	GP	-	-	-	100	-	100	1	-
							Total	23	
3	DSC7	3	1	-	40	60	100	4	3
	DSC8	3	1	-	40	60	100	4	3
	DSC9	3	1	-	40	60	100	4	3
	One Course from GE3	3	-	-	40	60	100	3	3
		-	-	2	40	60	100	1	3
		Or							
		3	1	-	40	60	100	4	3
	SEC3	2	1	-	40	60	100	3	3
	VAC1/ MOOCS	1	-	-	40	60	100	1	3
		-	-	2	40	60	100	1	3
		or							
		-	-	-	100	-	100	2	-
	GP	-	-	-	100	-	100	1	-
							Total	22	
4	DSC10	3	1	-	40	60	100	4	3
	DSC11	3	1	-	40	60	100	4	3
	DSC12	3	1	-	40	60	100	4	3
	One Course from GE4	3	-	-	40	60	100	3	3
		-	-	2	40	60	100	1	3
		Or							
		3	1	-	40	60	100	4	3

	SEC4	2	1	-	40	60	100	3	3
	VAC2/ MOOCS	1	-	-	40	60	100	1	3
		-	-	2	40	60	100	1	3
		or							
		-	-	-	100	-	100	2	-
	GP	-	-	-	100	-	100	1	-
							Total	23	
5	DSC13	3	1	-	40	60	100	4	3
	DSC14	3	1	-	40	60	100	4	3
	DSC15	3	1	-	40	60	100	4	3
	One Course from DSE1	3	1	-	40	60	100	4	3
	One Course from GE5	3	-	-	40	60	100	3	3
		-	-	2	40	60	100	1	3
		Or							
		3	1	-	40	60	100	4	3
	VAC3/ Seminar/ MOOCS	2	-	-	40	60	100	2	3
		Or							
		-	-	-	100	-	100	2	-
							Total	22	
6	DSC16	3	1	-	40	60	100	4	3
	DSC17	3	1	-	40	60	100	4	3
	DSC18	3	1	-	40	60	100	4	3
	One Course from DSE2	3	1	-	40	60	100	4	3
	One Course from GE6	3	-	-	40	60	100	3	3

		-	-	2	40	60	100	1	3
		Or							
		3	1	-	40	60	100	4	3
	Dissertation or Project or Internship	-	-	-	50	50	100	2	-
							Total	22	
7	DSC19	3	1	-	40	60	100	4	3
	Two course from DSE3	3	1	-	40	60	100	4	3
	Or								
	One Course from DSE3 and One Course from GE7	3	1	-	40	60	100	4	3
	MOOCS	-	-	-	100	-	100	2	-
	Research Project	-	-	-	100	-	100	4	-
							Total	18	
8	Two course from DSE3	3	1	-	40	60	100	4	3
	Or								
	Two Courses from DSE4 or One Course DSE4 and One Course from GE8	3	1	-	40	60	100	4	3
	Research Project	-	-	-	50	50	100	8	-
	Comprehensive Vive-Voce	-	-	-	100	-	100	2	-
							Total	18	

List of Discipline Specific Core Courses (DSC) For

B.Sc. (Hons./ Hons. with Research) Mathematics

For Academic Session 2026-27 and After

DSC	Course Code	Course Name	Contact Hours			Marks			Cr	Exam Hrs.
			L	T	P	CIA	ESE	Total		
DSC1	RBM4101	Algebra	3	1	-	40	60	100	4	3
DSC2	RBM4102	Elementary Real Analysis	3	1	-	40	60	100	4	3
DSC3	RBM4103	Calculus	3	1	-	40	60	100	4	3
DSC4	RBM4201	Theory of Real Functions	3	1	-	40	60	100	4	3
DSC5	RBM4202	Ordinary Differential Equations	3	1	-	40	60	100	4	3
DSC6	RBM4203	Geometry and Vector Calculus	3	1	-	40	60	100	4	3
DSC7	RBM4301	Group Theory	3	1	-	40	60	100	4	3
DSC8	RBM4302	Multivariate Calculus	3	1	-	40	60	100	4	3
DSC9	RBM4303	Partial Differential equations	3	1	-	40	60	100	4	3
DSC10	RBM4401	Ring Theory and Vector Spaces	3	1	-	40	60	100	4	3
DSC11	RBM4402	Riemann Integration & Series of Functions	3	1	-	40	60	100	4	3
DSC12	RBM4403	Graph Theory	3	1	-	40	60	100	4	3
DSC13	RBM4501	Linear Algebra	3	1	-	40	60	100	4	3
DSC14	RBM4502	Set Theory and Metric Spaces	3	1	-	40	60	100	4	3
DSC15	RBM4503	Numerical Analysis	3	1	-	40	60	100	4	3
DSC16	RBM4601	Complex Analysis	3	1	-	40	60	100	4	3
DSC17	RBM4602	Integral Transform and Fourier Analysis	3	1	-	40	60	100	4	3
DSC18	RBM4603	Discrete Mathematics	3	1	-	40	60	100	4	3
DSC19	RBM4701	Research Methodology	3	1	-	40	60	100	4	3

List of Discipline Specific Elective Courses (DSE) For

B.Sc. (Hons./ Hons. with Research) Mathematics

For Academic Session 2026-27 and After

DSE	Course Code	Course Name	Contact Hours			Marks			Cr	Exam Hrs.
			L	T	P	CIA	ESE	Total		
DSE1A	RBME4501	Mathematical Modelling	3	1	-	40	60	100	4	3
DSE1B	RBME4502	Optimization Techniques	3	1	-	40	60	100	4	3
DSE1C	RBME4503	Number Theory	3	1	-	40	60	100	4	3
DSE2A	RBME4601	Boolean Algebra & Automata Theory	3	1	-	40	60	100	4	3
DSE2B	RBME4602	Fuzzy Mathematics	3	1	-	40	60	100	4	3
DSE2C	RBME4603	Ordinary and Partial Differential Equations	3	1	-	40	60	100	4	3
DSE3A	RBME4701	Abstract Algebra	3	1	-	40	60	100	4	3
DSE3B	RBME4702	Topology	3	1	-	40	60	100	4	3
DSE3C	RBME4703	Real Analysis	3	1		40	60	100	4	3
DSE3D	RBME4704	Analytical Geometry	3	1	-	40	60	100	4	3
DSE4A	RBME4801	Advance Algebra	3	1	-	40	60	100	4	3
DSE4B	RBME4802	Advance Real Analysis	3	1		40	60	100	4	3
DSE4C	RBME4803	Functional Analysis	3	1		40	60	100	4	3
DSE4D	RBME4804	Computational Fluid Dynamics	3	1		40	60	100	4	3

Generic Elective Courses (Minor Courses)
List 1 - Data Science

For B.Sc. (Hons./ Hons. with Research) Mathematics

For Academic Session 2026-27 and After

GE	Course Code	Course Name	Contact Hours			Marks			Cr	Exam Hrs.
			L	T	P	CIA	ESE	Total		
GE1A	RBMG1101	Python Programming	3	-	-	40	60	100	3	3
	RBMG1151	Python Programming Lab	-	-	2	40	60	100	1	3
GE2A	RBMG1201	Data Science & Analytics	3	-	-	40	60	100	3	3
	RBMG1251	Data Science & Analytics Lab	-	-	2	40	60	100	1	3
GE3A	RBMG4301	Database Management System	3	-	-	40	60	100	3	3
	RBMG4351	Database Management System Lab	-	-	2	40	60	100	1	3
GE4A	RBMG4401	Artificial Intelligence	3	1	-	40	60	100	4	3
GE5A	RBMG4501	Machine Learning	3	-	-	40	60	100	3	3
	RBMG4551	Machine Learning Lab	-	-	2	40	60	100	1	3
GE6A	RBMG4601	Big Data Analysis	4	0	-	40	60	100	4	3
GE7A	RBMG4701	Block Chain Technology	3	1	-	40	60	100	4	3
GE8A	RBMG4801	Augmented & Virtual Reality	3	1	-	40	60	100	4	3

Generic Elective Courses (Minor Courses)
List 2 – Computer Science

For B.Sc. (Hons./ Hons. with Research) Mathematics

For Academic Session 2026-27 and After

GE	Course Code	Course Name	Contact Hours			Marks			Cr	Exam Hrs.
			L	T	P	CIA	ESE	Total		
GE1B	RBMG4101	Programming Using C	3	-	-	40	60	100	3	3
	RBMG4151	Programming Using C Lab	-	-	2	40	60	100	1	3
	RBMG1251	Data Science & Analytics Lab	-	-	2	40	60	100	1	3
GE2B	RBMG1202	Operating System	3	1	-	40	60	100	4	3
GE3B	RBMG4302	Computer Network	3	1	-	40	60	100	4	3
GE4B	RBMG4402	Java Programming	3	-	-	40	60	100	3	3
	RBMG4451	Java Programming Lab	-	-	2	40	60	100	1	3
GE5B	RBMG4502	Web Technologies	3	-	-	40	60	100	3	3
	RBMG4551	Web Technologies Lab	-	-	2	40	60	100	1	3
GE6B	RBMG4602	Software Engineering	3	1	-	40	60	100	4	3
GE7B	RBMG4702	Information Security & Cyber Law	3	1	-	40	60	100	4	3
GE8B	RBMG4802	Cloud Computing	3	1	-	40	60	100	4	3

Generic Elective Courses (Minor Courses)
List 3 – Economics

For B.Sc. (Hons./ Hons. with Research) Mathematics

For Academic Session 2026-27 and After

GE	Course Code	Course Name	Contact Hours			Marks			Cr	Exam Hrs.
			L	T	P	CIA	ESE	Total		
GE1C	RHSG1101	Microeconomics-I	3	1	-	40	60	100	4	3
GE2C	RHSG1202	Microeconomics-II	3	1	-	40	60	100	4	3
GE3C	RHSG1303	Macroeconomics -I	3	1	-	40	60	100	4	3
GE4C	RHSG1404	Macroeconomics -II	3	1	-	40	60	100	4	3
GE5C	RHSG1505	Indian Economy	3	1	-	40	60	100	4	3
GE6C	RHSG1606	International Trade	3	1	-	40	60	100	4	3
GE7C	RHSG1707	Demography and Population Studies	3	1	-	40	60	100	4	3
GE8C	RHSG1808	Labour Economics	3	1	-	40	60	100	4	3

List of Skill Enhancement Courses (SEC) For

B.Sc. (Hons./ Hons. with Research) Mathematics
For Academic Session 2026-27 and After

SEC	Course Code	Course Name	Contact Hours			Marks			Cr	Exam Hrs.
			L	T	P	CIA	ESE	Total		
SEC1	RBMS2101	Descriptive Statistic	2	1	-	40	60	100	3	3
SEC2	RBMS2202	Probability & Distribution	2	1	-	40	60	100	3	3
SEC3	RBMS2303	Statistical Inference	2	1	-	40	60	100	3	3
SEC4	RBMS1404	Applied Statistics	2	1	-	40	60	100	3	3

List of Value-Added Courses (VAC) For

B.Sc. (Hons./ Hons. with Research) Mathematics
For Academic Session 2026-27 and After

VAC	Course Code	Course Name	Contact Hours			Marks			Cr	Exam Hrs.
			L	T	P	CIA	ESE	Total		
VAC1	RBMV4301	R Programming	1	-	-	40	60	100	1	3
	RBMV4351	R Programming (Lab)	-	-	2	40	60	100	1	3
VAC2	RBMV4401	Web Development	1	-	-	40	60	100	1	3
	RBMV4451	Web Development (Lab)	-	-	2	40	60	100	1	3
VAC3	RBMV2501	Vedic Mathematics	2	-	-	40	60	100	2	3

List of Ability Enhancement Courses (AEC) For

B.Sc. (Hons./ Hons. with Research) Mathematics
For Academic Session 2026-27 and After

CC	Course Code	Course Name	Contact Hours			Marks			Cr	Exam Hrs.
			L	T	P	CIA	ESE	Total		
AEC1	RHSA1101	Professional & Workplace Communication	3	-	-	40	60	100	3	3
AEC2	RBSA1201	Environment and Ecological Sustainability	3	-	-	40	60	100	3	3

Program	**B.Sc. (Hons./ Hons. with Research) Mathematics**				
Year	**1**	**Semester**		**1**	
Course Name	**Algebra**				
Code	**RBM4101**				
Course Type	**DSC**	**L**	**T**	**P**	**Credit**
Pre-Requisite	**10+2 Mathematics**	**3**	**1**	**-**	**4**
Course Objectives	The objective of the course is to develop a fundamental understanding of relations and algebraic structures, polynomial equations, modular arithmetic, and congruence relations. The course aims to equip students with the ability to solve cubic and quartic equations, analyze systems of linear equations using matrix methods, and determine characteristic equations, eigenvalues, and eigenvectors of matrices.				
Course Outcomes: After completion of the course, students will be able to:					
CO1	Recognize the Relations & algebraic structure.				
CO2	Solve cubic and quartic polynomial equations with special condition on roots and in general.				
CO3	Understand the basic concepts of modular arithmetic and basic properties of congruence.				
CO4	Recognize consistent and inconsistent systems of linear equations using matrix method and determined characteristic equation, Eigenvalues and Eigenvector of matrices.				

Module	**Course Contents**	**Contact Hrs.**	**Mapped CO**
1	Relations, Equivalence relations, Partitions, Mapping, Composition of mapping, Binary operations. ([1] chapter 1) Algebraic Structures, Groupoids, Commutative and Associative Groupoids, Identities and inverse of Groupoids, Semigroup with an Identity Element; Introduction of Homomorphism ([1] chapter 2).	15	CO1
2	General properties of polynomials and equations, Fundamental theorem of algebra, Relations between the roots and the coefficients. ([2] Chapter 3) Newton's method for integral roots, Descartes' rule of signs, De-Moivre's theorem for integer, rational indices and their applications. ([2] Chapter 4) The nth roots of unity; Synthetic division method; ([2] Chapter 3) Cardan's solution of the cubic equation; Descartes' solution of the quartic equation. ([3] Chapter 13)	15	CO2
3	Division algorithm in $\mathbb{Z}$, Divisibility and the Euclidean algorithm, ([3] Chapter 4) Fundamental theorem of arithmetic, Modular arithmetic and basic properties of congruences; Principles of mathematical induction. ([3] Chapter 4)	15	CO3
4	Rank of a matrix, Echelon forms; ([1] Chapter 6) System of linear equations, Solution of the matrix equation $AX = B$; ([1] Chapter 7) Eigenvalues and Eigenvectors, Cayley-Hamilton Theorem. ([1] Chapter 8).	15	CO4

Reference Books

1. Schaum's outline series, Theory and Problems of Group theory, McGRAW Hill Book Company
2. MK Singal, Asha Rani Singal, Algebra (31st Ed) R Chand &Co, New Delhi, 2020.
3. Goodaire, Edgar G., & Parmenter, Michael M.. Discrete Mathematics with Graph Theory (3rd Ed.). Pearson Education Pvt. Ltd. Indian Reprint 2018.
4. Chandrika Prasad, Text Book on Algebra and Theory of Equations Pothishala, 1963.

Online Resources

5. https://onlinecourses.nptel.ac.in/e-learning/preview/noc21_ma71
1. https://onlinecourses.nptel.ac.in/e-learning/preview/noc26_ma21

Course Articulation Matrix														
PO-PSO	**PO1**	**PO2**	**PO3**	**PO4**	**PO5**	**PO6**	**PO7**	**PO8**	**PO9**	**PO10**	**PO11**	**PO12**	**PSO1**	**PSO2**
CO1	3	1	2	0	0	0	0	3	0	0	0	3	1	3
CO2	3	1	3	0	0	0	0	3	0	0	0	3	1	3
CO3	2	1	3	1	0	0	0	3	0	0	0	3	1	2
CO4	3	1	3	2	0	1	0	3	0	1	0	3	2	3

Program	B.Sc. (Hons./ Hons. with Research) Mathematics				
Year	1	Semester	1		
Course Name	Elementary Real Analysis				
Code	RBM4102				
Course Type	DSC	L	T	P	Credit
Pre-Requisite	10+2 Mathematics	3	1	-	4
Course Objectives	The object of the course is to provide basic concepts of real number system and the concepts of convergence and divergence of sequences and series of real numbers.				
Course Outcomes: After completion of the course, students will be able to:					
CO1	Understand the fundamental properties of the real numbers, including completeness, Archimedean and density property of rational numbers in $\mathbb{R}$				
CO2	Understand nested interval property, neighbourhood of a point in $\mathbb{R}$ and learn to define sequences in terms of functions from $\mathbb{N}$ to a subset of $\mathbb{R}$ and find the limit, recognize convergent, divergent and monotonic sequences.				
CO3	Recognize sub-sequences, calculate limit superior and inferior of a bounded sequence. Learn to identify infinite series and its convergence.				
CO4	Understand and apply the ratio, root, alternating series and limit comparison tests for convergence and absolute convergence of an infinite series of real numbers.				

Module	Course Contents	Contact Hrs.	Mapped CO
1	Algebraic and order properties of $\mathbb{R}$, Absolute value of a real number, Bounded above and bounded below sets, Supremum and infimum of a non-empty subset of $\mathbb{R}$, The completeness property of $\mathbb{R}$, Archimedean property, Density of rational numbers in $\mathbb{R}$ ([1] Chapter 2).	15	CO1
2	Definition and types of intervals, nested interval property ([1] Chapter 2), Neighbourhood of a point in $\mathbb{R}$, open and closed set in $\mathbb{R}$ ([1] Chapter 11). Sequences: Sequences and their limits, Convergent sequence, Limit theorems, Monotone sequences, Monotone convergence theorem ([1] Chapter 3).	15	CO2
3	Subsequences, Bolzano-Weierstrass theorem for sequences. Limit superior and limit inferior for bounded sequence, Cauchy sequence, Cauchy's convergence criterion ([1] Chapter 3). Infinite Series: Convergence and divergence of infinite series of real numbers, Necessary condition for convergence ([3] Chapter 8).	15	CO3
4	Cauchy criterion for convergence, Tests for convergence of positive terms series, Integral test, Basic comparison test, Limit comparison test, D'Alembert's ratio test, Cauchy's n^{th} root test, Raabe's test, Alternating series, Leibniz test, Absolute and conditional convergence ([3] Chapter 8).	15	CO4

Suggested Readings

1. Bartle, Robert G., & Sherbert, Donald R, Introduction to Real Analysis (4th ed.). John Wiley & Sons. Wiley India Edition 2011.
2. Bilodeau, Gerald G., Thie, Paul R., & Keough, G. E., An Introduction to Analysis (2nd ed.). Jones and Bartlett India Pvt. Ltd. Student Edition. Reprinted 2015.
3. Denlinger, Charles G., Elements of Real Analysis. Jones and Bartlett India Pvt. Ltd. Student Edition. Reprinted 2015.

Online Resources

1. https://nptel.ac.in/courses/122104017
2. https://nptel.ac.in/courses/111106142

Course Articulation Matrix														
PO-PSO	**PO1**	**PO2**	**PO3**	**PO4**	**PO5**	**PO6**	**PO7**	**PO8**	**PO9**	**PO10**	**PO11**	**PO12**	**PSO1**	**PSO2**
CO1	3	1	2					3				3	1	3
CO2	3	1	3	1				3				3	1	3
CO3	3	1	3	1				3				3	1	3
CO4	3	1	3	2				3				3	2	3

Program	B.Sc. (Hons./ Hons. with Research) Mathematics				
Year	1	Semester	1		
Course Name	Calculus				
Code	RBM4103				
Course Type	DSC	L	T	P	Credit
Pre-Requisite	10+2 Mathematics	3	1	-	4
Course Objectives	The objective of the course is to provide the concept of limit, continuity and differentiability and to apply the knowledge to solve problems.				
Course Outcomes: After completion of the course, students will be able to:					
CO1	Understand continuity and differentiability in terms of limits and graphs of certain functions.				
CO2	Understand the consequences of various mean value theorems for differentiable functions.				
CO3	Understand the concepts of asymptotes and inflexion points in curve tracing.				
CO4	Compute the reduction formulae of standard transcendental functions with applications.				

Module	Course Contents	Contact Hrs.	Mapped CO
1	$\varepsilon - \delta$ definition of a limit, Infinite limits, Continuity and types of discontinuities ([1] Chapter 2); Differentiability of a function ([1] Chapter 3), Successive differentiation: Calculation of the nth derivatives, Leibnitz theorem ([1] Chapter 5). Partial differentiation, Euler's theorem on homogeneous functions ([1] Chapter 12).	15	CO1
2	Rolle's theorem, Mean value theorems, Taylor's and Maclaurin's series expansions of one variable ([1] Chapter 7). Indeterminate forms ([1] Chapter 16).	15	CO2
3	Asymptotes ([1] Chapter 9), Curvature, Concavity and inflexion points ([1] Chapter 10), Singular points, Tangents at the origin and nature of singular points, Curve tracing ([1] Chapter 11).	15	CO3
4	Integration of irrational algebraic functions and transcendental functions, Reduction formulae for $\int \sin^n x\,dx$, $\int \cos^n x\,dx$, $\int \sin^m x \cos^n x\,dx$, $\int x^n \sin mx\,dx$, $\int x^n \cos mx\,dx$ and $\int x^n (\log x)^m\,dx$ ([2] Chapter 3&4). Definite integral as a limit of sum ([2] Chapter 5),	15	CO4

Suggested Readings

1. Gorakh Prasad, Differential Calculus (19th ed.). Pothishala Pvt. Ltd. Allahabad, 2016.
2. Gorakh Prasad, Integral Calculus. Pothishala Pvt. Ltd. Allahabad, 2015.

Online Resources

1. https://archive.nptel.ac.in/courses/111/106/111106146/
2. https://vidyamitra.inflibnet.ac.in/index.php/search?subject%5B%5D=&course%5B%5D=Calculus&domain%5B%5D=Physical+%26+Basic+Sciences

Course Articulation Matrix														
PO-PSO	**PO1**	**PO2**	**PO3**	**PO4**	**PO5**	**PO6**	**PO7**	**PO8**	**PO9**	**PO10**	**PO11**	**PO12**	**PSO1**	**PSO2**
CO1	3	1	2					3				3	1	3
CO2	3	1	3	1				3				3	1	3
CO3	3	1	3	1				3				3	1	3
CO4	3	1	3	2				3				3	2	3

Program	B.Sc. (Hons./ Hons. with Research) Mathematics				
Year	1	Semester		2	
Course Name	Theory of Real Functions				
Code	RBM4201				
Course Type	DSC	L	T	P	Credit
Pre-Requisite	10+2 Mathematics	3	1	-	4
Course Objectives	The objective of the course is to provide the knowledge and the key concepts of calculus, namely, limits, continuity, differentiability and their applications.				
Course Outcomes: After completion of the course, students will be able to:					
CO1	Understand the concepts of continuous and uniformly continuous functions and apply fundamental theorems of continuity to solve mathematical problems.				
CO2	Understand the concept of differentiability and chain rule of differentiability.				
CO3	Understand the concept behind various mean value theorems for differentiable functions.				
CO4	Find expansions for algebraic & transcendental function with the help of Taylor's & Maclaurin's theorem.				

Module	Course Contents	Contact Hrs.	Mapped CO
1	Continuous functions, algebra of continuous functions, continuous functions on interval; Boundedness theorem; Maximum- minimum theorem; location of roots theorem; Bolzano intermediate value theorem, preservation of intervals theorem; uniform continuity, non-uniform continuity criteria, uniform continuity theorem. ([1] Chapter 5)	15	CO1
2	Monotonic functions, sign of derivatives; Differentiability of a function at a point and in an interval, The Chain Rule; Caratheodory's theorem; Algebra of differentiable functions. ([1] Chapter 6)	15	CO2
3	Interior extremum theorem, Rolle's theorem (without proof), First mean value theorem (without proof). Intermediate value property for derivatives, Darboux's theorem, Cauchy's mean value theorem, Application of mean value theorems. ([1] Chapter 6)	15	CO3
4	Power Series, Radius of Convergence, Cauchy-Hadamard theorem, Differentiation and Integration of Power Series, Abel's Theorems. ([2] Chapter 17)	15	CO4

Suggested Readings:

1. S.C. Malik & Savita Arora, Mathematical Analysis, (2nd Edition), New Age Int. Publishers.
2. Shanti Narayan & M.D. Raisinghania, Elements of Real Analysis, (Reprint 2021) S.Chand.
3. R. G. Bartle and D. R. Sherbert, Introduction to Real Analysis (4th Edition), John Wileyand Sons (Asia) Pvt. Ltd., Singapore, 2010.
4. K. A. Ross, Elementary Analysis, The Theory of Calculus, Undergraduate Texts in Mathematics, Springer (SIE), Indian reprint, 2004.
5. A. Mattuck, Introduction to Analysis, Prentice Hall, 1999.

Online Resources:

1. https://nptel.ac.in/courses/111105098
2. https://nptel.ac.in/courses/111106053
3. https://nptel.ac.in/courses/111105069

Course Articulation Matrix														
PO-PSO	**PO1**	**PO2**	**PO3**	**PO4**	**PO5**	**PO6**	**PO7**	**PO8**	**PO9**	**PO10**	**PO11**	**PO12**	**PSO1**	**PSO2**
CO1	3	1	3	1				3				3	1	3
CO2	3	1	3	1				3				3	1	3
CO3	3	1	3	2				3				3	2	3
CO4	3	1	3	1				3				3	1	3

Program	B.Sc. (Hons./ Hons. with Research) Mathematics				
Year	1	Semester		2	
Course Name	Ordinary Differential Equations				
Code	RBM4202				
Course Type	DSC	L	T	P	Credit
Pre-Requisite	10+2 Mathematics	3	1	-	4
Course Objectives	The objective of the course is to introduce the students to understand and solve of Differential Equations, create various Mathematical models and their applications in everyday life.				
Course Outcomes: After completion of the course, students will be able to:					
CO1	Understand the genesis of ordinary differential equations of first order and first degree.				
CO2	Learn various techniques of getting exact solutions of linear differential equations of Second and higher order.				
CO3	Develop the concept of a general solution of a linear differential equation of an arbitrary order and also learn a few methods to obtain the general solution of such equations.				
CO4	Formulate mathematical models in the form of ordinary differential equations to suggest possible solutions of the day to day problems arising in physical, chemical and biological disciplines.				

Module	Course Contents	Contact Hrs.	Mapped CO
1	Basic concepts and genesis of ordinary differential equations, Order and degree of a differential equation ([2] Chapter 1, Part I), Differential equations of first order and first degree, Equations in which variables are separable, Homogeneous equations, Linear differential equations and equations reducible to linear form, Exact differential equations, Integrating factor ([2] Chapter 2, Part I), First order higher degree equations solvable for x, y and p. Clairaut's form and singular solutions ([2] Chapter 4, Part I).	15	CO1
2	Second Order Linear Differential Equations: Solutions of homogeneous linear ordinary differential equations of second order with constant coefficients ([1] Chapter 2), Euler- Cauchy's linear differential equations, Legendre's linear differential equations. Transformations of the equation by changing the dependent/independent variable, Method of variation of parameters ([2] Chapter 10, Part I), Reduction of order ([1] Chapter 2). Higher Order Linear Differential Equations: Linearly dependent and linearly independent solutions on an interval, Wronskian and its properties.	15	CO2
3	Power series method ([2] Chapter 7, Part II), Frobenius method ([2] Chapter 8, Part II), Legendre's equation, Legendre polynomials, Rodrigue's formula, Orthogonality of Legendre polynomials ([2] Chapter 9, Part II), Bessel's equation, Bessel functions and their properties, Recurrence relations ([2] Chapter 11, Part II).	15	CO3
4	Application of first order differential equations to acceleration-velocity model ([5] Chapter 2), Growth and	15	CO4

	Decay model ([4] Chapter 2). Introduction to compartmental models ([4] Chapter 2), Lake pollution model (with case study of Lake Burley Griffin) ([4] Chapter 2), Drug Assimilation models ([4] Chapter 2), population models (with limited growth, exponential growth) Epidemic models ([5] Chapter 2 or [4] Chapter 3).		

Suggested Readings

1. Erwin Kreyszig, Advanced Engineering Mathematics (10th edition). Wiley, 2011.
2. M. D. Raisinghania, Advanced Differential Equations, Eighteenth Edition, S. Chand,2013.
3. H. I. Freedman, Deterministic Mathematical Models in Population Ecology. Marcel Dekker Inc, 1980.
4. Barnes, Belinda &Fulford, Glenn R., Mathematical Modelling with Case Studies, Using Maple and MATLAB (3rd ed.). CRC Press, Taylor & Francis Group, 2015.
5. Edwards, C. Henry, Penney, David E., & Calvis, David T., Differential Equation and Boundary Value Problems: Computing and Modeling(5th ed.). Pearson Education, 2015.

Online Resources

1. https://archive.nptel.ac.in/courses/111/106/111106100/

Course Articulation Matrix														
PO-PSO	**PO1**	**PO2**	**PO3**	**PO4**	**PO5**	**PO6**	**PO7**	**PO8**	**PO9**	**PO10**	**PO11**	**PO12**	**PSO1**	**PSO2**
CO1	3	1	2	1				3				3	1	3
CO2	3	1	3	2		1		3		1		3	1	3
CO3	3	1	3	2		1		3		1		3	2	3
CO4	3	2	3	3	2	1		3		1		3	3	3

Program	B.Sc. (Hons./ Hons. with Research) Mathematics				
Year	1	Semester		2	
Course Name	Geometry and Vector Calculus				
Code	RBM4203				
Course Type	DSC	L	T	P	Credit
Pre-Requisite	10+2 Mathematics	3	1	-	4
Course Objectives	The objective of the course is to introduce the basic tools of vector calculus and geometric properties of different conic sections which are helpful in understanding their applications in Planetary motion and real-world problems.				
Course Outcomes: After completion of the course, students will be able to:					
CO1	Understand the geometrical terminology and have a detailed clear cut idea of planes and straight lines.				
CO2	Explain the geometrical and theoretical concept of Sphere with its properties.				
CO3	Explain the concept of three dimensional spaces				
CO4	Understand the calculus of vector valued functions and apply the knowledge to solve various problem.				

Module	Course Contents	Contact Hrs.	Mapped CO
1	Planes: Distance of a point from a plane, Angle between two planes, pair of planes, Bisectors of angles between two planes, Straight lines: Equations of straight lines, Distance of a point from a straight line, Distance between two straight lines, Distance between a straight line and a plane, ([4] Chapter III).	15	CO1
2	Spheres: Different forms, Intersection of two spheres, Orthogonal intersection, Tangents and normal, Radical plane, Radical line, Coaxial system of spheres, Pole, Polar and Conjugacy ([4] Chapter V).	15	CO2
3	Space curves, Algebraic curves, Ruled surfaces, Some standard surfaces, Classification of quadric surfaces, Cone, Cylinder, Central conicoids. Tangent plane, Normal, Polar planes and Polar lines. ([4] Chapter VI,VII).	15	CO3
4	Vector valued functions and their graphs, Limits and continuity of vector functions, Differentiation and integration of vector functions, Projectile motion, Unit tangent, Normal and binormal vectors, Curvature and Torsion ([5] Chapter 13)	15	CO4

Suggested Readings

1. Leonard Eugene Dickson, First Course in the Theory of Equations. The Project Gutenberg E Book (http://www.gutenberg.org/ebooks/29785) 2009.
2. Edgar G. Goodaire& Michael M. Parmenter, Discrete Mathematics with Graph Theory (3rd edition).Pearson Education Pvt. Ltd. India 2015.
3. David C. Lay, Steven R. Lay & Judi J. McDonald, Linear Algebra and its Applications (5th edition).Pearson Education Pvt. Ltd. India 2016.
4. Robert J. T. Bill. An Elementary Treatise on Coordinate Geometry of Three Dimensions. Macmillan India Ltd 1994.

5. Thomas, Jr. George B., Weir, Maurice D., & Hass, Joel (2014). Thomas' Calculus (13th Ed.)Pearson Education, Delhi. Indian Reprint 2017.
6. B. C. Das, B. N. Mukherjee. Differential Calculus (55th Edition), U.N.Dhur& Sons Private Ltd., Kolkata 2015.

Online Resources

1. https://nptel.ac.in/courses/111104095
2. https://archive.nptel.ac.in/courses/111/105/111105122/

Course Articulation Matrix														
PO-PSO	**PO1**	**PO2**	**PO3**	**PO4**	**PO5**	**PO6**	**PO7**	**PO8**	**PO9**	**PO10**	**PO11**	**PO12**	**PSO1**	**PSO2**
CO1	3	1	2					3				3	1	3
CO2	3	1	2					3				3	1	3
CO3	3	1	2					3				3	1	3
CO4	3	1	3	2				3				3	2	3

Program	B.Sc. (Hons. / Hons. with Research) Mathematics				
Year	2	Semester	3		
Course Name	Group Theory				
Code	RBM4301				
Course Type	DSC	L	T	P	Credit
Pre-Requisite	Basic Concept of algebraic structure & Number System.	3	1	0	4
Course Objectives	The objective of the course is to introduce fundamental theory of groups and their homomorphisms. Cayley Theorem and its application are also studied in detail.				
Course Outcomes: After completion of the course, students will be able to:					
CO1	Understand the fundamental concepts of subgroup, cyclic group.				
CO2	Know about fundamental concept of Permutation group, Alternating Group, Cayley theorem and its applications.				
CO3	Explain the significance of the notion of cosets, normal subgroups and Quotient groups.				
CO4	Recognize group homomorphism and group isomorphism.				

Module	Course Contents	Contact Hrs.	Mapped CO
1	Groups, Subgroups, Cyclic groups, Fundamental theorem of cyclic groups. ([1] Chapter 1)	15	CO1
2	Permutation, Cycle notation for permutations, Properties of permutations, Even and odd permutations, Symmetric group, Dihedral group, alternating groups, Cayley's theorem and its applications. ([1] Chapter 2)	15	CO2
3	Cosets, Properties of cosets, Lagrange's theorem, ([1] Chapter 2) Cauchy's theorem for finite Abelian groups, Normal subgroups, Simple groups, Quotient groups. ([1] Chapter 3)	15	CO3
4	Group homomorphisms, Properties of homomorphisms, Fundamental Theorem of group homomorphism; Group isomorphisms, Properties of isomorphisms, First, second and third isomorphism theorems for groups. ([1] Chapter 3)	15	CO4

Suggested Readings

1. Vijay k Khanna and S K Bhambri, A Course in Abstract Algebra (4th edition), Vikash Publishing House Pvt Ltd.
2. Joseph A. Gallian, Contemporary Abstract Algebra (4th edition). Narosa
3. John B. Fraleigh, A First Course in Abstract Algebra (7th edition). Pearson.
4. I. N. Herstein, Topics in Algebra (2nd edition). Wiley India.

Online Resources

1. https://archive.nptel.ac.in/courses/111/106/111106113/
2. https://onlinecourses.swayam2.ac.in/cec23_ma19/preview

Course Articulation Matrix														
PO-PSO	**PO1**	**PO2**	**PO3**	**PO4**	**PO5**	**PO6**	**PO7**	**PO8**	**PO9**	**PO10**	**PO11**	**PO12**	**PSO1**	**PSO2**
CO1	3	1	2					3				3	1	3
CO2	3	1	3	1				3				3	1	3
CO3	3	1	3	2				3				3	2	3
CO4	3	1	3	2				3				3	2	3

Program	B.Sc. (Hons./ Hons. with Research) Mathematics				
Year	2	Semester	3		
Course Name	Multivariable Calculus				
Code	RBM4302				
Course Type	DSC	L	T	P	Credit
Pre-Requisite	Calculus, Vector Calculus	3	1		4
Course Objectives	The objective of the course is to develop an understanding of the differentiation and integration of the function of several variables and their applications.				
Course Outcomes: After completion of the course, students will be able to:					
CO1	Learn conceptual variations while advancing from one variable to several variables in calculus.				
CO2	Understand the extrema of multivariable functions subject to the given constraints on variables.				
CO3	Understand Inter-relationship amongst the line integral, double and triple integral formulations.				
CO4	Understand Green, Gauss and Stokes' theorems and their applications in various problems.				

Module	Course Contents	Contact Hrs.	Mapped CO
1	Functions of several variables, Limits and continuity, Partial differentiation, Higher order Partial derivatives, Total differentiation, Chain rule, Euler's theorem for homogeneous functions, Taylor's theorem for functions of two variables and more variables ([1] Chapter 15).	15	CO1
2	Envelopes and Evolutes, Extrema of functions of two and more variables, Method of Lagrange multipliers ([1] Chapter 15).	15	CO2
3	Double integration, Change of order of integration, Area by double integration, Triple integration, Volume by triple integrals, Dirichlet integral ([1] Chapter 17 & 18).	15	CO3
4	Gradient, Divergence and Curl, Line integrals, Surface integrals, Green's theorem, Stokes' theorem, The Gauss divergence theorem ([1] Chapter 17 & 18).	15	CO4

Suggested Readings

1. S. C. Malik and S. Arora, Mathematical Analysis, 4th Ed., Wiley Eastern Ltd., 2011.
2. Prasad, Gorakh, Differential Calculus (19th ed.). Pothishala Pvt. Ltd. Allahabad 2016.
3. James Stewart, Multivariable Calculus (6th edition). Thomson Brooks/Cole. Cengage 2012.
4. G.B. Thomas and R.L. Finney, Calculus, 9th Ed., Pearson Education, Delhi, 2005.

Online Resources

1 . https://archive.nptel.ac.in/courses/111/107/111107108/

Course Articulation Matrix														
PO-PSO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2
CO1	3	1	2					3				3	1	3
CO2	3	1	3	1				3				3	1	3
CO3	3	1	3	2		1		3		1		3	2	3
CO4	3	1	3	2		1		3		1		3	2	3

Program	B.Sc. (Hons./Hons. with Research) Mathematics				
Year	2	Semester	3		
Course Name	Partial Differential Equations				
Code	RBM4303				
Course Type	DSC	L	T	P	Credit
Pre-Requisite	Basic Knowledge of differential equations	3	1	0	4
Course Objectives	The objective of the course is to introduce the concept of partial differential equations and their applications.				
Course Outcomes: After completion of the course, students will be able to:					
CO1	Understand partial differential equations, their construction and existence of solution.				
CO2	Apply various analytical methods for computing solutions of various PDEs.				
CO3	Understand and solve the homogeneous and non-homogeneous equations with constant coefficients.				
CO4	Understand the formation and solution of some significant PDEs like wave equation, heat equation.				

Module	Course Contents	Contact Hrs.	Mapped CO
1	Order and degree of Partial differential equations, Concept of linear and non-linear partial differential equations, Classification of first order Partial differential equations, Derivation of partial differential equation by the elimination of arbitrary constants and arbitrary functions ([1] Chapter 1, Part III).	15	CO1
2	Lagrange's method, Some special type of equation which can be solved easily by methods other than the general method ([1] Chapter 2, Part III), Charpit's method, Special method of solutions applicable to certain standard form ([1] Chapter 3, Part III).	15	CO2
3	Homogeneous and non-homogeneous equations with constant coefficients ([1] Chapter 4 & 5, Part III), Partial differential equations reducible to equations with constant coefficients ([1] Chapter 6, Part III).	15	CO3
4	Second order PDE with variable coefficients ([1] Chapter 7, Part II), Classification of second order PDE ([1] Chapter 8, Part III), Solution of heat and wave equations in one and two dimensions by method of separation of variables ([2] Chapter 12).	15	CO4

Suggested Readings

1. M. D. Raisinghania, Advanced Differential Equations, Nineteenth Edition 2018 (Reprint with updates, S. Chand 2020.
2. Erwin Kreyszig, Advanced Engineering Mathematics (10th edition), Wiley, 2011.
3. TynMyint-U & Lokenath Debnath, Linear Partial Differential Equation for Scientists and Engineers (4th edition). Springer India 2013.
4. H. T. H. Piaggio, An Elementary Treatise on Differential Equations and Their Applications. CBS Publishers, 2004.

5. S. B. Rao & H. R. Anuradha, Differential Equations with Applications. University Press 1996.
6. Ian N. Sneddon, Elements of Partial Differential Equations. Dover Publications 2006.

Online Resources

1. https://www.youtube.com/playlist?list=PLgMDNELGJ1CZpu0rJvVh-bUHGFINS7xIk
2. https://www.youtube.com/playlist?list=PLOzRYVm0a65eWglxWw5WzQLrlG2EaiTIi

Course Articulation Matrix														
PO-PSO	**PO1**	**PO2**	**PO3**	**PO4**	**PO5**	**PO6**	**PO7**	**PO8**	**PO9**	**PO10**	**PO11**	**PO12**	**PSO1**	**PSO2**
CO1	3	1	2	1				3				3	1	3
CO2	3	1	3	2		1		3		1		3	2	3
CO3	3	1	3	2		1		3		1		3	2	3
CO4	3	2	3	3		1		3		1		3	3	3

Program	B.Sc. (Hons./Hons. with Research) Mathematics				
Year	2	Semester	4		
Course Name	Ring Theory and Vector Spaces				
Code	RBM4401				
Course Type	DSC	L	T	P	Credit
Pre-Requisite	Group theory	3	1	0	4
Course Objectives	The objective of the course is to develop in depth understanding of rings and vector spaces.				
Course Outcomes: After completion of the course, students will be able to:					
CO1	Understand the fundamental concepts of Ring, Subring, Integral domain, Field.				
CO2	Know about basic concept of Ideals, Prime Ideals and Maximal Ideal.				
CO3	Learn about ring homomorphism, Polynomial ring, Remainder and Factor theorem.				
CO4	Understand the basic concept of Vector Space, subspace, basis and dimension.				

Module	Course Contents	Contact Hrs.	Mapped CO
1	Introduction to Rings, Properties of Rings, Examples of ring including Z_m, Z[i], Z[w], Matrix ring, Quaternion ring, quotient ring, Subrings, Integral Domain, Fields ([2] Chapter 4).	15	CO1
2	Characteristics of a Ring, Ideals, Properties of Ideals, Factor Rings, Prime Ideals and Maximal ideals ([2] Chapter 5).	15	CO2
3	Ring Homomorphism, Properties of Ring Homomorphisms, First isomorphism theorem of rings, Ring of polynomials over R, Addition and Multiplication in R[x], Division algorithm for F[x], Remainder theorem, Factor Theorem ([1] Chapter 8).	15	CO3
4	Vector Space: Definition and Examples, Linear combination, Subspace, Linear dependance and Independence, Basis, Dimensions, Quotient space, Dimension of Quotient space ([1] Chapter 10).	15	CO4

Suggested Readings

1. Vijay K Khanna and S K Bhambri, A Course in Abstract Algebra (4^{th} edition), Vikash Publishing House Pvt Ltd 2013.
2. John B. Fraleigh, A First Course in Abstract Algebra (7^{th} edition). Pearson, 2006.
3. I. N. Herstein, Topics in Algebra (2nd edition). Wiley India 2006.
4. Ramji Lal. Algebra (Volume I), Shail Publication.

Online Resources

1. https://onlinecourses.nptel.ac.in/noc21_ma06/preview
2. https://onlinecourses.nptel.ac.in/noc22_ma76/preview

Course Articulation Matrix														
PO-PSO	**PO 1**	**PO 2**	**PO 3**	**PO 4**	**PO 5**	**PO 6**	**PO 7**	**PO 8**	**PO 9**	**PO10**	**PO11**	**PO12**	**PSO1**	**PSO2**
CO1	3	1	2					3				3	1	3
CO2	3	1	3	1				3				3	1	3
CO3	3	1	3	2				3				3	2	3
CO4	3	1	3	2				3				3	2	3

Program	B.Sc. (Hons./ Hons. with Research) Mathematics				
Year	2	Semester	4		
Course Name	Riemann integration & Series of Functions				
Code	RBM4402				
Course Type	DSC	L	T	P	Credit
Pre-Requisite	Calculus, Elementary Real Analysis, Sequence and Series.	3	1	-	4
Course Objectives	The objective of the course is to provide a knowledge and the key concepts of calculus and theory of Reimann integration.				
Course Outcomes: After completion of the course, students will be able to:					
CO1	Apply the concepts of Riemann integration and determine the integrability of functions using Riemann sums and related properties.				
CO2	Evaluate definite integrals using the Fundamental Theorems of Calculus and Mean Value Theorems for integrals.				
CO3	Analyze and test the convergence of improper integrals involving unbounded functions and infinite intervals.				
CO4	Examine the pointwise and uniform convergence of sequences and series of functions and their implications on continuity, differentiability and integrability.				

Module	Course Contents	Contact Hrs.	Mapped CO
1	Riemann integral: Partition and Riemann (or Darboux) sums, Properties of Riemann sums, Upper and Lower Riemann integrals, Riemann integrability, Necessary and Sufficient condition for integrability, Riemann integrability of continuous, bounded and monotonic functions. ([1] Chapter 13)	15	CO1
2	Properties of Integrable functions, Integrability of the sum, difference, Product and Quotient of integrable functions, Integrability of the modulus, square of bounded integrable functions, Inequalities for an integral, First Mean Value theorem, Continuity and Derivability of the integral function, Fundamental theorem of Integral calculus. ([1] Chapter 13)	15	CO2
3	Improper Integrals: Integration of Unbounded Functions with Finite Limits of Integration, Comparison tests for Convergence at *a* (and *b)* of $\int_a^b f\,dx$. General test for Convergence, Infinite range of Integration. Comparison Tests for Convergence at ∞. Convergence of Beta and Gamma functions. ([2] Chapter 11)	15	CO3
4	Uniform Convergence of Sequence and Series of Functions: Pointwise and uniform convergence of sequence of functions, theorems on continuity, derivability and integrability of the limit function of a sequence of functions; Series of functions, theorems on the continuity and derivability of the sum function of a series of functions, Cauchy criterion for uniform convergence and Weierstrass M-Test. ([2] Chapter 12)	15	CO4

Suggested Readings:

1. Shanti Narayan & M.D. Raisinghania, Elements of Real Analysis, S.Chand. Reprint 2021.
2. S.C. Malik & Savita Arora, Mathematical Analysis, (2nd Edition), New Age Int. Publishers.
3. R. G. Bartle and D. R. Sherbert, Introduction to Real Analysis (4th Edition), John Wileyand Sons (Asia) Pvt. Ltd., Singapore, 2010.
4. K. A. Ross, Elementary Analysis, The Theory of Calculus, Undergraduate Texts in Mathematics, Springer (SIE), Indian reprint, 2004.
5. A. Mattuck, Introduction to Analysis, Prentice Hall, 1999.

Online Resources:

1. https://nptel.ac.in/courses/111106142
2. https://onlinecourses.swayam2.ac.in/e-learning/preview/cec24_ma22
3. https://www.youtube.com/watch?v=QWksDaGZbYc

Course Articulation Matrix														
PO-PSO	**PO1**	**PO2**	**PO3**	**PO4**	**PO5**	**PO6**	**PO7**	**PO8**	**PO9**	**PO10**	**PO11**	**PO12**	**PSO1**	**PSO2**
CO1	3	1	3	1				3				3	1	3
CO2	3	1	3	1				3				3	1	3
CO3	3	1	3	2				3				3	2	3
CO4	3	1	3	2				3				3	2	3

Program	B.Sc. (Hons.) Mathematics				
Year	2	Semester		4	
Course Name	Graph Theory				
Code	RBM4403				
Course Type	DSC	L	T	P	Credit
Pre-Requisite	10+2 Mathematics	3	1		4
Course Objectives	The objective of the course is to understand and apply the fundamental concepts in graph theory.				
Course Outcomes: After completion of the course, students will be able to:					
CO1	Understand the basic ideas of Graphs.				
CO2	Apply the knowledge to discuss natures of problems.				
CO3	Understand the concept of planarity and matrix representation of graph				
CO4	Understand the concepts and applications of Coloring, Covering and Partitioning.				

Module	Course Contents	Contact Hrs.	Mapped CO
1	Graph and basic properties of graphs, finite and infinite graphs, incidence and degree, isolated and pendent vertices, Null graph, pseudo graph, complete graph, bipartite graph ([1] Chapter 1), Isomorphism, subgraphs, walk, path and circuits, connected graph, disconnected graph and components ([1] Chapter 2).	15	CO1
2	Euler circuit, Euler graph, Chinese post man problem, Hamiltonian circuit, Hamiltonian graph, travelling salesman problem ([1] Chapter 2). Directed and weighted graph, shortest path, Dijikstra's algorithm, Floyed-Warshall algorithm. ([1] Chapter 7 & 11).	15	CO2
3	Cut-sets and its properties, connectivity of graph, planar graph, maps and region, Eulers formula, planarity of graph, matrix representation of graph and its applications ([1] Chapter 7 & 11).	15	CO3
4	Coloring, Covering and Partitioning: Chromatic number, Chromatic Partitioning, Chromatic Polynomial, Matching, Covering, Four colour conjecture, Five-colour theorem, enumeration of graph. ([1] Chapter 8).	15	CO4

Suggested Readings

1. Narsingh Deo, *Graph Theory with Applications to Engineering and Computer Science,* Prentice Hall.

2. B**.** A. Davey and H. A. Priestley, *Introduction to Lattices and Order*, Cambridge University Press, Cambridge, 1990.
3. Edgar G. Goodaire and Michael M. Parmenter, *Discrete Mathematics with Graph Theory,* 2ndEdition, Pearson Education (Singapore), Indian Reprint 2003.
4. Rudolf Lidl and Gunter Pilz, *Applied Abstract Algebra*, 2nd Ed., Undergraduate Texts in Mathematics, Springer (SIE), Indian reprint, 2004.

Online Resources

1. https://books.google.com/books?id=k86aDwAAQBAJ
2. https://nptel.ac.in/courses/111101080

Course Articulation Matrix														
PO-PSO	**PO1**	**PO2**	**PO3**	**PO4**	**PO5**	**PO6**	**PO7**	**PO8**	**PO9**	**PO10**	**PO11**	**PO12**	**PSO1**	**PSO2**
CO1	3	1	2					3				3	1	3
CO2	3	1	3	1		1		3		1		3	1	3
CO3	3	1	3	1		1		3		1		3	2	3
CO3	3	1	3	2		1		3		1		3	2	3

Program	B.Sc. (Hons./Hons. with Research) Mathematics				
Year	3	Semester	5		
Course Name	Linear Algebra				
Code	RBM4501				
Course Type	DSC	L	T	P	Credit
Pre-Requisite	Foundation of Groups and Vector Spaces	3	1	0	4
Course Objectives	The objective of the course is to providing the fundamental knowledge pertaining to Linear Algebra such as linear transformation, rank nullity theorem, Inner Product Space, Adjoints, Unitary operator and Normal Operator.				
Course Outcomes: After completion of the course, students will be able to:					
CO1	Understand the basic concept of Linear Transformation, Rank Nullity Theorem.				
CO2	Know about Matrix of Linear operator, Linear Functional, Dual and Double Dual Space.				
CO3	Compute inner product and determine orthogonality on vector spaces, apply Gram-Schmidt orthogonalization process.				
CO4	Find Adjoints Operators, Unitary Operators, Normal Operators and orthogonal compliment.				

Module	Course Contents	Contact Hrs.	Mapped CO
1	Linear Transformation: Definition, Kernal and Image, Rank and Nullity, Rank-Nullity theorem, Singular and Non-Singular Linear mapping, Isomorphism. ([1] Chapter 5)	15	CO1
2	Matrix of a linear Operator, Properties of Matrix representation, change of Basis. ([1] Chapter 6) Linear Functionals, Annihilator, Dual Space, Dual Basis, Double Dual space. ([1] Chapter 11)	15	CO2
3	Inner product spaces and orthogonality, Cauchy Schwarz inequality, Orthogonal and Orthonormal Vectors, Gram Schmidt orthogonalization process. ([1] Chapter 7)	15	CO3
4	Adjoint Operators, Self-Adjoint Operators, Orthogonal and Unitary operators, Orthogonal and Unitary matrices, Unitary Operators, Normal Operators, Positive definite operators. ([1] Chapter 13)	15	CO4

Reference Books

1. Seymour Lipschutz & Marc Lipson- Linear Algebra (Schaum's outlines) 3rd edition, Tata McGRAW Hill.
2. Vijay K Khanna and S K Bhambri. A Course in Abstract Algebra(4th edition), Vikash Publishing House Pvt Ltd, 2013.
3. Kenneth Hoffman & Ray Kunze. Linear Algebra (2nd edition). Prentice-Hall, 2015.
4. Nathan Jacobson . Basic Algebra I & II (2nd edition).Dover Publications, 2009.
5. Vivek Sahai &Vikas Bist. Linear Algebra (2nd Edition).Narosa Publishing House, 2013.
6. Gilbert Strang. Linear Algebra and its Applications (2nd edition).Elsevier, 2014.

Online Resources

1. https://onlinecourses.nptel.ac.in/noc20_ma21/preview
2. https://archive.nptel.ac.in/courses/111/104/111104137/#

Course Articulation Matrix														
PO-PSO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2
CO1	3	1	3	1				3				3	1	3
CO2	3	1	3	2		1		3		1		3	2	3
CO3	3	1	3	2		1		3		1		3	2	3
CO4	3	1	3	2		1		3		1		3	2	3

Program	B.Sc. (Hons. / Hons. with Research) Mathematics				
Year	3	Semester	5		
Course Name	Set Theory and Metric Spaces				
Code	RBM4502				
Course Type	DSC	L	T	P	Credit
Pre-Requisite	Basic knowledge of Real Analysis	3	1	0	4
Course Objectives	The objective of the course is to introduce the concepts of finite and infinite sets, partially ordered sets and Metric spaces.				
Course Outcomes: After completion of the course, students will be able to:					
CO1	Understand the concepts of countable and uncountable sets and the cardinality of a set.				
CO2	Understand several standard concepts of metric spaces.				
CO3	Identify the continuity of a function defined on metric spaces.				
CO4	Understand concept of completeness of metric space.				

Module	Course Contents	Contact Hrs.	Mapped CO
1	Finite and infinite sets, Countable and uncountable sets, Cardinality of sets ([2] Chap. 4), Partially ordered set ([1] Chapter 14), Axiom of choice ([1] Chapter 15), Zorn's lemma ([1] Chapter 16), Schröder Bernstein theorem ([1] Chapter 22).	15	CO1
2	Definition and examples of metric spaces, Distance between two sets, Diameter of a set, Open spheres and closed spheres, Neighborhood of a point, Interior point and its properties, Open sets, Limit points and its properties, Closed sets, Adherent Point, closure of a set, Interior of a set, exterior and boundary points ([2] Chapter 19).	15	CO2
3	Subspaces of metric space, Dense sets, nowhere dense sets, separable spaces, Product of metric spaces, Continuous functions on metric space, properties of continuous functions, uniform continuity ([2] Chapter 19).	15	CO3
4	Cauchy and Convergent sequences, Complete metric Space, properties of complete metric space, Cantor's intersection theorem, Baire's category theorems ([2] Chapter 19).	15	CO4

Suggested Readings:

1. P. R. Halmos, Naive Set Theory, Springer, 1974.
2. Shanti Narayan, Elements of Real Analysis 13th edition, S. Chand Publication, 2012.
3. E. T. Copson, Metric Spaces, Cambridge University Press, 1988.
4. P. K. Jain & Khalil Ahmad, Metric Spaces Narosa, 2019.
5. S. Kumaresan, Topology of Metric Spaces (2nd edition) Narosa, 2011.
6. Satish Shirali & Harikishan L. Vasudeva, Metric Spaces, Springer-Verlag, 2006.

7. Micheál O'Searcoid, Metric Spaces, Springer-Verlag, 2009.
8. G. F. Simmons, Introduction to Topology and Modern Analysis. McGraw-Hill, 2004.

Online Resources

1. https://www.youtube.com/playlist?list=PLbMVogVj5nJSxFihV-ec4A3z_FOGPRCo-

Course Articulation Matrix														
PO-PSO	**PO1**	**PO2**	**PO3**	**PO4**	**PO5**	**PO6**	**PO7**	**PO8**	**PO9**	**PO10**	**PO11**	**PO12**	**PSO1**	**PSO2**
CO1	3	1	2					3				3	1	3
CO2	3	1	3	1				3				3	1	3
CO3	3	1	3	1				3				3	1	3
CO4	3	1	3	2				3				3	2	3

Program	B.Sc. (Hons./ Hons. with Research) Mathematics				
Year	3	Semester	5		
Course Name	Numerical Analysis				
Code	RBM4503				
Course Type	DSC	L	T	P	Credit
Pre-Requisite	Basic knowledge of Calculus	3	1	0	4
Course Objectives	The aim of the course is to understand the concept of Numerical Integration, interpolation and extrapolation.				
Course Outcomes: After completion of the course, students will be able to:					
CO1	Obtain numerical solutions of algebraic and transcendental equations.				
CO2	Find numerical solutions of system of linear equations and check the accuracy of the solutions.				
CO3	Learn about various interpolating and extrapolating methods.				
CO4	Apply various numerical methods in real life problems.				

Module	Course Contents	Contact Hrs.	Mapped CO
1	Round-off error and computer arithmetic, Local and global truncation errors, Algorithms, and convergence ([2] Chapter 4). Bisection method, False position method, Newton's method, and secant method for solving equations ([2] Chapter 6).	15	CO1
2	Partial and scaled partial pivoting, Lower and upper triangular (LU) decomposition of a matrix and its applications, Thomas method for tridiagonal systems, Gauss-Jacobi, Gauss-Seidel and successive over-relaxation (SOR) methods ([1] Chapter 3).	15	CO2
3	Finite difference operators, Gregory-Newton forward and backward difference interpolations. Lagrange and Newton Divided difference Interpolations ([1] Chapter 4). Numerical differentiation, Numerical Integration: Trapezoidal rule, Simpson's rules ([1] Chapter 5).	15	CO3
4	Numerical solution of ODE; introduction, Taylor's Series method, Picard's method of successive approximation, Euler's Method, Runge -Kutta method of order 4. ([2] Chapter 13).	15	CO4

Suggested Readings

1. M..K..Jain, S R K Iyengar, R K Jain, Numerical Methods for Scientific and Engineering Computation, New Age International Publishers,7th Edition, 2019.
2. E. Balagurusamy, Numerical Methods, McGraw-Hill, International Edition, 2015.

Online Resources

1. https://heecontent.upsdc.gov.in/SearchContent.aspx
2. https://swayam.gov.in/explorer?searchText=statistics

Course Articulation Matrix													
PO-PSO	**PO1**	**PO2**	**PO3**	**PO4**	**PO5**	**PO6**	**PO7**	**PO8**	**PO9**	**PO10**	**PO11**	**PO12**	**PSO1**	**PSO2**
CO1	3	1	3	2		2		3		2		3	1	3
CO2	3	1	3	2		2		3		2		3	1	3
CO3	3	1	3	2		2		3		2		3	2	3
CO4	3	2	3	3		3		3		3		3	3	3

Program	B.Sc. (Hons./Hons. with Research) Mathematics				
Year	3	Semester		6	
Course Name	Complex Analysis				
Code	RBM4601				
Course Type	DSC	L	T	P	Credit
Pre-Requisite	Basic concept of Analysis	3	1	0	4
Course Objectives	The objective of the course is to introduce the concept of the functions of complex variables, analytic functions, contour integrations and some applications.				
Course Outcomes: After completion of the course, students will be able to:					
CO1	Understand the concept of the limit, continuity and differentiability of functions of complex variables.				
CO2	Understand the concept of an analytic function and their properties.				
CO3	Understand the complex integration and their properties and apply these to evaluate complex contour integrals.				
CO4	Represent functions as Taylor and Laurent series, classify singularities and poles, find residues and evaluate complex integrals using the residue theorem.				

Module	Course Contents	Contact Hrs.	Mapped CO
1	Complex number, Algebra of complex numbers and their geometrical representation, Regions in the complex plane, Complex functions and their limits including limit at infinity, Continuity and Differentiability ([1] Chapter 1, 2).	15	CO1
2	Analytic functions, Cauchy Riemann equations, sufficient conditions for differentiability, Harmonic functions ([1] Chapter 2), Analyticity and zeros of exponential, trigonometric and logarithmic functions. ([1] Chapter 3).	15	CO2
3	Contours, Contour Integrals, Cauchy theorem (without proof), Cauchy-Goursat theorem (without proof), Cauchy integral formula, Derivative of analytic function, Liouville's theorem, Fundamental theorem of algebra ([1] Chapter 4).	15	CO3
4	Power series, Radius of convergence, Taylor series, Laurent series, Nature of singularities ([1] Chapter 5), Residues, Cauchy's residue theorem, Jordan's lemma (without proof), Evaluation of proper and improper integrals ([1] Chapter 6).	15	CO4

Suggested Readings

1. James Ward Brown & Ruel V. Churchill, Complex Variables and Applications (VIIIth edition). McGraw-Hill Education, 2009.
2. Lars V. Ahlfors, Complex Analysis (3rd edition). McGraw-Hill Education,2017.
3. Joseph Bak & Donald J. Newman, Complex Analysis (3rd edition). Springer, 2010.
4. John B. Conway, Functions of One Complex Variable. Springer-Verlag, 1973.
5. Theodore W. Gamelin, Complex Analysis. Springer-Verlag, 2001.

6. George Polya & Gordon Latta, Complex Variables. Wiley, 1974.
7. H. A. Priestley, Introduction to Complex Analysis. Oxford University Press, 2003.

Online Resources

1. https://www.youtube.com/playlist?list=PLbMVogVj5nJS_i8vfVWJG16mPcoEKMuWT

Course Articulation Matrix														
PO-PSO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2
CO1	3	1	3	1				3				3	1	3
CO2	3	1	3	1				3				3	1	3
CO3	3	1	3	2		1		3		1		3	2	3
CO4	3	1	3	2		1		3		1		3	2	3

Program	B.Sc. (Hons./ Hons. with Research) Mathematics				
Year	3	Semester	6		
Course Name	Integral Transform and Fourier Analysis				
Code	RBM4602				
Course Type	DSC	L	T	P	Credit
Pre-Requisite	Basic Knowledge of Analysis	3	1		4
Course Objectives	The objective of the course is to develop an understanding of the concept of Laplace, inverse Laplace transforms, Fourier transforms and the concept of Fourier series and their applications.				
Course Outcomes: After completion of the course, students will be able to:					
CO1	Understand the concept of Laplace transform.				
CO2	Understand the concept of Inverse Laplace transform and apply to solve the differential equations.				
CO3	**Determine** Fourier Integral, Fourier sine and cosine transform of a function.				
CO4	Expand periodic functions into Fourier series the knowledge of which is useful in signal processing and determine the Fourier sine, cosine series for functions defined on an interval.				

Module	Course Contents	Contact Hrs.	Mapped CO
1	Laplace transform, Linearity, First Shifting theorem, Change of scale property, Existence theorem, Laplace transforms of derivatives and integrals ([1] Chapter 6).	15	CO1
2	Convolution theorem, Inverse Laplace transform, Linearity property of inverse Laplace transform, Inverse transform of derivatives, Applications of Laplace transform in obtaining solutions of ordinary differential equations ([1] Chapter 6).	15	CO2
3	Fourier Integral, Fourier complex transform, Fourier and inverse Fourier transforms, Fourier sine and cosine transforms, Inverse Fourier sine and cosine transforms, Linearity property, Change of scale property, Shifting property, Relation between Fourier and Laplace transforms. Convolution theorem for Fourier transform, and its application. ([2] Chapter 20).	15	CO3
4	Periodic functions, Trigonometric series, Fourier series of period 2π, Euler's formulae, Functions having arbitrary period, Change of interval, Even and odd functions, Half range sine and cosine series. Harmonic Analysis. ([1] Chapter 11).	15	CO4

Suggested Readings

1. Erwin Kreyszig, Advanced Engineering Mathematics (10th edition). Wiley 2011.
2. B.S. Grewal, Higher Engineering Mathematics, 33rd Edition-Fifth reprint, Khanna Publishers.
3. Charles K. Chui, An Introduction to Wavelets.Academic Press 1992.
4. Walter Rudin, Fourier Analysis on Groups. Dover Publications 2017.
5. A.Zygmund, Trigonometric Series (3rd edition). Cambridge University Press 2002.

Online Resources

1 . https://archive.nptel.ac.in/courses/111/106/111106139/

Course Articulation Matrix														
PO-PSO	**PO1**	**PO2**	**PO3**	**PO4**	**PO5**	**PO6**	**PO7**	**PO8**	**PO9**	**PO10**	**PO11**	**PO12**	**PSO1**	**PSO2**
CO1	3	1	2	1				3				3	1	3
CO2	3	1	3	2		1		3		1		3	2	3
CO3	3	1	3	2		1		3		1		3	2	3
CO4	3	2	3	2		1		3		2		3	2	3

Program	B.Sc. (Hons./ Hons. with Research) Mathematics				
Year	3	Semester		6	
Course Name	Discrete Mathematics				
Code	RBM4603				
Course Type	DSC	L	T	P	Credit
Pre-Requisite	Elementary Set Theory	3	1		4
Course Objectives	The objective of the course is to provide the basic concepts in mathematical logic and discrete mathematics.				
Course Outcomes: After completion of the course, students will be able to:					
CO1	Understand the notion of mathematical thinking, mathematical proofs and algorithmic thinking, and be able to apply the problem solving.				
CO2	Understand asymptotic notation, its significance and be able to use it to analyse asymptotic performance for some basic algorithmic examples.				
CO3	Understand the concepts of mathematical logic for analyzing propositions and proving theorems				
CO4	Understand some basic properties of Tree and be able to relate these to practical examples.				

Module	Course Contents	Contact Hrs.	Mapped CO
1	**Introduction;** Sets - finite and infinite sets, uncountable infinite sets, functions, relations, operations on relation, composite relations, equality of relations ,properties of binary relations, closure, partial ordering relations ([1] Chapter 2). Counting - Pigeonhole principle, mathematical induction, principle of inclusion and exclusion([1] Chapter 5 and 6).	15	CO1
2	**Growth of Functions and Recurrences:** Asymptotic notations, summation formulas and properties, bounding summations, approximation by integrals ([1] Chapter 3). Recurrence Relation & Generating function: recurrence relations, linear recurrence relations with constant coefficients and their solution, numeric function, generating functions, solution of recurrence relation by method of generating functions ([1] Chapter 8).	15	CO2
3	**Propositional Logic**: Definition of propositions, Well-formed formulas, tautologies, satisfiability, contradiction, algebra of proposition, Normal form, theory of inference ([1] Chapter 12).	15	CO3
4	**Trees:** Definition and Properties, Pendant vertices in a tree, Distance and centers in a tree, Spanning tree, Cayley's Formula, Minimal spanning tree, Prim and Kruskal's algorithm. Traversing of tree. ([2] Chapter3).	15	CO4

Suggested Readings:

1. Kenneth Rosen, Discrete Mathematics and Its Applications, Sixth Edition, McGraw Hill 2006.
2. Narsingh Deo, *Graph Theory with Applications to Engineering and Computer Science,* Prentice Hall.
3. j. P. Tremblay and R Manohar, Discrete Mathematical structure wit Application to computer Science. Tata McGraw Hill
4. T.H. Coremen, C.E Leiserson, R. L Rivest, Introduction to algorithms, 3rd edition Prentice Hall on India, 2009.
5. M. O. Albertson and J. P. Hutchinson, Discrete Mathematics with Algorithms, John Wiley Publication, 1988.
6. D.J. Hunter, Essentials of Discrete Mathematics, Jones and Bartlett Publishers, 2008.

Online Resources:

1. https://books.google.com/books?id=k86aDwAAQBAJ
2. https://nptel.ac.in/courses/111101080

Course Articulation Matrix														
PO-PSO	**PO1**	**PO2**	**PO3**	**PO4**	**PO5**	**PO6**	**PO7**	**PO8**	**PO9**	**PO10**	**PO11**	**PO12**	**PSO1**	**PSO2**
CO1	3	1	3	1		1		3		1		3	1	3
CO2	3	1	3	2		2		3		2		3	1	3
CO3	3	1	3	1		1		3		1		3	1	3
CO4	3	1	3	2		2		3		2		3	2	3

Program	**B.Sc. (Hons./ Hons. with Research) Mathematics**				
Year	**3**	**Semester**		**5**	
Course Name	**Mathematical Modelling**				
Code	**RBME4501**				
Course Type	**DSE**	**L**	**T**	**P**	**Credit**
Pre-Requisite	**PDE**	**3**	**1**	**0**	**4**
Course Objectives	The objective of this course is to introduce the students to understand and create various mathematical models and their applications in everyday life.				
Course Outcomes: After completion of the course, students will be able to:					
CO1	Able to assess and articulate what type of modeling techniques are appropriate for a given physical system.				
CO2	Construct a mathematical model of a given physical system and analyze it.				
CO3	Learnt to predictions of the behavior of a given physical system based on the analysis of its mathematical model.				
CO4	Learn about mathematical modelling through Linear Programming.				

Module	**Course Contents**	**Contact Hrs.**	**Mapped CO**
1	Introduction to Mathematical modeling, its need, techniques and classifications. Mathematical modeling in Population dynamics, Economics, Medicine, Arms race and Battles. ([1] Chapter 3).	15	CO1
2	Mathematical modeling through in Planetary motions, Circular motion, motion of Satellites and miscellaneous mathematical models.([1] Chapter 4).	15	CO2
3	Mathematical modeling through difference equations: Economics and Finance, Population Dynamics and Genetics ([1] Chapter 5).	15	CO3
4	.Modeling through linear programming; graphical solution, simplex method ([1] Chapter 10).	15	CO4

Suggested Readings:

1. J. N.Kapur, Mathematical Modeling, New Age International Publisher, 2005.
2. Frank R.Giordano, D.Maurice Weirand William P. Fox : A First Course in Mathematical Modeling, Thomson Learning, Londonand NewYork, 2003.
3. J. N.Kapur, Mathematical Modeling in medicine and Biology, New Age Publication. [4]. D.N. Burghes, Mathematical Modeling in the Social Management and LifeScience, Ellie Herwood and John Wiley.

Online Resources:

1. https://www.slideshare.net/slideshow/kapur-j-n-mathematical-modelling-pdf/265434733

Course Articulation Matrix														
PO-PSO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2
CO1	3	1	2	2	1	1		3		1		3	1	3
CO2	3	1	3	3	1	1		3	1	1		3	2	3
CO3	3	1	3	2	1	1		3	1	1		3	2	3
CO3	3	1	3	3	2	2		3	1	2		3	2	3

Program	B.Sc. (Hons./ Hons. with Research) Mathematics				
Year	3	Semester	5		
Course Name	Optimization Techniques				
Code	RBME4502				
Course Type	DSE	L	T	P	Credit
Pre-Requisite	10+2 Mathematics	3	1	0	4
Course Objectives	The objective of the course is to Understand L.P.P' s that arise in practical situations. Learn difference between Transportation and Assignment problem. Learn difference PERT and CPM. Understand Job sequencing and its different types.				
Course Outcomes: After completion of the course, students will be able to:					
CO1	Ability to identify and develop operational research models from the verbal description of the real life problems.				
CO2	Ability of solving Linear programming problem, Transportation and Assignment problems, etc.				
CO3	Ability of solving Job sequencing problems.				
CO4	Calculate early/late start/finish times, identify the critical path, and determine total and free float for activities.				

Module	Course Contents	Contact Hrs.	Mapped CO
1	Mathematical formulation of LPP, Graphical solution for two variables and special cases (infeasible, unbounded and alternative optimal solution) ([1] Chapter 2). Simplex method, Artificial variable technique, Two phase method, Big M method ([2] Chapter 4). Primal and dual problem, Duality theorem, dual Simplex method. ([2] Chapter 5).	15	CO1
2	Transportation Problem: Mathematical formulation, Methods of obtaining initial and optimum solution, degeneracy in transportation problems, unbalanced Transportation Problem. Assignment Problem: Methods of obtaining optimum solution, Hungarian Algorithm, Maximization problem. ([1] Chapter 10).	15	CO2
3	Sequencing: Introduction to Sequencing, Basic assumptions, Types of Sequencing Problems, Johnsons Procedure for n Jobs through 2-3 machines. ([2] Chapter 20).	15	CO3
4	Project management: Basic Concept of network Scheduling, Events and activities, Rules for drawing network diagram, Project planning reducing critical events and activities, Critical path. Applications of CPM and PERT techniques in Project planning and control. ([2] Chapter 25).	15	CO4

Suggested Readings:

1. KANTI SWAROOP, P.K. GUPTA & MANMOHAN, Operation Research, 16th, S. Chand &
2. Co. New Delhi, 2013.
3. J. K. SHARMA, Operations Research: Theory & Applications, 4th, Macmillan India Ltd, 2011.
4. H. A. Taha,Operations Research: An introduction, 8th, Pearson, 2011.
5. R. K. Gupta: Operations Research, 25th edition, Krishna Prakash media(P) LTD., 2008.

Online Resources:

1. https://www.edx.org/search?q=statistics
2. https://www.coursera.org/search?query=statistics&

Course Articulation Matrix														
PO-PSO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2
CO1	3	1	3	2	2	1		3	1	1		3	1	3
CO2	3	1	3	3	2	2		3	1	2		3	2	3
CO3	3	1	3	2	1	1		3	1	1		3	1	3
CO4	3	1	3	3	2	2		3	2	2		3	2	3

Program	B.Sc. (Hons./Hons. with Research) Mathematics				
Year	3	Semester	5		
Course Name	Number Theory				
Code	RBME4503				
Course Type	DSE	L	T	P	Credit
Pre-Requisite	Basic understanding of number systems	3	1	0	4
Course Objectives	The objective of the course is to introduce the properties of numbers and concept of number theoretic functions and their properties.				
Course Outcomes: After completion of the course, students will be able to:					
CO1	Learn about some fascinating discoveries related to the properties of prime numbers and some of the open problems in number theory.				
CO2	Know the properties of Number Theory.				
CO3	Know about number theoretic functions and modular arithmetic.				
CO4	Acquire the basic knowledge of Legendre symbol and its properties and Quadratic Reciprocity law.				

Module	Course Contents	Contact Hrs.	Mapped CO
1	Divisibility theorem in Integers, Primes and their Distributions, Fundamental Theorem of Arithmetic, Greatest Common Divisor, Euclidean Algorithms, Linear Diophantine Equation ([1] Chapter 2), Goldbach Conjecture ([1] Chapter 3).	15	CO1
2	Introduction to Congruence, Linear Congruence. Chinese Remainder Theorem ([1] Chapter 4), Polynomial Congruence, System of Linear Congruence, complete set of Residues, Chinese Remainder Theorem, Fermat's Little Theorem, Wilsons Theorem ([1] Chapter 5).	15	CO2
3	Number Theoretic Functions, Sum and Number of Divisors, Totally Multiplicative Functions, Definition and Properties of the Dirichlet Product, the Mobius Inversion Formula, Greatest Integer Function ([1] Chapter 6), Euler's Phi function, Euler's Theorem, Reduced Set of Residues ([1] Chapter 7).	15	CO3
4	Order of an integer modulo n, Primitive Roots of Primes, Composite Numbers having Primitive Roots ([1] Chapter 8), Euler's Criterion, Legendre Symbol and its Properties, Quadratic Reciprocity Law ([1] Chapter 6).	15	CO4

Suggested Readings

1. D. M. Burton, Elementary Number Theory, (6thEditiobn), McGraw Hill.
2. K.H. Rosen, Elementary Number Theory & its Applications, Pearson Addition Wesley.
3. I. Niven and H.S. Zuckerman, An Introduction to Theory of Numbers, Wiley Eastern Pvt. Ltd.

4. Neville Robinns, Beginning Number Theory (2nd Edition), Narosa Publishing HousePvt. Limited, Delhi.

Online Resources

1. https://archive.nptel.ac.in/courses/111/101/111101137/
2. https://archive.nptel.ac.in/courses/111/103/111103020/

Course Articulation Matrix														
PO-PSO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2
CO1	3	2	2	1				3				3	1	3
CO2	3	1	3	1				3				3	1	3
CO3	3	1	3	1				3				3	1	3
CO4	3	2	3	2				3				3	2	3

Program	B.Sc. (Hons./ Hons. with Research) Mathematics				
Year	3	Semester	6		
Course Name	Boolean Algebra & Automata Theory				
Code	RBME4601				
Course Type	DSE	L	T	P	Credit
Pre-Requisite	Basic knowledge of algebra and number system	3	1	0	4
Course Objectives	The objective of the course is to illustrate Boolean algebra with various techniques of circuit verification, extend concepts of poset by study of lattice, study of automata theory and make solving in mathematics and computer science problems.				
Course Outcomes: After completion of the course, students will be able to:					
CO1	Acquire the knowledge of Lattices theory				
CO2	Understand the knowledge of Boolean algebra and able to optimize simple logic using Karnaugh maps.				
CO3	Elaborate and expand their understanding of the tools helpful in the implementation of circuit design.				
CO4	Develop a strong background in reasoning about finite state automata and formal languages.				

Module	Course Contents	Contact Hrs.	Mapped CO
1	Definition, examples and basic properties of ordered sets, partial order set, Hasse diagram, duality principle, product of two poset, lattices and its properties, sub-lattices, direct product and homomorphism, isomorphic lattice, distributive lattice, bounded lattice, complemented lattices, modular lattice ([1] Chapter 7).	15	CO1
2	Boolean algebras, principle of duality, Boolean polynomials, minimal forms of Boolean polynomials, Boole's Theorem, Disjunctive normal form, conjunctive normal form, Bool's Expansion Theorem, Quinn-McCluskey method, Karnaugh diagrams. ([1] Chapter 10).	15	CO2
3	Introduction to Switching algebra, Switching Functions, ([2] Chapter 3). Logic Gates, Truth Tables, Digital Circuits, Combinational Circuits, Equivalent circuit, Circuit Simplification, draw logic circuit from Boolean expression, Designing of combinational circuits- Half Adder, Full Adder, Decoders, Encoders, Multiplexers and its applications. ([2] Chapter 5).	15	CO3
4	Finite Automata- Basic concepts of automation theory, Deterministic Finite Automation (DFA), transition function, transition table, Non Deterministic Finite Automata (NDFA), Mealy and Moore machine, Minimization of finite automation([3] Chapter 2).	15	CO4

Suggested Readings:

1. Kenneth H. Rosen, Discrete Mathematics and its Applications, 7th Ed., McGraw-Hill, Indian Edition, 2012.
2. Elliott Mendelson: Boolean algebra and Switching Circuits, McCraw Hi11.2020.
3. John E. Hoprcroft, Rajeev Motwani, Jeffrey D. Ullman: Introduction to Automata Theory, Languages and Computation, Pearson Education, 2000
4. K. L. P. Mishra and N. Chandrasekaran, Theory of Computer Science, Automata, Languages and Computation, 3rd Ed. Printice Hall of India Pvt. Ltd., New Delhi, 2008.
5. Peter Linz, Formal Languages and Automata, Narosa Publishing House, New Delhi.
6. Edgar G. Goodaire and Michael M. Parmenter, Discrete Mathematics with Graph Theory, (2nd Ed.), Pearson Education (Singapore), Indian Reprint 2003.

Online Resources;

1. https://heecontent.upsdc.gov.in/
2. https://archive.nptel.ac.in/courses/111/103/111103016/
3. https://archive.nptel.ac.in/courses/106/105/106105185/

Course Articulation Matrix														
PO-PSO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2
CO1	3	1	2	1				3				3	1	3
CO2	3	1	3	2		2		3		2		3	1	3
CO3	3	1	3	2		3		3		3		3	2	3
CO4	3	1	3	2		2		3		3		3	2	3

Program	B.Sc. (Hons./Hons. with Research) Mathematics				
Year	3	Semester		6	
Course Name	Fuzzy Mathematics				
Code	RBME4602				
Course Type	DSE	L	T	P	Credit
Pre-Requisite	Basic knowledge of set theory	3	1	0	4
Course Objectives	The objective of the course is to develop the fundamental concepts such as fuzzy sets, operations and fuzzy relations				
Course Outcomes: After completion of the course, students will be able to:					
CO1	interpret fuzzy set theory and the concepts of fuzzy relations.				
CO2	identify the similarities and differences between probability theory and fuzzy set theory.				
CO3	Understand the concepts of classical and multivalued logics.				
CO4	interpret fuzzy set theory and uncertainty concepts				

Module	Course Contents	Contact Hrs.	Mapped CO
1	Classical and Fuzzy sets: Crisp sets, Crisp relation, Maxmin composition, Properties of membership function, Fuzzy sets and their basic concepts, Operations on fuzzy sets, Fuzzy arithmetic, Fuzzy relations, Fuzzy relation equations based on sup–i composition and Inf–i composition, Fuzzification and Defuzzification.(Chapter 2, 3[1]).	15	CO1
2	Possibility theory and fuzzy sets: Possibility theory, Fuzzy measure, Evidence theory, Fuzzy sets and possibility theory. (Chapter 1, 15[1]).	15	CO2
3	Fuzzy and Classical logic: Multivalued logic, Fuzzy propositions, Fuzzy quantifiers, Inference from conditional fuzzy propositions, Fuzzy statistical process control. (Chapter 5, 8, 10[1]).	15	CO3
4	Uncertainty based Information: Information and Uncertainty, Non specificity of Crisp sets, Non specificity of Fuzzy sets, Fuzziness of Fuzzy sets, Fuzzy sets in Business management, Psychology, Foods and nutrition with good number of case studies.(Chapter 1, 8, 13[1]).	15	CO4

Suggested Readings:

1. T.J. Ross: Fuzzy Logic with Engineering and Applications,Wiley Student Edition, 2010.
2. B.M Ayyub and L.N. Kanal: Analysis and Management of Uncertainty: Theory and Application, North Holland, New York, 1992.
3. W. Bandler and W. Nather: Fuzzy Data Analysis, Kluwer Academic Press, 1996.
4. A. Wesley: Fuzzy Mathematical Techniques with Applications, 1985.
5. J.K. George: Fuzzy Sets and Fuzzy Logic, Theory and Applications, Yuan Prentice Hall,2006.

Online Resources:

1. https://youtu.be/oWqXwCEfY78?list=PLjZ9ULh2Ff9FWvv-DiZHP6RN0kMr_4aW4

Course Articulation Matrix														
PO-PSO	**PO1**	**PO2**	**PO3**	**PO4**	**PO5**	**PO6**	**PO7**	**PO8**	**PO9**	**PO10**	**PO11**	**PO12**	**PSO1**	**PSO2**
CO1	3	1	3	1		1		3		1		3	1	3
CO2	3	1	3	2		1		3		1		3	1	3
CO3	3	1	3	2		1		3		1		3	2	3
CO4	3	1	3	2		2		3		2		3	2	3

Program	B.Sc.(Hons./Hons. with Research) Mathematics				
Year	3	Semester	6		
Course Name	Ordinary and Partial Differential Equations				
Code	RBME4603				
Course Type	DSE	L	T	P	Credit
Pre-Requisite	Basic concept of ODE and PDE	3	1	0	4
Course Objectives	The objective of the course is to introduce the concept of ODE, existence and uniqueness solution and various analytic methods for computing the solutions of partial differential equations.				
Course Outcomes: After completion of the course, students will be able to:					
CO1	Understand ordinary differential equations of various types, their solutions, and fundamental concepts about their existence.				
CO2	Understand the concept of autonomous system, Phase Plane and Its phenomena, types of critical points and stability for Linear Systems.				
CO3	Understand the concept and applications of eigen value problems and differential equations of Strum Liouville type.				
CO4	Apply various analytic methods for computing solutions of various PDEs.				

Module	Course Contents	Contact Hrs.	Mapped CO
1	Linear Second Order Equations; Initial value problem ([1] Chapter 3), Existence and Uniqueness by Picard's Theorem ([1] Chapter 13), Wronskian, Separation and comparison theorems, Poincare phase plane, Operator Methods for Finding Particular Solutions ([1] Chapter 11)	15	CO1
2	Autonomous System, The Phase Plane and Its Phenomena, Types of Critical Points. Stability, Critical Points and Stability for Linear Systems, Stability by Liapunov's Direct Method, Simple Critical Points of Nonlinear Systems. ([1] Chapter 11).	15	CO2
3	Boundary Value Problems; Sturm–Liouville system, Eigen values and eigen functions ([3] Chapter 5), Simple properties, Expansion in eigen functions, Green's function method ([3] Chapter 6).	15	CO3
4	Partial Differential Equations; Cauchy problems and characteristics, Classification of Second order PDE's, Reduction to canonical forms, Derivation of the equations of mathematical physics and their solutions by separation of variables. ([2] Chapter 2)	15	CO4

Suggested Readings

1. G. F. Simmons, Ordinary Differential Equations with Applications and Historical Notes. Tata McGraw Hill Edition, IIIrd Edition, 2017.
2. IAN. Sneddon: Theory of Partial differential equations, McGraw-Hill, International Student Edition.
3. R. Courant and D. Hilbert: Methods of Mathematical Physics, Vol. I. & II, Tata McGraw-Hill, New Delhi, 1975

Online Resources

1. https://www.youtube.com/playlist?list=PLLy_2iUCG87CX7wprwaVnYbVce1ftGlDV

Course Articulation Matrix														
PO-PSO	**PO1**	**PO2**	**PO3**	**PO4**	**PO5**	**PO6**	**PO7**	**PO8**	**PO9**	**PO10**	**PO11**	**PO12**	**PSO1**	**PSO2**
CO1	3	1	3	2				3				3	1	3
CO2	3	1	3	2		1		3		1		3	2	3
CO3	3	1	3	3		1		3		1		3	2	3
CO4	3	2	3	3		2		3		2		3	3	3

Program	B.Sc. (Hons./Hons. with Research) Mathematics				
Year	4	Semester	7		
Course Name	Abstract Algebra				
Code	RBME4701				
Course Type	DSE	L	T	P	Credit
Pre-Requisite	Foundation of Group theory and Ring theory	3	1	0	4
Course Objectives	This objective of the course is to develop the theoretical concepts of group, ring, bilinear and quadratic form of matrix.				
Course Outcomes: After completion of the course, students will be able to:					
CO1	Understand the basic concepts of group actions and their applications.				
CO2	Recognize the fundamental theorem of finitely generated abelian group.				
CO3	Understand the basic concept of Principal integral domain, Unique factorization domain.				
CO4	Understand the concept and explain the significance of Matrix of Bilinear form and Quadratic form.				

Module	Course Contents	Contact Hrs.	Mapped CO
1	Automorphism, Inner automorphism and conjugate elements, Characteristic subgroups, Conjugate elements, Relation of conjugacy and classes of conjugate elements, Self-conjugate elements, Counting principle and the class equation of a finite group, Group actions, Orbits and stabilizers, Orbit-stabilizer theorem, Sylow theorems (With out proof) ([2] Chapter 4).	15	CO1
2	External Direct Product: Definition and Examples, Properties of External direct product, group of unit modulo n as an external direct product, Fundamental theorem of finitely generated abelian group. ([1] Chapter 8)	15	CO2
3	Euclidean domains, Principal ideal domain (PID), Unique factorization domains, Fundamental Theorem of Arithmetic, ([2] Chapter 9), Gauss Theorem ([5] Chap. 7).	15	CO3
4	Bilinear forms, Matrix of a Bilinear forms, Quadratic Forms, Matrix of a Quadratic forms, Quadratic forms corresponding to any given symmetric matrix. ([6] Chapter 12).	15	CO4

Suggested Readings:

5. Joseph A. Gallian, Contemporary Abstract Algebra (4th edition). Narosa
6. Vijay k Khanna and S K Bhambri, A Course in Abstract Algebra (4th edition), Vikash Publishing House Pvt Ltd.
7. John B. Fraleigh, A First Course in Abstract Algebra (7th edition). Pearson.
8. I. N. Herstein, Topics in Algebra (2nd edition). Wiley India.
9. Ramji Lal, Algebra (Volume II), Shail Publication.
10. Schaum's outlines, Linear Algebra, third edition, Tata McGraw-Hills.

Online Resources:

1. https://archive.nptel.ac.in/courses/111/106/111106131/
2. https://digimat.in/nptel/courses/video/111105161/L18.html

Course Articulation Matrix														
PO-PSO	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6	PO 7	PO 8	PO 9	PO 10	PO 11	PO 12	PSO 1	PSO 2
CO1	3	1	3	1				3				3	1	3
CO2	3	1	3	2				3				3	2	3
CO3	3	1	3	2				3				3	2	3
CO4	3	1	3	2				3				3	2	3

Program	B.Sc. (Hons./Hons. with Research) Mathematics				
Year	4	Semester	7		
Course Name	Topology				
Code	RBME4702				
Course Type	DSE	L	T	P	Credit
Pre-Requisite	Basic knowledge of Analysis	3	1	0	4
Course Objectives	The objective of the course is to introduce the concept of the topological spaces and their properties.				
Course Outcomes: After completion of the course, students will be able to:					
CO1	Understand the concepts of topological spaces and the basic definitions of open sets, neighbourhood, interior, exterior, closure and their axioms for defining topological space.				
CO2	Understand the concept of compactness, ascoli's theorem.				
CO3	Understand how points of space are separated by open sets, Housdroff spaces and their importance.				
CO4	Understand connectedness and topological properties.				

Module	Course Contents	Contact Hrs.	Mapped CO
1	Topological Spaces: The Definition and examples, Elementary concepts, Open bases and open subbases, Weak topologies ([1] Chapter 3).	15	CO1
2	Compactness: Compact spaces, Products of spaces, Tychonoff's theorem and locally compact spaces, Compactness for metric spaces, Ascoli's theorem. ([1] Chapter 4).	15	CO2
3	Separation: T1 spaces and Hausdorff spaces, Completely regular spaces and normal spaces, Urysohn's lemma and the Tietze extension theorem, The Urysohn imbedding theorem. ([1] Chapter 5).	15	CO3
4	Connectedness: Connected spaces, The components of a spaces, Totally disconnected spaces, Locally connected spaces. ([1] Chapter 6).	15	CO4

Suggested Readings:

1. G.F. Simmon's: Introduction to Topology and Modern Analysis, Tata McGraw Hill Edition.
2. W. J. Pervin: Foundations of General Topology.
3. Willard: Topology, Academic press.
4. Vicker: Topology via logic, (School of Computing, Imperial College, London).
5. J. R. Munkers: Topology, A First Course, Prentice Hall of India Pvt. Ltd.

Online Resources:

1. https://www.youtube.com/playlist?list=PLbMVogVj5nJRR7zYZifYopb52zjoScx1d

Course Articulation Matrix														
PO-PSO	**PO1**	**PO2**	**PO3**	**PO4**	**PO5**	**PO6**	**PO7**	**PO8**	**PO9**	**PO10**	**PO11**	**PO12**	**PSO1**	**PSO2**
CO1	3	1	3	1				3				3	1	3
CO2	3	1	3	2				3				3	2	3
CO3	3	1	3	2				3				3	2	3
CO4	3	1	3	2				3				3	2	3

Program	B.Sc. (Hons. /Hons. with Research) Mathematics				
Year	4	Semester	7		
Course Name	Real Analysis				
Code	RBME4703				
Course Type	DSE	L	T	P	Credit
Pre-Requisite	Basic knowledge of metric space and convergence.	3	1	0	4
Course Objectives	The connective of the course is to develop the concepts compactness and connectedness o of the metric and differentiation and integration of the function of several variables and their applications.				
Course Outcomes: After completion of the course, students will be able to:					
CO1	Understand the concepts of compactness and connectedness in the metric space.				
CO2	Learn the concepts of Continuity and Compactness, Continuity and connectedness and Reimann-Stielties integral and its properties.				
CO3	Understand the concepts of Riemann Stielties integral and its properties.				
CO4	Understand and apply the concepts of uniform convergence and approximation of continuous function.				

Module	Course Contents	Contact Hrs.	Mapped CO
1	Metric spaces, Compact sets, Perfect sets, Connected sets ([1] Chapter 2)	15	CO1
2	Limits of functions, Continuous functions, Continuity and Compactness, Continuity and connectedness, Discontinuities, Monotone functions. ([1] Chapter 4)	15	CO2
3	Definition and existence of the Riemann Stieltjes integral, Properties of the integral, Integration of vector valued functions, Rectifiable curves. ([1] Chapter 6)	15	CO3
4	Sequences and series of functions: Uniform convergence, Uniform convergence and continuity, Uniform convergence and integration, Uniform convergence and differentiation, Approximation of a continuous function by a sequence of polynomials. ([1] Chapter 7)	15	CO4

Suggested Readings:

1. Walter Rudin, *Principle of Mathematical Analysis* (3rd edition) McGraw- Hill, 1976, International Student Edition.
2. K. Knopp, *Theory and Application of Infinite Series*.
3. T. M. Apostol, *Mathematical Analysis*, Narosa Publishing House, New Delhi, 1985.
4. P. Natanson: Theory of Functions of a Real Variable, Volume 1, Frederick Pub. Co., 1964
5. H. L. Royden: Real Analysis, McMillan Publication Co. Inc. New York.

Online Resources:

1. https://archive.nptel.ac.in/courses/111/106/111106053/

Course Articulation Matrix														
PO-PSO	PO1	PO 2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO 10	PO1 1	PO 12	PSO1	PSO2
CO1	3	1	3	1				3				3	1	3
CO2	3	1	3	2				3				3	2	3
CO3	3	1	3	2				3				3	2	3
CO4	3	2	3	2				3				3	2	3

.Program	B.Sc. (Hons./ Hons. with Research) Mathematics				
Year	4	Semester	7		
Course Name	Analytical Geometry				
Code	RBME4704				
Course Type	DSE	L	T	P	Credit
Pre-Requisite	Basic Concept of Co-ordinate Geometry	3	1	0	4
Course Objectives	The objective of the course is to develop an understanding of the concept of conicoid, plane section of conicoid, generating line of conicoid with their mathematical equations using analytical methods.				
Course Outcomes: After completion of the course, students will be able to:					
CO1	Classify conicoids and understand their nature and geometrical properties.				
CO2	Understand the nature of plane sections of conicoids, umbilics of a paraboloid and classify the general equation of second degree.				
CO3	Apply and determine generating lines and classify the quadrics.				
CO4	Understand and apply the concept of central points and General equation of second degree.				

Module	Course Contents	Contact Hrs.	Mapped CO
1	The conicoid: The general equation of second degree, shapes of surfaces. Intersection of a line with conicoid; tangent lines and tangent plane at a point, condition of tangency, director sphere, normal, number of normals from a given point. Plane of contact. The polar plane of a point. Enveloping cone and cylinder ([1] Chapter 8).	15	CO1
2	Plane sections of conicoids: Nature of the plane section of central conicoid; axes of central plane section, area plane sections, axes of non-central plane section, circular sections, sections of paraboloids, circular sections of paraboloids, umbilics of a paraboloid, ([1] Chapter 9).	15	CO2
3	Generating line of conicoids: Ruled surfaces, generating lines of a hyperboloid of one sheet, equations of the two generating lines, projections of the generators, intersection of perpendicular generator of the hyperboloid, central point, hyperbolic paraboloid, central points, line of striction ([1] Chapter 10).	15	CO3
4	General equation of second degree: Reduction to canonical forms with classification, Polar plane of a point. Diameter plane conjugate to a given direction. Principal direction and planes. Transformations of coordinates. Quadrics of revolution.([1] Chapter 11).	15	CO4

Suggested Readings:

1. Shanti Narayan, Dr. P.K. Mittal, Analytical Solid Geometry, 16th Ed. S. Chand Publishing.
2. S. L. Loney The Elements of Coordinate Geometry, McMillan and Company, London.
3. R. J. T. Bill, Elementary Treatiseon Coordinate Geometry of Three Dimensions, McMillan India Ltd, 1994.

Online Resources:

1. NPTEL/SWAYAM/ MOOCS/Openstax.org
2. https://openlearninglibrary.mit/edu/courses
3. http://heecontent.upsdc.gov.in/SearchContent.aspx

Course Articulation Matrix														
PO-PSO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2
CO1	3	1	2	1				3				3	1	3
CO2	3	1	3	1				3				3	1	3
CO3	3	1	3	2				3		1		3	1	3
CO4	3	1	3	2				3		1		3	2	3

Program	B.Sc. (Hons./Hons. with Research) Mathematics				
Year	4	Semester	8		
Course Name	Advance Algebra				
Code	RBME4801				
Course Type	DSE	L	T	P	Credit
Pre-Requisite	Knowledge of Groups and Fields	3	1	0	4
Course Objectives	The objective of the course is to introduce fundamental concepts of Field Theory and Galois Theory.				
Course Outcomes: After completion of the course, students will be able to:					
CO1	Understand the concept of extension of field.				
CO2	Understand the concept splitting field, normal extension, Multiple roots.				
CO3	Understand the concept of Galois theory.				
CO4	Understand the concept of Polynomials solvable by radicals, ruler and the compass constructions.				

Module	Course Contents	Contact Hrs.	Mapped CO
1	Algebraic extensions of fields; Irreducible polynomials and Eisenstein criterion, Adjunction of roots-Algebraic extensions, algebraically closed fields ([3] Chapter 6).	15	CO1
2	Normal and separable extensions; Splitting fields, Normal extensions, Multiple roots, Finite Fields-Separable extensions ([2] Chapter 11).	15	CO2
3	Galois theory; Automorphism groups and fixed fields, Fundamental theorem of Galois theory, Fundamental theorem of Algebra ([3] Chapter 10).	12	CO3
4	Roots of unity, Polynomials solvable by radicals, Ruler and Compass constructions ([5] Chapter 15).	13	CO4

Suggested Readings

11. Joseph A. Gallian, Contemporary Abstract Algebra (4th edition). Narosa
12. Ramji Lal, Shail Publication, Algebra (Volume 2)
13. John B. Fraleigh, A First Course in Abstract Algebra (7th edition). Pearson.
14. I. N. Herstein, Topics in Algebra (2nd edition). Wiley India.
15. Vijay K Khanna and S K Bhambri, A Course in Abstract Algebra(4th edition), Vikash Publishing House Pvt Ltd.

Online Resources

1. Introduction to Galois Theory - Course (nptel.ac.in)
2. https://math.mit.edu/~dav/galois.pdf

Course Articulation Matrix														
PO-PSO	**PO1**	**PO2**	**PO3**	**PO4**	**PO5**	**PO6**	**PO7**	**PO8**	**PO9**	**PO10**	**PO11**	**PO12**	**PSO1**	**PSO2**
CO1	3	1	3	1				3				3	1	3
CO2	3	1	3	2				3				3	2	3
CO3	3	2	3	3				3				3	3	3
CO4	3	2	3	3				3				3	3	3

Program	B.Sc. (Hons./Hons. with Research) Mathematics				
Year	4	Semester	8		
Course Name	Advance Real Analysis				
Code	RBME4802				
Course Type	DSE	L	T	P	Credit
Pre-Requisite	Basic knowledge of real analysis.	3	1	0	4
Course Objectives	The objective of the course is to develop the advanced concept of real analysis and give sufficient knowledge of the subject which can be used by students for further applications in their respective domains of interest.				
Course Outcomes: After completion of the course, students will be able to:					
CO1	Understand the concepts of measure and Lebesgue measure.				
CO2	Learn the properties of Lebesgue integral and understand the concepts of non-negative functions.				
CO3	Understand the convergence and differentiation of a monotonic functions.				
CO4	Understand Minkowski and Holder's inequalities.				

Module	Course Contents	Contact Hrs.	Mapped CO
1	Algebra of sets, Borel sets, Outer measure, Measurable sets and Lebesgue measure, A non-measurable set, Measurable functions, Little word's three principles. ([1] Chapter 3).	15	CO1
2	The Lebesgue integral of a bounded function over a set of finite measure, The integral of a non-negative function, The general Lebesgue integral. ([1] Chapter 4).	15	CO2
3	Convergence in measure, Differentiation of a monotone functions, Functions of bounded variation. ([1] Chapter 5).	15	CO3
4	Differentiation of an integral, Absolute continuity, The Lp-spaces, The Minkowski and Holder's inequalities, Convergence and completeness. ([1] Chapter 4 & 5).	15	CO4

Suggested Readings:

1. H. L. Royden: Real Analysis , Pearson Education (3rd Edition) (Low Price Edition).
2. P. R. Halmos: Measure Theory, Van Nostrand, 1950.
3. G. de Barra: Measure Theory and Integration, Wiley Eastern, 1981.
4. E. Hewitt and K. Stromberg: Real and Abstract Analysis, Springer, 1969.
5. P. K. Jain and V. P. Gupta: Lebesgue Measure and Integration, New Age International, New Delhi, 2000.
6. Walter Rudin: Principle of Mathematical Analysis (3rd edition) McGraw Hill, International Student Edition, 1976.

Online Resources:

1. https://archive.nptel.ac.in/courses/111/108/111108135/
2. https://onlinecourses.nptel.ac.in/noc20_ma02/preview

Course Articulation Matrix														
PO-PSO	**PO1**	**PO2**	**PO3**	**PO4**	**PO5**	**PO6**	**PO7**	**PO8**	**PO9**	**PO10**	**PO11**	**PO12**	**PSO1**	**PSO2**
CO1	3	1	3	2				3				3	2	3
CO2	3	1	3	2				3				3	2	3
CO3	3	1	3	2				3				3	2	3
CO4	3	2	3	2				3				3	2	3

Program	B.Sc. (Hons./Hons. with Research) Mathematics				
Year	4	Semester	8		
Course Name	Functional Analysis				
Code	RBME4803				
Course Type	DSE	L	T	P	Credit
Pre-Requisite	Knowledge of Set theory and vector space.	3	1	0	4
Course Objectives	The objective of the course is to provide a foundation in functional analysis, focusing on various spaces.				
Course Outcomes: After completion of the course, students will be able to:					
CO1	To understand topological-algebraical structures and the methods by which the knowledge of these methods can be applied to analytic problems				
CO2	Understand the concept of normed linear spaces and various properties operators defined on them.				
CO3	Understand the main properties of bounded operators between Banach and Hilbert spaces, the basic results associated to different types of convergences in normed spaces and the spectral theorem and some of its applications.				
CO4	Understand the concept of the spectrum of bounded operators and how much it will be helpful in solving certain differential equations.				

Module	Course Contents	Contact Hrs.	Mapped CO
1	Banach Spaces; Definition and some examples continuous linear transformations, The Hahn-Banach theorem ([1] Chapter 9).	15	CO1
2	The natural imbedding of N in N**, the open mapping theorem, Closed Graph Theorem, The conjugate of an operator, The uniform boundedness Theorem. ([1] Chapter 9).	15	CO2
3	Pre-Hilbert space and Hilbert spaces; The definition and some simple properties, Orthogonal complements, orthogonal sets, the conjugate space H*. ([1] Chapter 10, [2] Chapter 3).	15	CO3
4	The adjoint of an operator, Self adjoint operators, Normal and Unitary operators, Projections. Finite dimensional spectral theory; Spectrum of an operator, the spectral theorem. ([1] Chapter 10& 11).	15	CO4

Suggested Readings:

1. G. F Simmons, Introduction to Topology & Modern Analysis, McGraw Hill Education (India) Pvt. Ltd., New Delhi.
2. E. Kreyszig, Introductory Functional Analysis with applications, John-Wiley and Sons, New York.
3. Walter Rudin, Functional Analysis, McGraw Hill, New Delhi.

Online Resources:

1. https://onlinecourses.nptel.ac.in/noc22_ma22/preview
2. https://archive.nptel.ac.in/courses/111/105/111105037/

Course Articulation Matrix														
PO-PSO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO 10	PO11	PO 12	PSO1	PSO2
CO1	3	1	3	2				3				3	2	3
CO2	3	1	3	2		1		3		1		3	2	3
CO3	3	2	3	3		1		3		1		3	3	3
CO4	3	2	3	3		1		3		1		3	3	3

Program	B.Sc. (Hons./Hons. with Research) Mathematics				
Year	4	Semester		8	
Course Name	Computational Fluid Dynamics				
Code	RBME4804				
Course Type	DSE	L	T	P	Credit
Pre-Requisite	PDE and basic knowledge of fluid dynamics principles	3	1	0	4
Course Objectives	The objective is to introduce the concept of the basics of fluid flow, its model and tool to solve the fluid flow problems.				
Course Outcomes: After completion of the course, students will be able to:					
CO1	Develop concept of computational fluid dynamics and the application of PDE.				
CO2	Apply CFD codes in the design of fluid systems and components.				
CO3	Provide the essential numerical background for solving the PDE's governing the fluid flow and use of viscous terms in the NS equations.				
CO4	Understand boundary layer flow, Incompressible & compressible viscous flow.				

Module	Course Contents	Contact Hrs.	Mapped CO
1	Introduction: Basics of CFD, Advances of computational fluid dynamics, Partial Differential Equations Types, Governing equations and assumptions, Boundary conditions ([5] Chapter 2).	15	1
2	Basics of Discretization Techniques: Explicit schemes, implicit schemes ([5] Chapter 3), Grid generation ([5] Chapter 10), Finite Difference Method, Finite Volume Method and Finite Element Method ([5] Chapter 4).	15	2
3	Solving the Fluid Dynamic Equations: Flows governed by reduced Navier-Stokes Equations, Convective-Diffusive equations, Internal and external flows, supersonic inviscid flows ([1] Vol. 2 Chapter 16).	15	3
4	Laminar boundary layer flow, unsteady boundary layers, finite difference methods for two dimensional flows ([1] Vol. 2 Chapter 11), Incompressible ([1] Vol. 2 Chapter 17) & compressible Viscous Flow ([1] Vol. 2 Chapter 18).	15	4

Suggested Readings:

1. C. A. J. Fletcher, Computational Techniques for Fluid Dynamics, Volume 1 & 2, Springer Verlag, 1992.
2. C. Y. Chow, Introduction to Computational Fluid Dynamics, John Wiley, 1979.
3. M. Holt, Numerical Methods in Fluid Mechanics, Springer Verlag, 1977.
4. H. J. Wirz and J. J. Smolderen, Numerical Methods in Fluid Dynamics, Hemisphere, 1978.
5. D. A. Anderson, J. C. Tannehill and R. H. Pletcher, Computational Fluid Dynamics and Heat
6. Transfer, McGraw Hill, 1984.

Online Resources:

1. https://archive.nptel.ac.in/courses/112/105/112105254/
2. https://www.youtube.com/playlist?list=PL8EAF844326CBB2E3

Course Articulation Matrix														
PO-PSO	**PO1**	**PO2**	**PO3**	**PO4**	**PO5**	**PO6**	**PO7**	**PO8**	**PO9**	**PO10**	**PO11**	**PO12**	**PSO1**	**PSO2**
CO1	3	1	3	2	1	2		3		2		3	2	3
CO2	3	1	3	3	1	3	1	3	1	3		3	2	3
CO3	3	1	3	3	1	3	1	3	1	3		3	3	3
CO4	3	2	3	3	2	2	1	3	1	2		3	3	3

Program	**B.Sc. (Hons./ Hons. with research) Mathematics**				
Year	**1**	**Semester**	**1**		
Course Name	**Python Programming**				
Code	**RBMG1101**				
Course Type	**GE**	**L**	**T**	**P**	**Credit**
Pre-Requisite	Basic Knowledge of Computer Fundamentals	**3**	1	**-**	3
Course Objectives	To provide programming constructs such as variables, conditional logic, looping, functions and the concepts of String, List and Tuples, Dictionary, Sets etc. Data handling using Numpy and Pandas Library.				

Course Outcomes: Upon successful completion of course, a student will be able to:	
CO1	Analyse, design and execute Python programs that integrate variables, operators, conditional statements and loops to solve basic real-world problems.
CO2	Understand Python data structures, including strings, lists, tuples, sets, and dictionaries, along with their characteristics and applications.
CO3	Integrate modules, object-oriented programming, file handling, and exception handling concepts to create efficient and maintainable Python applications.
CO4	Understand the fundamentals of data visualization and the role of graphical representation in data analysis and interpretation.

Module	**Course Contents**	**Contact Hrs.**	**Mapped CO**
1	**Python Introduction and Setting up the Environment:** Introduction to Python Programming, Python Interpreter and Interactive Mode, Basic Syntax and Data Types: Input/output, Comments, Variables, Data types, Typecasting; Operators: Arithmetic, Assignment, Comparison, Logical, Identity, Membership, Bitwise operators; Conditional Statements: if, if-else, else. Loops: while, for, break, continue, pass, range. ([1] Chapter 1-2).	15	1
2	**Data Structures and Functions:** Strings, Lists: Creating, Properties, Indexing, Slicing, Methods, Modifying lists. Tuples: Syntax, Properties, Indexing, Slicing, Methods. Sets, Dictionaries ([1] Chapter 1-4). Functions: Creating, Calling, Arguments, Variables, Scope and Lifetime of Variables, local variables, global variables, Recursion, Lambda Functions, map(), filter() and	15	2

	reduce() ([1] Chapter 6).		
3	**Modules and Exceptions:** Importing module, Creating and exploring modules, Math module, Random module, Time module. Packages: Creating, Importing. OOPs: Classes & Objects, Inheritance. Files: Opening, Reading, Writing, Closing files. Exceptions & Error Handling: Syntax errors, Logical errors, try/except/finally ([1] Chapter 16).	15	3
4	**Matplotlib:** Plotting from a script, Line Colors and Styles: Axes Limits, Labelling Plots; Simple Scatter Plots, Visualizing Errors, Histograms, Binnings, and Density. Kernel density estimation, Geographic Data with Basemap: Map Projections, Drawing a Map Background - Plotting Data on Maps, Visualization with Seaborn: Pair plots ([5] Chapter 1-5).	15	4

Suggested Readings

1. Core Python Programming" by Dr. R. Nageswara Rao is a highly popular, comprehensive textbook primarily published by Dreamtech Press
2. Python Data Science Handbook: Essential Tools for Working with Data by Jake VanderPlas, O'Reilly Media, (2017)
3. Matthes, Eric. *Python Crash Course: A Hands-On, Project-Based Introduction to Programming*. 3rd ed., No Starch Press, 2023.
4. Sweigart, *Practical Programming for Total Beginners*. 2nd ed., No Starch Press, 2019.
5. Hands-On Python Seaborn: A Practical Guide to Data Visualization by Sarful Hassan (2025).
6. Ramalho, Luciano. *Fluent Python: Clear, Concise, and Effective Programming*. 2nd ed., O'Reilly Media, 2022.
7. Chun, Wesley J. Chun. *Core Python Programming*. 2nd ed., Pearson Education, 2006.

Online Resources

1. https://archive.nptel.ac.in/courses/106/106/106106182/
2. https://nptel.ac.in/courses/106106212\

PO-PSO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2
CO1	3	1	3	2	1	3		3		3	1	2	1	3
CO2	2	1	2	1		3		3		3		2	1	2
CO3	3	2	3	2		3		3		3	1	2	2	3
CO4	2	1	3	2	1	3		3		3	1	2	1	2

Program	B.Sc. (Hons./ Hons. with research) Mathematics				
Year	1	Semester		1	
Course Name	Python Programming Lab				
Code	RBMG1151				
Course Type	GE	L	T	P	Credit
Pre-Requisite	Basic Concept of Computer Fundamentals	-	-	2	1
Course Objectives	To implement conditional logic, looping, functions and the concepts of String, List, Tuples and Data Visualization.				
Course Outcomes: Upon successful completion of course, a student will be able to:					
CO1	Apply Python programming fundamentals, including variables, operators, input/output statements, conditional branching, and iterative constructs, to develop solutions for computational problems.				
CO2	Utilize Python data structures such as strings, lists, tuples, dictionaries, and sets to organize, manipulate, and analyze data effectively.				
CO3	Develop modular Python programs using user-defined and recursive functions, and employ built-in modules to solve mathematical and real-world problems efficiently.				
CO4	Implement file handling operations, object-oriented programming concepts, and basic data visualization techniques using Matplotlib/Seaborn for data processing and graphical representation.				

The Lab work based on the course RBMG1151 shall include the problems on the following:

1. **Basics & Control Flow:** Variables, mathematical operators, and I/O statements. Conditional branching: if, if-else, and if-elif-else statements. Iterative statements and loops: for, while, and nested loops.

2. **Data Structures:** Strings: Slicing, concatenation, and built-in methods (slice(), dict(), eval(), etc). Lists and Tuples: Traversing, slicing, finding minimum/maximum values, and removing duplicates. Dictionaries: Creating key-value pairs, updating records, and sorting. Sets: Set operations (union, intersection, difference).

3. **Functions & Modules:** Creating user-defined functions and passing arguments. Recursive functions (e.g., calculating sum of first n natural

numbers, Fibonacci series). Importing and utilizing built-in Python modules (e.g., math, random, string).

4. **File Handling & OOP:** File I/O operations: Creating, opening, reading, writing, and appending text files.

5. Object-Oriented Programming (OOP): Implementing classes, objects, inheritance, and constructors.

6. **Matplotlib / Seaborn:** Basic data plotting and graph creation.

Online Resources

1. https://archive.nptel.ac.in/courses/106/106/106106182/
2. https://nptel.ac.in/courses/106106145

PO-PSO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2
CO1	3	1	3	2		3	1	3		3	1	2	1	3
CO2	2	1	2	1		3		3		3		2	1	2
CO3	3	2	3	2		3	1	3		3	1	2	2	3
CO4	2	1	3	2		3		3		3	1	2	2	2

Program	**B.Sc. (Hons./ Hons. with research) Mathematics**				
Year	**1**	**Semester**	**2**		
Course Name	**Data Science and Analytics**				
Code	**RBMG1201**				
Course Type	**GE**	**L**	**T**	**P**	**Credit**
Pre-Requisite	Basic Knowledge of Programming Principles	**3**	1	**-**	4
Course Objectives	To enhance the foundational concepts to extract actionable insights from data and to navigate the entire data lifecycle from data collection and cleaning to statistical analysis, visualization.				

Course Outcomes: Upon successful completion of course, a student will be able to:	
CO1	Analyze scope, lifecycle, data types, and application domains of Data Science, and identify suitable data formats for data-driven problem solving.
CO2	Understand web scraping and data extraction techniques using tools such as BeautifulSoup and Scrapy to collect data from web sources while adhering to ethical and legal guidelines.
CO3	Understand data preprocessing tasks including data cleaning, transformation, integration, reduction, and discretization to prepare datasets for analysis and decision-making.
CO4	Create, manipulate, analyze, and manage structured datasets through array operations, data filtering, handling missing values, and DataFrame operations.

Module	**Course Contents**	**Contact Hrs.**	**Mapped CO**
1	**Definition and scope of Data Science and Data Analytics:** Introduction to Data Science; Data types, structured, semi-structured, unstructured; Data Science lifecycle: problem definition, data collection, preprocessing, modeling, evaluation, deployment, Application Domains of data science ([1] Chapter 3-5). Data formats: CSV, Excel, JSON, XML ([3] Chapter 1).	15	1
2	**Web Scraping and Data Extraction:** Introduction to Web Scraping, HTML Fundamentals, DOM Structure, HTTP Requests and Responses. Web Scraping using BeautifulSoup, Scrapy, etc. Data Extraction from Websites, Handling Dynamic Content, API-based Data Collection. Ethical and Legal Considerations ([5] Chapter 9).	15	2

3	**Data cleaning, Data reduction, Data transformation:** Handling missing values, Removing duplicates, Outlier detection, Data transformation: Normalization and standardization. Encoding categorical variables, Data integration and data pipelines. Data Pre-processing and Data discretization ([2] Chapter 3).	15	3
4	**Introduction and overview of Data Science tools**: **NumPy and Pandas:** NumPy Arrays: Array Operations, Indexing and slicing, Reshaping, Mathematical operations on arrays, Statistical functions, Introduction to matrix operations. Series and DataFrame, Creating DataFrames from lists, dictionaries, and CSV files. Reading and Writing Data, Data Inspection, Data Selection and Filtering, Handling Missing Data: dropna(), fillna(), Adding and deleting columns, Sorting and filtering data ([2] Chapter 4,5).	15	4

Suggested Readings

1. Sharda, R., Delen, D., & Turban, E. (2020). Business Intelligence, Analytics, and Data Science: A managerial perspective (4th ed.). Pearson.
2. Wes McKinny, (2nd edition) Python for Data Analysis, O'reilly.
3. Provost, F., & Fawcett, T. (2013). Data Science for Business: What you need to know about data mining and data-analytic thinking. O'Reilly Media.
4. Winston, W. L. (2019). Microsoft Excel Data Analysis and Business Modeling (6th ed.). Microsoft Press.
5. Grus, J. (2019). *Data science from scratch: First principles with Python* (2nd ed.). O'Reilly Media.

Online Resources

1. https://youtu.be/La-NZ6jOfoQ
2. https://people.smp.uq.edu.au/DirkKroese/DSML/DSML.pdf

PO-PSO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2
CO1	3	2	3	1	1	2		3		3	1	3	1	3
CO2	2	2	3	2	1	3		3		3	3	2	2	2
CO3	3	2	3	3	1	3		3	1	3	2	3	2	3
CO4	3	1	3	2	1	3		3	1	3	1	3	2	3

Program	B.Sc. (Hons./ Hons. with research) Mathematics				
Year	1	Semester		2	
Course Name	Data Science and Analytics Lab				
Code	RBMG1251				
Course Type	GE	L	T	P	Credit
Pre-Requisite	Basic Concepts of Programming Fundamentals	-	-	2	1
Course Objectives	To apply data science techniques to solve real-world problems in various domains such as mathematics, business, e-commerce and engineering.				

Course Outcomes: Upon successful completion of course, a student will be able to:	
CO1	Create and manipulate NumPy arrays and matrices, and perform arithmetic, reshaping, and matrix operations for numerical computation and data analysis.
CO2	Apply statistical techniques using Pandas Series and DataFrames to summarize, organize, and interpret data effectively.
CO3	Utilize Pandas for data management tasks including reading datasets, handling missing values, filtering records, sorting data, and merging DataFrames.
CO4	Analyze and transform datasets using grouping, aggregation, and data manipulation techniques to extract meaningful insights and support data-driven decision making.

The Lab work based on the course RBMG1251 shall include the problems on the following:

1. **Creation and Analysis of NumPy Arrays:** Create a one-dimensional array and a two-dimensional array using NumPy. Display the elements of the arrays and examine their dimensions, shape, size, and data type. Analyze how NumPy stores data efficiently.
2. **Arithmetic Operations on NumPy Arrays:** Create two NumPy arrays of equal size and perform addition, subtraction, multiplication, and division operations. Observe the element-wise nature of NumPy operations and compare the results with conventional Python lists.
3. **Matrix Operations Using NumPy:** Generate a 3×3 random matrix using NumPy. Compute its transpose and inverse. Analyze the significance of these operations in mathematical computations and data analysis.
4. **Statistical Analysis Using Pandas Series:** Create a Pandas Series containing numerical data. Calculate the mean, median, and standard deviation of the data. Interpret the results and explain the importance of these statistical measures in data analysis.

5. **Student Data Management Using Pandas DataFrame:** Create a DataFrame containing student details such as Name, Roll Number, and Marks. Display the records and sort the DataFrame based on student marks. Analyze the usefulness of sorting in organizing data.
6. **Reading and Displaying Data from a CSV File:** Read a CSV file using Pandas and display its contents. Examine the structure of the dataset, including rows, columns, and data types. Discuss the importance of CSV files in data storage and exchange.
7. **Handling Missing Values in a Dataset:** Load a dataset containing missing values. Detect the missing entries and apply dropna() and fillna() functions to handle them. Compare the outcomes of both methods and discuss their applications.
8. **Merging DataFrames in Pandas:** Create two DataFrames containing related information and merge them using appropriate Pandas functions. Examine different types of joins and understand their role in data integration.
9. **Reshaping NumPy Arrays:** Create a one-dimensional array with twelve elements and reshape it into a 3×4 matrix. Observe how data is arranged during reshaping and discuss practical applications of array restructuring.
10. **Matrix Multiplication Operations:** Create two compatible NumPy matrices and perform matrix multiplication as well as element-wise multiplication. Compare the results and explain the differences between these operations.
11. **Filtering Data in a Pandas DataFrame:** Create a DataFrame containing student information and marks. Filter the records of students who scored more than a specified percentage. Analyze how conditional filtering helps in extracting meaningful information.
12. **Grouping and Aggregation of Data:** Use a dataset containing categorical and numerical data. Apply the groupby() function to group records and calculate aggregate statistics such as count, mean, and sum. Interpret the grouped results

Online Resources

1. https://archive.nptel.ac.in/courses/106/106/106106182/
2. https://nptel.ac.in/courses/106106145

PO-PSO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2
CO1	3	1	3	2		3		3		3		3	1	3
CO2	3	1	3	2	1	3		3		3		3	1	3
CO3	3	1	3	2				3	1	3		3	2	3
CO4	3	1	3	3	1	3		3	1	3		3	2	3

Program	**B.Sc. (Hons./ Hons. with research) Mathematics**				
Year	**2**	**Semester**	**3**		
Course Name	**Database Management System**				
Code	**RBMG4301**				
Course Type	**GE**	**L**	**T**	**P**	**Credit**
Pre-Requisite	Knowledge of Computer Fundamentals that includes concepts of Computer Architecture, Storage and Hardware	**3**	-	**-**	3
Course Objectives	To introduce fundamental concepts, terminology and application of databases, design concepts and creation of relational databases basics and provide fundamental concepts of MongoDB.				
Course Outcomes: Upon successful completion of course, a student will be able to:					
CO1	Understand Database systems and Database Management Systems software.				
CO2	Model data in applications using Conceptual Modeling tools such as ER Diagrams and Design Database schemas based on the model.				
CO3	Create Database and Relations using SQL Queries. Demonstration and understanding of Normalization theory.				
CO4	Compare between SQL and NOSQL and Performing creation, Insertion, Updating and Deletion operations using MongoDB.				

Module	**Course Contents**	**Contact Hrs.**	**Mapped CO**
1	**Introduction to DBMS:** Introduction to Traditional File Oriented System. Concept of Database Management System. Advantages of DBMS over the File Oriented System. Components of DBMS, Database Administrator and Database Users. Three level Architecture of Database System, Data Independence, Data Abstraction. Introduction to Database Models ([1] Chapter 1).	15	1
2	**Relational and E-R model:** Relational Data Model: Relational Database, Codd's Rules , Entity Types, Entity Set, Strong and Weak Entities , Attribute and Keys Concept, Foreign key, Relationships types. Entity-Relationship Model: Concepts, Notation for ER Diagram, Mapping Constraints, Keys, Aggregation, Specialization and Generalization, Relational Algebra ([1] Chapter 6).	15	2

3	**Introduction to SQL and Transaction:** Structured Query Language, SQL Data Types, DDL, DML, DCL Operations, Basic and nested SQL Queries, JOIN, Aggregate Operators[1] Chapter 3). Normalization: Functional Dependencies, Normal Form up to 3rd Normal Form, BCNF([1] Chapter 7). Introduction to Transaction Processing, Properties of Transactions, Schedules and Concurrent Transactions. ([1] Chapter 17). Locking Techniques for Concurrency Control, ([1] Chapter 18).	15	3
4	**Introduction to MongoDB:** SQL vs NOSQL, MongoDB- Database, Collection, and Document, Data Types, ObjectId in MongoDB, MongoDB Compass, MongoDB Shell ([7] Chapter 1),.CRUD Operations, Create Database and Collection, Drop Database and Collection, Create Database using MongoDB Compass, Create Database using MongoShell, Insert(), Creating Arrays. Introduction to JSON, InsertOne(), InsertMany(), Update(), UpdateOne(),UpdateMany() Delete Single Document Using MongoShell. ([7] Chapter 5).	15	4

Suggested Readings

1. Abraham Silberschatz, Korth, S. Sudarshan, "Database Systems Concepts", 4thEdition, McGraw Hill, 1997.
2. Bipin Desai, "An Introduction to database Systems", Galgotia Publications, 1991
3. Date, "Database Management Systems", Pearson Education Asia.
4. Naveen Prakash,"Introduction to Database Management Systems", Tata McGraw Hill.
5. Ivan Bayross, "Database Technologies", Sybex Computer Books Inc.
6. MongoDB Fundamentals: A Hands-on Guide to Using MongoDB and Atlas in the Real World Book by Juned Ahsan, Liviu Nedov, and Michael Harrison
7. MongoDB Complete Guide Paperback – 1 July 2021 by Manu Sharma Author

Online Resources

1. https://archive.nptel.ac.in/courses/106/105/106105175/
2. https://nptel.ac.in/courses/106106220

PO-PSO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2
CO1	2	1	2	1		3		3		3	1	2	1	2
CO2	3	1	3	2		3	1	3	1	3	1	2	1	3
CO3	3	1	3	2		3	1	3	1	3	1	2	1	3
CO4	3	2	3	2		3		3	1	3	1	2	2	3

Program	B.Sc. (Hons./ Hons. with research) Mathematics				
Year	2	Semester	3		
Course Name	Database Management System Lab				
Code	RBMG4351				
Course Type	GE	L	T	P	Credit
Pre-Requisite	Fundamental computer knowledge that includes concepts of Data, Information and storage.			2	1
Course Objectives	To implement fundamental concepts, design and creation of relational databases basics and implement CRUD opertaions in MongoDB.				

Course Outcomes: Upon successful completion of course, a student will be able to:	
CO1	Create database schema, table and performing various operations on table structure.
CO2	Perform various kind of DML operations on relations.
CO3	Decompose and join tables on the basis of Normalization process.
CO4	Create database using MongoDB and peforming various operations on data.

The Lab work based on the course RBMG4351 shall include the problems on the following:

1. Create the following tables:

(a) Client_master(client_no, Name, Address1, City, State, Pincode, Bal_due.
(b) Product_master(Product_no, Description, Profit,_percent, Unit_measure, Qty_on_hand, Sell_price , Cost_price.

2. Insert the following data into their respective tables:

i) Insert at least 6 rows in table **client_master**

client_no	Name	Address1	City	State	Pincode	Bal_due
001	IVAN	NAG	NAGPUR	Maharashtra	400054	15000
002	VANDANA	CHE	CHENNAI	Tamilnadu	780001	0
003	PRANAV	NAG	NAGPUR	Maharashtra	400057	5000
004	BASU	NAG	NAGPUR	Maharashtra	400056	0
005	RAVI	LKO	LUCKNOW	UP	226025	2000
006	ARTI	LKO	LUCKNOW	UP	226001	0

ii) Insert at least 10 rows in table **Product_master.**

Prod_no	Description	Profit_per	Unit_measure	Qty_on_hand	Sell_pric	Cost_price
P07865	1.22 floppies	5	Piece	100	525	500
P00001	1.44 floppies	5	Piece	100	525	500
P08865	1.22 Drive	5	Piece	2	1050	1000
P07975	1.44 Drive	5	Piece	10	1050	1000
P07965	540 HDD	4	Piece	10	8400	8000
P03453	Monitors	6	Piece	1	12000	1120

3: On the basis of above two tables answer the following Queries:

(a) Find out the names of all the clients.
(b) Retrieve the list of names and cities of all the clients.
(c) List the various products available from the product_master table.
(d) List all the clients who are located in Bombay.
(e) Display the information for client no 0001 and 0002.
(f) Find the products with description as '1.44 drive' and '1.22 Drive'.
(g) Find all the products whose sell price is greater than 5000.
(h) Find the list of all clients who stay in in city 'Nagpur' or city 'Delhi' or 'Chennai'.
(i) Find the product whose selling price is greater than 2000 and less than or equal to 5000.
(j) List the name, city and state of clients not in the state of 'Maharashtra'.

Q4. Perform operations on the table by using the table client master and product master:

(a) Change the selling price of 1.44 floppy drive to Rs.1150.00.
(b) Delete the record with client 0001 from the client master table.
(c) Change the city of client_no'0005' to Mumbai.
(a) Change the bal_due of client_no 0001, to 1000.
(b) Find out the clients who stay in a city whose second letter is a.
(c) Find out the name of all clients having 'a' as the second letter in their names.
(d) List the products in sorted order of their description.
(e) Count the total number of orders x.
(f) Calculate the average price of all the products.
(g) Calculate the minimum price of products.
(h) Determine the maximum and minimum prices
(i) Rename the tittle as max_priceandmin_price respectively.

(j) Count the number of products having price greater than or equal to 1500.

(b) Answer the following Queries

(a) Find out the product which has been sold to 'Ivan Sayross.'
(b) Find out the product and their quantities that will have do delivered.
(c) Find the product_no and description of moving products.
(d) Find out the names of clients who have purchased 'CD DRIVE'
(e) Find the products and their quantities for the orders placed by 'Vandan Saitwal ' and "Ivan Bayross".
(f) Find the products and their quantities for the orders placed by client_no " C00001" and "C00002".
(g) Display the s_order_date in the format "dd-mm-yy" e.g. "12- feb-96".

Q7. To implement the concept of grouping of Data.

(a) Print the description and total quantity sold for each product.
(b) Find the value of each product sold.
(c) Calculate the average quantity sold for each client that has a maximum order
value of 15000.
(d) Find out the products which have been sold to Ivan.
(e) Find the names of clients who have 'CD Drive'.
(f) Find the products and their quantities for the orders placed by 'Vandana' and 'Ivan'.
(g) Select product_no, total qty_ordered for each product.
(h) Select product_no, product description and qty ordered for each product.

Q8**.** To implement the concept of MongoDB.

(a) Create a table as named Employee using the fields as Emp_id ,Emp_Name, Emp_Desig, Emp_DOJ, Emp_Sal, Emp_Loc, Emp_Dno MongoDB Shell.
(b) Insert at least 10 numbers records in a table.
(c) Export all the data inserted in the table.
(d) Update the Employee Salary, and designation.
(e) Delete all the record whose date of joining is greater than specific date.
(f) Find the names of employee whose salary is more than 50000.
(g) Perform all above queries using Java Script and visualize all data using different plotting functions.
(h) Create connection of database using Python libraries, access data and visualize data.

Online Resources

1. https://archive.nptel.ac.in/courses/106/105/106105175/
2. https://nptel.ac.in/courses/106106220

PO-PSO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2
CO1	2	1	2	1		3		3		3		2	1	2
CO2	3	1	3	1		3		3		3		2	1	3
CO3	3	1	3	2		3	1	3	1	3		2	1	3
CO4	3	1	3	2		3		3	1	3		2	2	3

Program	**B.Sc. (Hons./ Hons. with research) Mathematics**				
Year	**2**	**Semester**	**4**		
Course Name	**Artificial Intelligence**				
Code	**RBMG4401**				
Course Type	**GE**	**L**	**T**	**P**	**Credit**
Pre-Requisite	Understanding of computer science fundamentals, particularly in algorithms, data structures	**3**	1	**-**	4
Course Objectives	To provide an introduction to the fundamental concepts of Knowledge representation, structured knowledge representation, Game playing and Natural language processing.				

Course Outcomes: Upon successful completion of course, a student will be able to:	
CO1	Analyze what constitutes "Artificial" Intelligence and how to identify systems with Artificial Intelligence.
CO2	Formalize a given problem in the language/framework of different AI methods (e.g., as a search problem, a s a constraint satisfaction problem, as a planning problem, etc).
CO3	Apply knowledge representation techniques and analyze the fundamental concepts of Natural Language Processing, including linguistic structures and semantic analysis.
CO4	Apply game-playing search techniques and explain the design, components, knowledge acquisition process, and applications of expert systems.

Module	**Course Contents**	**Contact Hrs.**	**Mapped CO**
1	Introduction: Foundations and history of AI, Applications of AI, Characteristics of intelligent agents ([1] Chapter 1). Problem Solving Methods: search strategies, Uninformed Search Strategies: Breadth- First Search, Depth-First Search, Depth Limited Search and Iterative Deepening Search ([1] Chapter 2). Informed Search Strategies: BFS, A* Algorithms, Hill-Climbing, Constraint Satisfaction Problem(CSP), Mean-End-Analysis ([1] Chapter 3).	15	1
2	Knowledge Representation: Representation and Mapping, ([1] Chapter 4). First Order Predicate Logic: Unification, modus pones, resolution, Forward and backward chaining, Non-monotonic Reasoning, probabilistic reasoning, Probability and Bayes Theorem. ([1] Chapter 10).	15	2
3	Structured knowledge representation: Semantic	15	3

	nets, exceptions and default frames, conceptual dependency and scripts, ([1] Chapter 12 Natural Language Processing: Introduction, Overview of Linguistics, Grammar and Languages, Semantic Analysis, Natural Language Generation, Natural Language Systems. ([1] Chapter 21).		
4	Game Playing: Overview, Mini-Max, Alpha-Beta Cut-off, Iterative deepening ([1] Chapter 25). Expert Systems: Need and justification for expert systems, and knowledge acquisition, and component of an expert system. ([1] Chapter 5).	15	4

Suggested Readings

1. Elaine Rich, Kevin Knight, Shivashankar B Nair, Artificial Intelligence, Third Edition, McGraw Hill Edition.
2. Russell Stuart Jonathan and Norvig Peter, Artificial Intelligence: A Modern Approach, 3rd Edition, Prentice Hall, 2010.

Online Resources

1. https://nptel.ac.in/courses/106105077
2. https://nptel.ac.in/courses/106102220

PO-PSO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2
CO1	3	2	3	1	1	2		3		3	1	3	1	3
CO2	3	2	3	3	1	3	1	3	1	3	1	3	2	3
CO3	3	2	3	2	1	3		3		3	1	3	2	3
CO4	3	2	3	3	1	3	1	3	1	3	1	3	2	3

Program	B.Sc. (Hons./ Hons. with research) Mathematics					
Year	3	Semester		5		
Course Name	Machine Learning					
Code	RBMG4501					
Course Type	GE	L	T	P	Credit	
Pre-Requisite	The Concepts of Artificial Intelligence and programming in Python.	3		-	3	
Course Objectives	To understand the basic theory underlying machine learning and implement various algorithms using Python.					

Course Outcomes: Upon successful completion of course, a student will be able to:

CO1	Explain the fundamental concepts of machine learning, including learning paradigms, training and testing processes, and distinguish between classification and regression problems.
CO2	Apply supervised and unsupervised machine learning algorithms to analyze data and solve real-world problems.
CO3	Evaluate machine learning models using validation techniques and performance improvement methods, including cross-validation, regularization, bias-variance analysis, and ensemble learning approaches.
CO4	Analyze the architecture and learning mechanisms of artificial neural networks, and implement perceptron and back propagation-based models for predictive tasks.

Module	Course Contents	Contact Hrs.	Mapped CO
1	**Introduction:** Definition of Learning Systems, Goals and Applications of Machine Learning. Aspects of developing a learning system: Training Data, Testing Data, Concept of Supervised Learning, Unsupervised Learning and Reinforcement Learning. Classification and Regression. Supervised Machine Learning Algorithms k-Nearest Neighbors, Linear Models, Naive Bayes Classifiers, Decision Trees, Support Vector Machines ([1] Chapter 1)	15	1
2	**Unsupervised Learning:** Dimensionality Reduction, Principal Component Analysis, factor	15	2

	analysis, Multidimensional Scaling, Linear Discriminant Analysis. ([1] Chapter 6). Clustering: Learning from Unclassified Data. Hierarchical Agglomerative Clustering, K-means Clustering ([1] Chapter 3).		
3	**Model Validation in Classification:** Cross Validation - Holdout Method, K-Fold, Stratified K-Fold, Leave-One-Out Cross Validation. Bias-Variance tradeoff, Regularization, Overfitting, Underfitting. Ensemble Methods: Boosting, Bagging, Random Forest ([1] Chapter 5).	15	3
4	**Artificial Neural Network:** Motivation, Neural Network Representation, Perceptron, Training Rule, Activation Functions and types of Activation Functions. Introduction to Gradient Descent and Delta Rule. Feed Forward Neural Network, Back Propagation Network: Overview, Back Propagation Algorithm ([4] Chapter 18).	15	4

Suggested Readings

1. Ethem Alpaydin, "Introduction to Machine Learning" 2nd Edition, The MIT Press, 2009.
2. Tom M. Mitchell, "Machine Learning", First Edition by Tata McGraw-Hill Education 2013.
3. Christopher M. Bishop, "Pattern Recognition and Machine Learning" by Springer, 2007.
4. Grus, J. (2019). *Data science from scratch: First principles with Python* (2nd ed.). O'Reilly Media.

Online Resources

1. https://archive.nptel.ac.in/courses/106/105/106105152/
2. https://www.digimat.in/nptel/courses/video/106105152/L01.html

PO-PSO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2
CO1	3	2	3	1		2		3		3	1	3	1	3
CO2	3	2	3	2	1	3	1	3	1	3	1	3	2	3
CO3	3	2	3	3	1	3	1	3	1	3	1	3	2	3
CO4	3	2	3	3	1	3	1	3	1	3	1	3	3	3

Program	**B.Sc. (Hons./ Hons. with research) Mathematics**				
Year	**3**	**Semester**	**5**		
Course Name	**Machine Learning Lab**				
Code	**RBMG4551**				
Course Type	**GE**	**L**	**T**	**P**	**Credit**
Pre-Requisite	The Concepts of Artificial Intelligence and object oriented programming.	**-**	-	**2**	1
Course Objectives	To understand the concepts underlying machine learning and implement various algorithms using Python.				

Course Outcomes: Upon successful completion of course, a student will be able to:	
CO1	Develop and implement supervised machine learning models using algorithms such as Linear Regression, K-Nearest Neighbors, Naive Bayes, and Decision Trees for prediction and classification tasks.
CO2	Apply data pre-processing techniques, including dataset preparation, feature selection, and train-test data splitting, to support effective machine learning model development.
CO3	Evaluate and interpret the performance of machine learning models using appropriate metrics and analyze the effectiveness of different algorithms for real-world applications.
CO4	Implement clustering and pattern recognition techniques to solve practical problems involving data segmentation, classification, and predictive analytics.

The Lab work based on the course RBMG4551 shall include the problems on the following:

1. **House Price Prediction Using Linear Regression:** Develop a machine learning model using Linear Regression to predict house prices based on relevant features and analyze the impact of different variables on the predicted price.
2. **Student Performance Prediction Based on Study Hours:** Implement a Linear Regression model to estimate student marks from study hours and evaluate the relationship between study time and academic performance.
3. **Iris Flower Classification Using K-Nearest Neighbors (KNN):** Build and evaluate a KNN-based classification model to categorize iris flowers into different species using their morphological features.
4. **Spam Detection Using Text Classification Techniques:** Design and implement a machine learning system to classify text messages as spam or ham and assess the effectiveness of the classification model.

5. **Customer/Data Segmentation Using K-Means Clustering:** Apply the K-Means clustering algorithm to group similar data instances and interpret the resulting clusters for pattern discovery.
6. **Salary Prediction Using Linear Regression:** Construct a predictive model to estimate employee salaries based on years of experience and analyze the performance of the regression model.
7. **Handwritten Digit Recognition System:** Develop and evaluate a machine learning application for recognizing handwritten digits using an appropriate classification algorithm and image dataset.
8. **Dataset Splitting for Model Training and Evaluation:** Perform data preprocessing by partitioning a dataset into training and testing subsets and examine the significance of data splitting in machine learning workflows.
9. **Model Performance Evaluation Using Accuracy Metrics:** Calculate and interpret the accuracy of a classification model using the accuracy_score function and analyze its effectiveness.
10. **Decision Tree Classification and Visualization:** Build a Decision Tree classifier for a given dataset and visualize the decision-making structure to understand classification rules.
11. **Student Pass-Fail Prediction System:** Develop a classification model to predict whether a student is likely to pass or fail based on academic performance indicators and evaluate the model's accuracy.
12. **Non-Linear Data Modeling Using Polynomial Regression:** Implement Polynomial Regression to model non-linear relationships in data and compare its performance with simple linear regression.
13. **Diabetes Prediction Using Decision Tree Classification:** Create a Decision Tree-based predictive model to classify individuals as diabetic or non-diabetic using relevant medical attributes.
14. **Fruit Classification Based on Physical Characteristics:** Design a machine learning model to classify fruits using features such as weight, size, color, or texture and analyze classification performance.
15. **Weather Condition Prediction Using Naive Bayes:** Implement a Naive Bayes classifier to predict weather conditions from historical data and evaluate the effectiveness of probabilistic classification techniques.

Suggested Readings

1. 1. Ethem Alpaydin, "Introduction to Machine Learning" 2nd Edition, The MIT Press, 2009.
2. Tom M. Mitchell, "Machine Learning", First Edition by Tata McGraw-Hill Education 2013.
3. Christopher M. Bishop, "Pattern Recognition and Machine Learning" by Springer, 2007.

Online Resources

1. https://archive.nptel.ac.in/courses/106/105/106105152/
2. https://www.digimat.in/nptel/courses/video/106105152/L01.html
3. https://www.kaggle.com/discussions/general/196686

PO-PSO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2
CO1	3	1	3	2		3		2		3		3	1	3
CO2	2	1	2	3		3		2		2		2	1	2
CO3	2	2	3	3	1	2		2		2	1	3	2	2
CO4	3	1	3	2	1	3		2		3		3	1	3

Program	**B.Sc. (Hons./ Hons. with research) Mathematics**				
Year	**3**	**Semester**	**6**		
Course Name	**Big Data Analysis**				
Code	**RBMG4601**				
Course Type	**GE**	**L**	**T**	**P**	**Credit**
Pre-Requisite	Basic knowledge of Database and Computer Networks	**3**	1	**-**	4
Course Objectives	To know the fundamental concepts of big data and analytics and explore tools and practices for working with big data.				
Course Outcomes: Upon successful completion of course, a student will be able to:					
CO1	Demonstrate understanding of Big Data technologies, Hadoop ecosystem components, MapReduce algorithms, and their applications in data-intensive environments.				
CO2	Introduce the tools required to Manage and Analyze Big Data like Hadoop and MapReduce.				
CO3	Introduce Fundamental techniques and Principles in achieving big Data Analytics with scalability and Streaming Capability.				
CO4	Learn skills that will help them to solve Complex real-World problems for Decision Support.				

Module	**Course Contents**	**Contact Hrs.**	**Mapped CO**
1	Introduction to Big Data ([1] Chapter 1). Hadoop distributed file System, Big Data and its Importance. Drivers for Big data ([1] Chapter 2). Big data Analytics, Big Data Applications ([1] Chapter 9).Algorithms using Map Reduce ([1] Chapter 3).	15	1
2	Introduction to Hadoop: Big Data: Apache Hadoop & Hadoop Eco-System ([1] Chapter 1) Moving Data in and out of Hadoop , Understanding Inputs and Outputs of Map Reduce, ([2] Chapter 2) Data Serialization ([2] Chapter 4).	15	2

3	Hadoop Architecture: Hadoop Architecture ([2] Chapter 3) Hadoop Storage: HDFS, Common Hadoop Shell Commands, Anatomy of File Write and Read, Name Node, Secondary Name Node, and Data Node ([2] Chapter 3). Hadoop Map Reduce Paradigm, Map and Reduce tasks, Job, Task trackers ([2] Chapter 5). HDFS Administering, Monitoring & Maintenance ([2] Chapter 9).	15	3
4	Hadoop Ecosystem and Yarn: Hadoop Ecosystem Components ([2] Chapter 11) Schedulers, Fair and Capacity, Hadoop2.0: New Features MRv1 vs MRv2, YARN ([2] Chapter 6).	15	4

Suggested Readings

1. Boris lublinsky, Kevin t. Smith, Alexey Yakubovich, "Professional Hadoop Solutions", Wiley, ISBN: 9788126551071, 2015.
2. Tom White, "HADOOP: The definitive Guide", O Reilly 2012.
3. Chris Eaton, Dirk deroos et al., "Understanding Big data", McGraw Hill, 2012.

Online Resources

1. https://archive.nptel.ac.in/courses/106/104/106104189/
2. https://www.digimat.in/nptel/courses/video/106104189/L01.html

PO-PSO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2
CO1	3	1	3	2		3		2		3		3	1	3
CO2	2	1	2	2		3		2		3		2	1	2
CO3	3	2	3	2	1	3		2	1	3		3	2	3
CO4	3	2	3	3	1	2		3	2	2		3	2	3

Program	B.Sc. (Hons./ Hons. with research) Computer Science				
Year	4	Semester	7		
Course Name	Block Chain Technology				
Code	RBMG4701				
Course Type	GE	L	T	P	Credit
Pre-Requisite	Knowledge of Cryptography	3	1	-	4
Course Objectives	Technical understanding of Blockchain technologies and develop familiarity of current technologies, tools, and implementation strategies.				
Course Outcomes: Upon successful completion of course, a student will be able to:					
CO1	Explain the fundamental concepts of blockchain technology, including blockchain architecture, distributed ledgers, mining mechanisms, transactions, consensus protocols, and network structures.				
CO2	Analyze the lifecycle of blockchain applications, blockchain forks, public and private blockchain networks, and the role of smart contracts in decentralized systems.				
CO3	Examine the principles of cryptocurrencies, including Bitcoin and Ethereum, their protocols, mining strategies, security vulnerabilities, legal aspects, and regulatory challenges.				
CO4	Evaluate distributed consensus mechanisms and blockchain-based applications in domains such as IoT, healthcare, domain name services, and emerging decentralized technologies.				

Module	Course Contents	ContactHrs.	Mapped CO
1	Blockchain: Introduction, Advantage over conventional distributed database, Blockchain Network, Mining Mechanism, Distributed Consensus, Merkle Patricia Tree Gas Limit, Transactions and Fee, Anonymity, Reward Chain Policy([4] Chapter 1).	15	1
2	Life of Blockchain application, Soft & Hard Fork, Private and Public block chain ([4] Chapter 1). Crypto currency: History, Distributed Ledger, Bit coin protocols-Mining strategy and rewards, Ethereal-Construction, DAO, Smart Contract, GHOST Vulnerability, Attacks, Sidechain, Name coin([4] Chapter 5).	15	2
3	Crypto currency Regulation: Stakeholders, Roots of Bit coin, Legal Aspects-Crypto currency Exchange, Black Market and Global	15	3

	Economy. Applications: Internet of Things, Medical Record Management System, Domain Name Service and future of Block chain ([4] Chapter 5).		
4	Distributed Consensus: Nakamoto consensus, Proof of Work, Proof of Stake, Proof of Burn, Difficulty Level Sybil Attack, Energy utilization and alternate ([4] Chapter 1).	15	4

Suggested Readings

1. Andreas M. Antonopoulos, Mastering Bitcoin: Unlocking Digital Cryptocurrencies, "O'ReillyMedia, Inc.", 03-Dec-2014 -Business &Economics.
2. Dr.GavinWood,"ETHEREUM:ASecureDecentralizedTransactionLedger,"Yellowpaper.2014.
3. Antony Lewis, The Basics of Bitcoins and Blockchains: An Introduction to Cryptocurrencies and the Technology that Powers Them (Cryptography, Crypto Trading, Digital Assets, NFT) Paperback– April13, 2021.

Online Resources

1. https://archive.nptel.ac.in/courses/106/104/106104220/
2. https://archive.nptel.ac.in/courses/106/105/106105235/

PO-PSO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2
CO1	2	1	3	2		3		2		3	1	2	1	2
CO2	2	1	3	2		3		2	1	3	1	2	1	2
CO3	2	2	3	2	1	3		2	1	3	3	2	2	2
CO4	3	2	3	3	2	3		3	2	3	2	3	2	3

Program	B.Sc. (Hons./ Hons. with research) Mathematics				
Year	4	Semester		8	
Course Name	Augmented & Virtual Reality				
Code	RBMG4801				
Course Type	GE	L	T	P	Credit
Pre-Requisite	Familiar with Different Computer Programming Languages as well as Concepts of Image Processing Tools.	3	1	-	4
Course Objectives	To gain the knowledge of historical and modern overviews and perspectives on virtual reality and the fundamentals 3D Interface, Software Technologies and the technical aspects of augmented and virtual reality systems.				
Course Outcomes: Upon successful completion of course, a student will be able to:					
CO1	Explain the evolution, architecture, components, and hardware technologies of Virtual Reality systems, including visual, auditory, and haptic interfaces used in immersive environments.				
CO2	Analyze 3D user interface concepts, interaction techniques, navigation methods, and evaluation approaches for effective user interaction in virtual environments.				
CO3	Apply software technologies and development tools for creating virtual environments, including VR databases, object modeling, interaction mechanisms, world authoring, and VR toolkits.				
CO4	Compare and evaluate Virtual Reality, Augmented Reality, and Mixed Reality technologies, their methodologies, challenges, visualization techniques, and real-world applications.				
Module	**Course Contents**			**Contact Hrs.**	**Mapped CO**
1	Introduction: A Brief History of Virtual Reality, The five Classic Components of a VR System, Basic features of VR systems, Architecture of VR systems, Early Commercial VR Technology Hardware Technologies For 3D User Interfaces: Visual Displays, Auditory Displays, Haptic Displays, Choosing Output Devices for 3D User Interfaces ([3] Chapter 1).			15	1
2	3D User Interfaces: Why 3D user interfaces, Major use tasks in VE, Interaction techniques for selection manipulation and navigation, 3D UI evaluation, Virtual Reality Applications: Engineering, Architecture Education, Medicine, Entertainment, Science,			15	2

	Training ([3] Chapter 2).		
3	Software Technologies: Database - World Space, World Coordinate, World Environment, Objects - Geometry, Position / Orientation, Hierarchy, Bounding Volume, Scripts and other attributes, VR Environment - VR Database, Tessellated Data, LODs, Cullers and Occluders, Lights and Cameras, Scripts, Interaction - Simple, Feedback, Graphical User Interface, Control Panel, 2D Controls, Hardware Controls, Room / Stage / Area Descriptions, World Authoring and Playback, VR toolkits, Available software in the market ([3] Chapter 3-4).	15	3
4	Augmented and Mixed Reality, Taxonomy, technology and features of augmented reality, difference between AR and VR, Challenges with AR, AR systems and functionality, Augmented reality methods, visualization techniques for augmented reality ([3] Chapter 7-9).	15	4

Suggested Readings:

1. Alan B Craig, William R Shermanand Jeffrey D Will, "Developing Virtual Reality Applications: Foundations of Effective Design", Morgan Kaufmann, 2009.
2. Doug A Bowman, Ernest Kuijff, Joseph JLa Viola, Jrand Ivan Poupyrev, "3D User Interfaces, Theory and Practice".
3. Burdea, Grigore Cand Philippe Coiffet, "Virtual Reality Technology",Wiley Interscience, India, 2003.

Online Resources

4. https://archive.nptel.ac.in/courses/121/106/121106013/
5. https://onlinecourses.swayam2.ac.in/nou23_ge34/preview

PO-PSO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2
CO1	2	1	2	1		3		2		3		2	1	2
CO2	2	1	3	2	1	3	1	2		3		2	1	2
CO3	2	1	2	3	1	3	1	3	1	3		2	2	2
CO4	2	2	3	2	2	3	1	3	1	3		2	2	2

Program	B.Sc. (Hons./ Hons. with Research) Mathematics				
Year	1	Semester		1	
Course Name	Programming using C				
Code	RBMG4101				
Course	GE	L	T	P	Credit
Pre-Requisite	Basic knowledge of computer and its operations	3		-	3
Course Objectives	The course is designed to provide complete knowledge of C language. Students will be able to develop logics which will help them to create programs, applications in C. Also by learning the basic programming constructs they can easily switch over to any other language in future				
Course Outcomes: Upon successful completion of course, a student will be able to:					
CO1	Learn and develop simple algorithms to solve various types of problems and develop problem solving skills coupled with Top-Down design principles.				
CO2	Develop the strategies of writing efficient and well-structured computer programs and develop the skills for formulating Iterative solutions to various problems.				
CO3	Learn various types of Operators and Functions in C programming and learn the concept of single and multi-dimensional Arrays & various Searching and Sorting techniques.				
CO4	Enhance the learning of C programming by using Pointers and Dynamic Memory Allocation functions.				

Module	Course Contents	Contact Hrs.	Mapped CO
1	Introduction to Programming Languages: Concept of Assembler, Compiler, Interpreter ([1] Chapter 1).The Role of Programming Languages, HLL, LLL, Programming Paradigms, Programming Environments. ([1] Chapter 1).Programming Basics: Structure of C Program, Writing and Executing the first C program, Syntax and Logical Errors in Compilation, Object and Executable Code. Components of C language: Standard I/O in C, Fundamental Data	15	1

2	Arithmetic expressions & Conditional Branching: Arithmetic Expressions and Precedence, Operators and Expression using Numeric and Relational Operators, Mixed-mode Operations, Type Conversion, Logical Operators, Bit-wise Operators, Assignment Operators, Operator Precedence and Associativity. Conditional Branching: Applying if-else and Switch-case Statements, Nesting If-Else([1] Chapter 6).Loops & Functions: Iteration and Loops, While, Do-while and for Loops, Multiple Loop Variables, Break and Continue Statements ([1] Chapter 6). Funs: Introduction, Types of Functions, Functions with Array, Passing Parameters to Functions, Call by value, Call by Reference([1] Chapter 7).	15	2
3	Arrays and Structures: Array Notation and Representation, Manipulating Array Elements, Arrays Using Multi-Dimensional, Character Arrays and Strings, Structure, Union, Enumerated Data Types, Array of Structures, Passing Arrays to Functions ([1] Chapter 9).Basic Algorithms: Searching & Basic Sorting Algorithms (Bubble and Selection).	15	3
4	Pointers & File Handling: Pointers: Pointers &Memory Allocation in C, Pointer to Pointer, Pointers to Structures, Problems with Pointers, Passing Pointers as Function Arguments, Using Arrays with Pointers, Passing Arrays to Functions. Static and Dynamic Memory Allocation: use of malloc(), calloc() and free() functions, Storage of Variables In Static and Dynamic Memory Allocation ([1] Chapter 10). File handling: Creating Files, various File handling modes, File I/O functions, Standard C Pre-processors, defining and calling Macros([1] Chapter 1-2).	15	4

Suggested Readings

1. Schaum's Outline of Programming with C by Byron Gottfried, McGraw-Hill
2. The C programming by Kernighan Brain W. and Ritchie Dennis M, PearsonEducation.
3. Computer Basics and C Programming by V.Rajaraman, PHI Learning Pvt. Limited, 2015.
4. Computer Concepts and Programming in C, R.S. Salaria, Khanna Publishing House.

Online Resources

1. https://nptel.ac.in/courses/106104128
2. https://nptel.ac.in/courses/106105151

PO-PSO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2
CO1	3	1	3	1		2		2		2		3	1	3
CO2	3	1	3	1		3		3		2		2	1	3
CO3	3	1	2	1		3		3		2		2	1	3
CO4	3	1	2	1		3		3		3		2	1	3

Program	**B.Sc. (Hons./ Hons. with Research) Mathematics**				
Year	**1**	Semester		1	
Course Name	**Programming using C Lab**				
Code	**RBMG4151**				
Course Type	**GE**	L	T	P	Credit
Pre-Requisite	Basic knowledge of computer and its operations			2	1
Course Objectives	The course is designed to provide Practical knowledge of C language. Students will be able to develop C language programs on various mathematical and computational problems which will help them to create applications in C.				
Course Outcomes: Upon successful completion of course, a student will be able to:					
CO1	Apply fundamental programming concepts, operators, control structures, functions, and recursion to develop solutions for mathematical and logical problems.				
CO2	Design and implement programs using arrays, strings, pointers, macros, and dynamic memory allocation to perform data manipulation, searching, sorting, merging, and other computational tasks efficiently.				
CO3	Develop logical C language program using array loops, functions, structure and union.				
CO4	Demonstrate concept of pointers, dynamic memory allocation and file handling.				

The Lab work based on the course RBMG4151 shall include the problems on the following:

1. **Digit Operations:**
   Explain the algorithm to calculate the sum and product of digits of an integer. Illustrate the process using a suitable example and discuss the role of modulus (%) and division (/) operators.
2. **Reversing a Number:**
   Describe a method for reversing the digits of a given number. Demonstrate the procedure with an example and explain the logic used.
3. **Harmonic Series Computation:**
   Explain how a program can compute the sum of the series:
   $S = 1 + 1/2 + 1/3 + 1/4 + ...$
   for the first n terms. Discuss the use of loops and floating-point variables.
4. **Alternating Series:**
   Describe an algorithm to calculate the sum of the series:
   $S = 1 - 2 + 3 - 4 + 5 - ...$
   for n terms. Explain how positive and negative terms are generated.

5. Palindrome Strings:
What is a palindrome? Explain different methods to determine whether a string is a palindrome. Illustrate with examples.

6. Prime Numbers:
Explain the logic used to test whether a number is prime. How can the same logic be extended to generate all prime numbers less than 100?

7. Factors of a Number:
Describe an algorithm to find all factors of a given integer. Explain the significance of factors in number theory.

8. Macros in C:
What are macros? Explain how a macro can be used to swap two numbers. Discuss the advantages and limitations of macros.

9. Array Operations:
Discuss the implementation of a menu-driven program for performing operations on an array. Explain the logic for:

- Displaying even and odd elements
- Finding sum and average
- Finding maximum and minimum values
- Removing duplicate elements
- Reversing the array

10. Character Frequency Count:
Explain how command-line arguments can be used to accept text input and count the occurrence of each alphabet. Discuss possible applications of this technique.

11. Swapping Using Pointers:
Explain how pointers can be used to swap two numbers. Compare this approach with swapping using a temporary variable.

12. Call by Reference:
Describe how a function can modify variables in the calling function by passing their addresses. Explain with a suitable example.

13. Circle Calculations Using Functions:
Discuss the design of a program in which the radius of a circle is passed to a function that calculates area and circumference. Explain parameter passing and function return mechanisms.

14. Dynamic Memory Allocation:
Explain the need for dynamic memory allocation. Compare malloc(), calloc(), and the new operator. Discuss how they can be used to calculate the sum of n user-entered numbers.

15. String Manipulation Using Pointers:
Explain the implementation of the following string operations:

- Displaying addresses of characters
- String concatenation with and without library functions
- String comparison
- String length calculation using pointers
- Case conversion
- Counting vowels
- String reversal

16. Merging Ordered Arrays:
Describe an efficient method for merging two sorted arrays into a single sorted array. Analyze its time complexity.

17. Fibonacci Series:

Compare recursive and iterative approaches for generating the Fibonacci series. Discuss their advantages and disadvantages.

18. Factorial Computation:

Explain recursive and iterative methods for calculating factorials. Compare memory usage and execution efficiency.

19. Structures and File Handling:

Describe how student information can be stored using structures and written to a file. Explain the advantages of structures in data organization.

20. File Copy with Whitespace Removal:

Discuss the steps involved in copying the contents of one text file to another while removing whitespace characters.

21. Array Reversal Using Pointers:

Explain how an array can be reversed in place using only a pointer parameter. Discuss the concept of pointer arithmetic.

22. Arrays Implemented with Pointers:

Describe how arrays can be accessed using pointers. Explain how sorting can be performed to display elements in ascending and descending order.

23. File Creation and Data Storage:

Discuss the steps involved in creating a file and storing information in it. Explain different file opening modes.

24. Reading Data from a File:

Explain the process of reading data from a file in C. Discuss commonly used file handling functions.

25. Deleting a Specific Line from a File:

Describe an algorithm to remove a particular line from a text file. Explain why a temporary file is often required in this process.

PO-PSO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2
CO1	3	1	3	2		3		3		2		3	1	3
CO2	3	1	3	2		3		3		3		3	1	3
CO3	2	1	2	2		3		3		2		2	1	2
CO4	2	1	2	2		3		3		3		2	1	2

Program	**B.Sc. (Hons./ Hons. with Research) Mathematics**				
Year	**1**	Semester		2	
Course Name	**Operating System**				
Code	**RBMG1201**				
Course	**GE**	L	T	P	Credit
Pre-Requisi	Basic knowledge of computer and its operations	3	1	-	4
Course Objectives	To learn how Operating System is Important for Computer System, make aware of different types of Operating System and their services, To learn different process scheduling algorithms, synchronization and secondary memory management				
Course Outcomes: Upon successful completion of course, a student will be able to:					
CO1	Understand the basic concept and types of Operating System.				
CO2	Learn Operating System organization i.e. concept of process, process synchronization etc.				
CO3	Learn the various kinds of process scheduling algorithms.				
CO4	Learn file management, I/O management and protection and security policies.				

Module	**Course Contents**	**Contact Hrs.**	**Mapped CO**
1	Introduction: Definition of operating system, History of Operating Systems , Single user/Multi User and Single and Multitasking OS; types of operating systems–multiprogramming systems, batch systems, time sharing systems, Distributed System, real time systems; Functions of operating system: Memory management, process management, device management, file management etc.	15	1
2	Operating System Organization: System calls and system programs. Process Management: System view of the process and resources, process abstraction, process hierarchy, threads; Process synchronization: concurrent processes, critical sections, methods for inter-process communication; classical two process and n-process solutions, hardware primitives for synchronization, semaphores, monitors, classical problems in synchronization (producer-consumer, readers-writer, dining philosophers etc.).	15	2

3	Process Scheduling: non-pre-emptive and pre-emptive scheduling algorithms-FCFS, SJF, SRTF, Round Robin etc., Semaphores. Memory Management: Memory address, Physical and virtual address space; memory allocation strategies – fixed and variable partitions, Concept of paging, segmentation, demand paging, virtual memory, page replacement algorithms, virtual memory	15	3
4	Deadlocks: prevention and avoidance, detection and recovery. File and I/O Management File concepts, Access methods, Directory structure, File system structure, files operations, files allocation methods, device management, Protection and Security, Policy mechanism, Authentication	15	4

Suggested Readings

1. A Silberschatz, P.B. Galvin, G. Gagne, Operating Systems Concepts, 8th Edition, John Wiley
2. 2. Publications 2008.G. Nutt, Operating Systems: A Modern Perspective, 2nd Edition Pearson
3. Education 1997.
4. 3. W. Stallings, Operating Systems, Internals & Design Principles , 5th Edition, Prentice Hall of India 2008.
5. 4. M. Milenkovic, Operating Systems- Concepts and design, Tata McGraw Hill 1992.

Online Resources

1. https://archive.nptel.ac.in/courses/106/105/106105214/
2. https://onlinecourses.nptel.ac.in/noc20_cs04/preview

PO-PSO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO	PO9	PO10	PO11	PO12	PSO1	PSO2
CO1	2	1	2			2		2		2		2	1	2
CO2	3	1	3	1		2		3		2		3	1	3
CO3	3	1	3	1		2		3		2		3	1	3
CO4	2	1	2	1		2		3		2	3	2	2	2

Program	B.Sc. (Hons./ Hons. with Research) Mathematics				
Year	2	Semester	3		
Course Name	Computer Networks				
Code	RBMG4302				
Course	GE	L	T	P	Credit
Pre-Requisite	Basic knowledge of computer and its operations	3	1	-	4
Course Objectives	Student will be able to learn the concept of computer networking, it's various types, reference models, layers of TCP/IP and OSI Model and various services.				
Course Outcomes: Upon successful completion of course, a student will be able to:					
CO1	Describe how Computer Networks are organized with the concept of layered Approach.				
CO2	Implement a simple LAN with Hubs, Bridges and Switches. Learn basic routing mechanisms, IP addressing scheme and internetworking concepts.				
CO3	Student will be able to learn the concept of multiple access control, network layer functions and protocols.				
CO4	Learn the various kind of protocols and services provided by application layer and transport layer.				

Module	Course Contents	Contact	Mapped CO
1	Fundamentals of Computer Networks: Network Definition, Network Topologies, Network Classifications, Network Protocol, Layered Network Architecture, Reference Models: OSI Reference Model, TCP/IP Reference model ([1] Chapter 1-2), Comparison of OSI and TCP/IP Models ([1] Chapter 2).	15	1
2	TCP/IP Protocol Suite: TCP/Ip layers and Protocols, ([1] Chapter 2). Networks Switching Techniques and Access Mechanisms: Circuit Switching, Packet switching- Connectionless Datagram Switching, Connection-Oriented virtual Circuit Switching, Dial-up Modems, Digital Subscriber Line, Cable TV for Data transfer([1] Chapter 8).Data Link Layer Functions and Protocol: Error Detection and Error Correction Techniques, Data-link Control- Framing and Flow Control, Error Recoveries Protocols- Stop and Wait ARQ, Go-back-n ARQ, Point to Point Protocol on Internet ([1] Chapter	15	2

3	Multiple Access Protocol and Networks: CSMA/CD Protocols; Ethernet LANS; Connecting LAN and Back-Bone Networks- Repeaters, Hubs, Switches, Bridges, Router and Gateways([1] Chapter 12).Networks Layer Functions and Protocols: Routing, Routing Algorithms: Distance Vector, Shortest Path Routing Algorithm, Network Layer Protocols: IP protocol, Internet Control Message Protocol, IGMP, ARP, RARP([1] Chapter 19-22)	15	3
4	Transport Layer Functions and Protocols: Transport services- Error control and Flow Control, Reliability, TCP and UDP, Connection Establishment and Release: Three way Handshaking, Concept of Socket and Ports ([1] Chapter 23-24). Application layer Protocol: Overview of WWW, URL, HTTP, SMTP, FTP, POP, TELNET. Domain Name System, Domain Name Servers, DNS Space ([1] Chapter 25-28)	15	4

Suggested Readings

1. B. A. Forouzan: Data Communications and Networking, Fourth edition, THM, 2007.
2. 2. Computer Network and Internet by Douglas E Comer.
3. 3. A. S. Tanenbaum: Computer Networks, Fourth edition, PHI, 2002.
4. 4. William Stallings, "Data and Computer Communication", Prentice Hall.

Online Resources

5. https://nptel.ac.in/courses/106105183
6. https://nptel.ac.in/courses/106106091

PO-PSO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2
CO1	2	1	2			2		2		2		2	1	2
CO2	3	1	3	2		3		3		3		3	1	3
CO3	3	1	3	1		3		3		3		3	1	3
CO4	2	1	2	1		3		3		3		2	1	2

Program	B.Sc. (Hons./ Hons. with research) Mathematics				
Year	2	Semester	4		
Course Name	Java Programming				
Code	RBMG4402				
Course Type	GE	L	T	P	Credit
Pre-Requisite	Basic Concept of Computer Languages.	3	1	-	3
Course Objectives	To understand the basic concepts and fundamentals of platform independent object-oriented language and implementing the Polymorphism, Abstraction and Inheritance using JAVA Programming.				

Course Outcomes: Upon successful completion of course, a student will be able to:

CO1	Apply fundamental Java programming concepts, including data types, operators, control structures, and methods, to develop simple Java
CO2	Design and implement object-oriented Java programs using arrays, strings, classes, constructors, and file handling techniques.
CO3	Develop modular and reusable Java applications using inheritance, interfaces, packages, and exception handling mechanisms.
CO4	Create advanced Java applications incorporating multithreading, database connectivity, GUI development, and event-driven programming concepts.

Module	Course Contents	Contact Hrs.	Mapped CO
1	**Introductionto Java**: Java Architecture and Features, Semantic and Syntax, differences between C++ and Java, Compiling and Executing a Java Program, Variables, Constants, Keywords Data Types ([1] Chapter 3). Operators: Arithmetic, Logical and Bitwise and Expressions, Comments, Doing Basic Program Output ([1] Chapter 4). Decision Making Constructs: Conditional Statements and Loops and Nesting ([1] Chapter 5). Java Methods: Defining, Scope, Passing and Returning Arguments, Type Conversion and Type Checking ([1] Chapter 7).	15	1
2	Arrays, Strings, I/O and Object-Oriented Programming: Creating & Using single& Multi-dimensional Arrays, Referencing Arrays. Strings: The Java String class, Creating & Using String Objects, Manipulating Strings, String	15	2

	Immutability & Equality, Passing Strings to & from Methods. String Buffer Classes: Simple I/O using Scanner class, Byte and Character streams, Reading/Writing from Console and Files. Principles of Object-Oriented Programming, Defining &Using Classes, Controlling Access to Class Members, Class Constructors, Method Overloading, Class Variables & Methods, Objects as parameters,		
3	Inheritance, Interfaces, Packages and Exceptionhandling: Inheritance: Single Level and Multilevel, Method Overriding, Dynamic Method Dispatch, Abstract Classes, Interfaces and Packages, Package and Class Visibility, Using Standard Java Packages: util, lang, io, net ([1] Chapter 9). WrapperClasses, Autoboxing/Unboxing, Enumerations and Metadata.Exception types, Uncaught Exceptions, Throw, Built-in Exceptions, Creating your own Exceptions ([1] Chapter 10).	15	3
4	Multi-Threading, Networking Basics and Database Connectivity, Applets and Event Handling: Multi-threading, creating single and multiple Threads, Thread prioritization, Suspending/resuming threads ([1] Chapter 11). Accessing and manipulating Databases using JDBC. Java Applets: Introduction to Applets, Writing Java Applets. Event Handling Mechanisms, Listener Interfaces. Introduction to AWT controls, Swing, Overview of servlets ([1] Chapter 23).	15	4

Suggested Readings

1. Herbert Schildt, “Java: The Complete Reference”, Seventh Edition.
2. Ken Arnold, James Gosling, David Homes, "The Java Programming Language", 4th Edition,
3. 2005.
4. 3. James Gosling, Bill Joy, Guy L Steele Jr, GiladBracha, Alex Buckley"The Java Language
5. Specification, Java SE 8 Edition (Java Series)", Published by Addison Wesley, 2014.

Online Resources

1. https://archive.nptel.ac.in/courses/106/105/106105191/
2. https://www.digimat.in/nptel/courses/video/106105191/L01.html

PO-PSO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2
CO1	3	1	3	1		3		3		2		3	1	3
CO2	3	1	3	2		3		3		3		3	1	3
CO3	3	1	3	2		3		3		3	1	3	1	3
CO4	3	1	3	2		3		3		3	1	3	1	3

Program	**B.Sc. (Hons./ Hons. with research) Mathematics**				
Year	**2**	**Semester**	**4**		
Course Name	**Java Programming Lab**				
Code	**RBMG4451**				
Course Type	**GE**	**L**	**T**	**P**	**Credit**
Pre-Requisite	Basic Concept of Computer Languages.	**-**	-	**2**	1
Course Objectives	To understand the basic concepts and fundamentals of platform independent object-oriented language and implement the Class, Objects, Polymorphism, Abstraction and Inheritance using JAVA Programming.				
Course Outcomes: Upon successful completion of course, a student will be able to:					
CO1	Apply fundamental Java programming concepts including data types, operators, control structures, arrays, strings, methods, and command-line arguments to develop basic application programs.				
CO2	Design and implement object-oriented programs using classes, objects, constructors, inheritance, packages, method overloading, access specifiers, and wrapper classes to solve computational problems.				
CO3	Develop robust Java applications by utilizing exception handling, multithreading, synchronization techniques, and user-defined exceptions for efficient and reliable program execution.				
CO4	Build Java-based networked and interactive applications using I/O streams, Scanner class, URL/URLConnection, socket programming, applets, and related APIs for communication and user interaction.				

The Lab work based on the course RBMG4451 shall include the problems on the following:

1. **Command Line Arguments**
   Write a Java program that accepts multiple integers through command line arguments and calculates their sum. Explain the concept of command line arguments and their advantages.

2. **Factorial Calculation**
   Develop a Java program to calculate the factorial of a given number. Explain the use of loops and recursion for factorial computation.

3. **Single Dimensional Array**
   Create a Java program that dynamically defines a one-dimensional array, stores values entered by the user, and displays the array elements. Discuss memory allocation in arrays.

4. Two Dimensional Array

Write a Java program to create a two-dimensional array and determine the number of rows and columns using the length property. Explain the concept of multidimensional arrays.

5. Decimal to Binary Conversion

Develop a Java program to convert a decimal number into its binary equivalent. Explain the algorithm used for number system conversion.

6. Prime Number Verification

Write a Java program that accepts a number from the keyboard and determines whether it is prime or composite. Discuss the logic used for prime number testing.

7. Interactive Summation

Design a Java program where the number of integers to be entered is specified through command line arguments, while the actual integers are entered interactively through the keyboard. Compute and display their sum.

8. String and StringBuffer Operations

Implement a Java program demonstrating the use of String and StringBuffer class methods such as setCharAt(), setLength(), append(), insert(), concat(), and equals(). Compare mutable and immutable strings.

9. Distance Class and Objects

Create a class named Distance to represent distance in feet and inches. Implement methods to input, display, and calculate distance values. Demonstrate object creation and the use of the this keyword.

10. Constructors and Object Cloning

Modify the Distance class by implementing constructors for initialization. Demonstrate reference assignment between objects and create a clone of an existing object. Explain shallow and deep copying concepts.

11. Function Overloading and Type Conversion

Write a Java program to demonstrate method overloading. Show how Java performs automatic type conversion when no exact matching function is available.

12. Access Specifiers and Parameter Passing

Develop a Java program to illustrate the differences between public and private access specifiers. Demonstrate pass-by-value behavior for primitive data types and reference passing for objects. Also explain the use of the final keyword.

13. Static Methods and Variable Arguments

Write a Java program to demonstrate the use of static methods and variable-length argument lists (varargs). Discuss the benefits of static members and flexible parameter passing.

14. Boxing and Unboxing

Implement a Java program to demonstrate autoboxing and unboxing between primitive data types and wrapper classes. Explain their role in collection frameworks.

15. Multi-File Program Using Scanner

Create a multi-file Java application where a message entered by the user is accepted in one class and displayed through a method defined in another class. Use the Scanner class for input handling.

16. Multilevel Package and Fibonacci Series

Develop a reusable Java class for generating the Fibonacci series and place it within a multilevel package structure. Create another program that accesses and uses this class.

17. Access Protection in Packages

Write a Java program to demonstrate different levels of access protection (public, protected, default, and private) among classes and subclasses belonging to the same package and different packages.

18. Divide by Zero Exception

Develop a Java program that accepts two numbers and performs division. Handle the ArithmeticException generated when the denominator is zero and display an appropriate message.

19. Nested Try Statements

Write a Java program using nested try-catch blocks to demonstrate exception handling. Explain the sequence in which catch handlers are checked and executed.

20. User-Defined Exceptions

Design a Java program that defines a custom exception class for handling application-specific errors. Demonstrate throwing and catching the user-defined exception.

21. Thread Priorities

Create a Java program that generates multiple threads with different priorities. Observe and explain the effect of thread priorities on execution.

22. Thread Synchronization

Implement the Producer–Consumer problem using Java threads. Demonstrate thread synchronization and inter-thread communication mechanisms.

23. URL and URLConnection

Write a Java program that creates a URL object and establishes a URLConnection. Retrieve and display various URL components and content-related information.

24. Datagram Client-Server Communication

Develop a simple UDP-based client-server application using datagram sockets. The server should send a message to the client, which displays it upon receipt.

25. Banner Animation Using Threads and Applets

Create a Java applet that displays a scrolling banner message. Implement multithreading to animate the text movement across the applet window from left to right.

Online Resources:

1) https://archive.nptel.ac.in/courses/106/105/106105191/
2) https://www.digimat.in/nptel/courses/video/106105191/L01.html

PO-PSO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2
CO1	3	1	2	1		3		3		2		3	1	3
CO2	3	1	3	2		3		3		3		3	1	3
CO3	2	1	3	2		3		3		3	1	2	1	2
CO4	2	1	3	3		3		3		3	1	2	2	2

Program	**B.Sc. (Hons./ Hons. with research) Mathematics**				
Year	**3**	**Semester**	**5**		
Course Name	**Web Technologies**				
Code	**RBMG4502**				
Course Type	**GE**	**L**	**T**	**P**	**Credit**
Pre-Requisite	The concepts of Internet, HTML	**3**	1	**-**	3
Course Objectives	To provide the basics of the internet, web terminologies, introducing scripting language concepts for developing client-side and server-side applications				

Course Outcomes: Upon successful completion of course, a student will be able to:

CO1	Understand basics of the Internet and World Wide Web and knowledge and skills for creation of web site considering both client and server-side programming.
CO2	Learn basic skill to develop responsive web applications and understand different web extensions and web services standards.
CO3	Understand basic concepts of Search Engine Basics and learn Web Service Essentials.
CO4	Learn Rich Internet Application Technologies and get acquainted with Web Analytics 2.0

Module	**Course Contents**	**Contact**	**Mapped**
1	Introduction to World Wide Web: Internet Standards, Introduction to WWW and WWW Architecture, Internet Protocols, Overview of HTTP, HTTP request – response, Generations of dynamic web pages. ([1] Chapter 2). Introduction to HTML and HTML5, HTML Tags, Anchors, Backgrounds, Images, Hyperlinks, Lists, Tables, Frames, HTML Forms. ([1] Chapter 4).	15	1

2	CSS and Java Script: The need for CSS, Introduction to CSS, Basic syntax and structure, Inline Styles, Embedding Style Sheets, Linking External Style, Backgrounds, Manipulating Text, Margins and Padding, Positioning using CSS ([1] Chapter 8). Java script Introduction, Core features, Data types and Variables, Operators, Expressions, Functions, Objects, Array([1] Chapter 9).	15	2

	JavaBean, Introduction to EJB ([1] Chapter 12).		
3	Database Connectivity: Database Basics, SQL, MySQL, PostgreSQL, JDBC API, Driver Types. Two-Tier and Three-Tier Models([1] Chapter 6). Connection Overview, Transactions, Driver Manager Overview, Statement Overview, Result Set Overview, Types of Result Sets, Prepared Statement Overview ([1] Chapter 7).	15	3
4	Java Applet and JSP: Java Web Programs and Applets, Web Application, Servlet, Servlet Life Cycle, Servlet Programming, Introduction to JSP, Life Cycle of a JSP Page, Translation and Compilation, Creating Static Content, Response and Page Encoding, Creating Dynamic Content, Using Objects within JSP Pages([1] Chapter 11).	15	4

Suggested Readings

1. J2EE: The complete Reference by James Keogh.
2. Java EE and HTML5 Enterprise Application Development (Oracle Press) by John Brock, Arun Gupta, GeertjanWielenga
3. Struts: The Complete Reference, 2nd Edition by James Holmes.

Online Resources

1. https://www.digimat.in/nptel/courses/video/106105084/L01.html
2. https://onlinecourses.swayam2.ac.in/nou24_cs09/preview

PO-PSO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2
CO1	2	1	2	1		3		3		3		2	1	2
CO2	2	1	2	2		3		3		3		2	1	2
CO3	2	1	2	2		2		2		3		2	1	2
CO4	2	2	2	2		3		3		3		2	1	2

Program	**B.Sc. (Hons./ Hons. with research) Mathematics**				
Year	**3**	**Semester**	**5**		
Course Name	**Web Technologies Lab**				
Code	**RBMG4551**				
Course Type	**GE**	**L**	**T**	**P**	**Credit**
Pre-Requisite	The concepts of Internet, HTML and CSS	**-**	-	**2**	1
Course Objectives	To provide the basics of the internet, web terminologies, introducing scripting language concepts for developing client-side and server-side applications.				

Course Outcomes: Upon successful completion of course, a student will be able to:	
CO1	Design and develop web pages using HTML elements, hyperlinks, multimedia components, tables, forms, image maps, and semantic tags to create structured and accessible websites.
CO2	Apply CSS techniques, including inline, internal, and external style sheets, to enhance the presentation, layout, and responsiveness of web pages.
CO3	Develop client-side interactive web applications using JavaScript for form validation, mathematical computations, event handling, and dynamic content generation.
CO4	Create Java Applets that implement graphics, animation, and event-driven programming concepts using mouse, button, and graphical user interface components.

The Lab work based on the course RBMG4551 shall include the problems on the following:

1. Text Formatting Tags

Design a web page that demonstrates the use of various HTML text formatting tags such as headings, bold, italic, underline, superscript, subscript, mark, and preformatted text. Explain the purpose and application of each tag.

2. Hyperlinks and Navigation

Create multiple web pages and establish navigation among them using hyperlinks. Demonstrate internal, external, and email links while explaining their significance in website development.

3. Cascading Style Sheets (CSS)

Develop a web page illustrating the use of Inline, Internal, and External Style Sheets. Compare the advantages and limitations of each CSS implementation technique.

4. Image Maps

Design a web page containing an image map with multiple clickable regions. Configure each region to redirect the user to different web pages and explain the working of image maps.

5. HTML Forms and Controls

Create a web-based form that utilizes various form controls such as text fields, password fields, radio buttons, checkboxes, drop-down lists, text areas, file upload controls, and submit/reset buttons. Discuss their practical applications.

6. Semantic HTML Elements

Design a web page using semantic HTML elements such as header, nav, section, article, aside, and footer. Explain how semantic elements improve accessibility and search engine optimization.

7. Tables and Layout Design

Create different types of tables using HTML and use table structures to organize web page content effectively. Demonstrate the use of row spanning, column spanning, and nested tables.

8. Multimedia Integration

Develop a web page that embeds multimedia elements including images, audio, video, and animations. Explain the HTML tags used for multimedia integration.

9. JavaScript Series Generation

Write a JavaScript program that generates and displays mathematical sequences such as factorial series, Fibonacci series, or any user-defined series. Explain the logic used for sequence generation.

10. Form Validation Using JavaScript

Design a web form and implement client-side validation using JavaScript. Validate mandatory fields, email addresses, passwords, and numeric inputs before form submission.

11. Prime Numbers Between 1 and 100

Develop a JavaScript program to identify and display all prime numbers between 1 and 100. Discuss the algorithm used for prime number detection.

12. Sum of Digits

Create a JavaScript application that accepts a number from the user and calculates the sum of its digits. Explain the iterative process used in the computation.

13. Word Count in a Sentence

Write a JavaScript program that accepts a sentence from the user and counts the total number of words without using the split() function. Explain the character-by-character processing technique employed.

14. Simple Calculator

Design a web-based calculator using JavaScript that performs basic arithmetic operations such as addition, subtraction, multiplication, and division. Discuss event handling in calculator design.

15. Circle Drawing Applet

Develop a Java Applet with dimensions 500 × 300 pixels that draws a centered circle of radius 100 pixels and displays the user's name at the center. Explain the use of graphics methods in Applet programming.

16. Multiple Circle Drawing

Create a Java Applet that draws ten red circles arranged vertically in the center of the applet window. Demonstrate the use of loops and graphics functions.

17. Animated Rectangle Filling

Build a Java Applet that displays a horizontal rectangle in its center and gradually fills it with color from left to right. Explain the concept of animation in Applets.

18. Mouse Event Handling

Develop a Java Applet that tracks mouse movements and displays the current mouse coordinates at the upper-left corner of the window. Draw a filled 10 × 10 pixel square at the current mouse location. Explain event-driven programming concepts.

19. Button Event Handling

Create a Java Applet containing a button whose label initially displays “Start.” Implement event handling such that the label toggles between “Start” and “Stop” whenever the button is clicked. Discuss action events and listener mechanisms.

Online Resources

1. https://www.digimat.in/nptel/courses/video/106105084/L01.html
2. https://onlinecourses.swayam2.ac.in/nou24_cs09/preview

PO-PSO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2
CO1	2	1	2	2		3		3		3		2	1	2
CO2	2	1	2	2		3		3		3		2	1	2
CO3	2	1	3	2		3		3		3		2	1	2
CO4	2	1	2	3		3		3		3		2	1	2

Program	**B.Sc. (Hons./ Hons. with research) Mathematics**				
Year	**3**	**Semester**	**6**		
Course Name	**Software Engineering**				
Code	**RBMG4602**				
Course Type	**GE**	**L**	**T**	**P**	**Credit**
Pre-Requisite	The concept of Software, HardwareTechnologiesand System	**3**	1	**-**	4
Course Objectives	To provides project-rich learning experiences to educate software engineers for success in a rapidly evolving Software development field.				

Course Outcomes: Upon successful completion of course, a student will be able to:

CO1	Get basic knowledge and understanding of the analysis and Design of Complex systems
CO2	Apply software engineering Principles and techniques.
CO3	Produce efficient, reliable, robust and cost-effective Software Solutions.
CO4	Manage time, processes and resources effectively by prioritizing competing demands to achieve personal and team goals Identify and analyzes the common threats in each domain.

Module	**Course Contents**	**Contact Hrs**	**Mapped CO**
1	Introduction: Introduction to Software, Software Application, System Evolution of Software, Software as System, Software Crisis, Significance of Software, Software characteristics, Changing nature of Software ([1] Chapter 1). Software Engineering as a Layered Technology, A Generic View of Software Engineering, Software Process framework, Framework and Umbrella Activities, Process Capability Maturity Model Integration (CMMI) ([1] Chapter 2).	15	1
2	Requirement Analysis & Specification: Software Requirement Analysis, Initiating Requirement Engineering Process, Requirement Analysis and Modeling Techniques: Software Process Models, Waterfall model, Prototyping, Flow Oriented Model. System Requirement Specification: Need for SRS, Characteristics of SRS, Components of SRS, Software Project Management, Software Project planning, Software Monitoring and Control, Estimation in Project Planning Process ([1] Chapter 3)	15	2

3	Risk Management: Software Risks, Risk Identification, Risk Projection and Risk Refinement, RMMM Plan ([1] Chapter 6). Quality Concepts, Software Quality Assurance, Software Reviews, Metrics for Process and Projects,Identify IT Project Risk, Risk Analysis and Assessment, Risk Strategies, Risk Monitoring and Control, Risk	15	3
4	Software Design & Testing: Design Objectives, Design Concepts, Architectural Design Elements, Software Architecture, Data Design at the Architectural Level and Component Level, Mapping of Data Flow into Software Architecture, Modeling Component Level Design ([1] Chapter 14). Software Testing Fundamentals: Strategic	15	4

1. Roger S. Pressman, Software Engineering: A practitioner's approach, McGraw Hill.
2. Rajib Mall, Fundamentals of Software Engineering, Prentice Hall India.
3. K.K. Aggarwal and Y. Singh, Software Engineering (2nd Edition), New Age International Publishers, 2008.

Online Resources

1. https://archive.nptel.ac.in/courses/106/101/106101061/
2. https://archive.nptel.ac.in/courses/106/105/106105182/

PO-PSO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2
CO1	2	1	3	3		2	1	2	1	2		2	1	2
CO2	2	1	3	3		2	1	3	1	2		2	1	2
CO3	2	1	3	3	1	2	1	3	2	2	1	2	1	2
CO4	1	2	2	2	1	1	3	3	3	1	2	1	2	1

Program	**B.Sc. (Hons./ Hons. with research) Mathematics**				
Year	**4**	**Semester**	7		
Course Name	**Information Security and Cyber Law**				
Code	**RBMG4702**				
Course Type	**GE**	**L**	**T**	**P**	**Credit**
Pre-Requisite	Fundamental comprehension of how computers and networks function	**3**	1	**-**	4
Course Objectives	To introduce the students the concepts of information security and different type of attacks in the cyber space cyber law.				
Course Outcomes: Upon successful completion of course, a student will be able to:					
CO1	Understand various algorithms of Cryptography and Network Security.				
CO2	Secure a Message over Insecure channel by Various Means.				
CO3	Learn about how to Maintain the Confidentiality, Integrity and Availability of Data.				
CO4	Understand various Protocols for Network Security to protect against the threats in the Networks.				

Module	**Course Contents**	**Contact Hrs**	**Mapped CO**
1	Program Security and Threats: Secure programs, Non malicious Program Errors, Malicious Codes Virus, Trap Doors, Salami Attacks, Covert Channels, Control Against Program([1] Chapter 21). Threats and Protection in OS: Memory and Address Protection, Access Control, File Protection, User Authentication ([1]	15	1
2	Introduction and Cryptography: Security Attacks, Computer Criminals, Security Services, Security Mechanisms ([1] Chapter 1).Cryptography: Substitution Ciphers, Transpositions Cipher, Confusion, Diffusion, ([1] Chapter 3) Symmetric, Asymmetric Encryption. DES Modes of DES, Uses of Encryption ([1] Chapter 4). Hash function, ([1] Chapter 11). Key exchange ([1] Chapter 10). Digital Signatures, Digital Certificates ([1] Chapter 13).	15	2

3	Database Security: Requirements, Reliability, Integrity, Sensitive Data, Inference, Multilevel Security ([1] Chapter 12). Network Security: Threats in Networks, Security Controls ([1] Chapter 17). Firewalls ([1] Chapter 23) Intrusion Detection Systems ([1] Chapter 22). Secure E-mails ([1] Chapter 19).	15	3
4	Administrating Security: Security Planning, Risk Analysis, Organizational Security Policy, Physical Security. Ethical issues in Security: Protecting Programs and Data. Information and Law ([1] Chapter 24).	15	4

Suggested Readings

1. W. Stallings, Cryptography and Network Security: Principles and Practice, Seventh
   a. Edition,Pearson.
2. AtulKahate, Cryptography and Network Security, Second Edition, Tata McGraw-Hill.
3. W. Stallings; Network Security Essentials: Applications and Standards, 4/E, 2010.

Online Resources

1. https://archive.nptel.ac.in/courses/106/106/106106129/
2. https://onlinecourses.nptel.ac.in/noc23_cs127/preview

PO-PSO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2
CO1	2	1	3	2		3		3		3	2	2	1	2
CO2	2	1	3	2		3		3		3	2	2	1	2
CO3	2	1	2	2	1	2		3		2	3	2	2	2
CO4	2	1	3	2	1	3		3		3	3	2	2	2

Program	**B.Sc. (Hons./ Hons. with research) Mathematics**				
Year	**4**	**Semester**	**8**		
Course Name	**Cloud Computing**				
Code	**RBMG4802**				
Course Type	**GE**	**L**	**T**	**P**	**Credit**
Pre-Requisite	Knowledge of database and computer networks	**3**	1	**-**	4
Course Objectives	To provide students with the fundamentals and sound foundation of the Cloud Computing so that they are able to start using and adopting Cloud Computing services and tools in their real life.				
Course Outcomes: Upon successful completion of course, a student will be able to:					
CO1	Analyze the trade-offs between deploying applications in the cloud and over the local infrastructure and Compare the advantages and disadvantages of various cloud computing platforms.				
CO2	Deploy applications over commercial Cloud Computing infrastructures such as Amazon Web Services, Windows Azure, and Google AppEngine.				
CO3	Analyze the Performance, scalability, and Availability of the underlying Cloud technologies and software.				
CO4	Identify security and Privacy issues in Cloud Computing and Solve a real- world problem using cloud computing through group collaboration.				

Module	**Course Contents**	**Contact Hrs**	**Mapped CO**
1	Overview of Cloud Computing Paradigm: Recent trends in Computing, Grid Computing, Cluster Computing, Distributed Computing, Utility Computing, Cloud Computing, Introduction to Cloud Computing; Evolution of Cloud Computing, Cloud Service Providers: Benefits and limitations of Cloud Computing ([1] Chapter 1).	15	1

2	Cloud Computing Architecture: Comparison with traditional Computing Architecture (client/server) ([1] Chapter 2). Services provided at various levels; Service Models- Infrastructure as a Service (IaaS), Platform as a Service (PaaS), Software as a Service (SaaS). How Cloud Computing works, Deployment Models- Public Cloud, Private Cloud, Hybrid Cloud, Community Cloud, Case study of NIST Architecture ([1] Chapter 2).	15	2
3	Information Storage in Cloud Computing: Introduction- Objectives, Storage as a Service, Storage Providers: Amazon Simple Storage Service, Nirvanix- Google Big Table Data store Mobile Me: Live Mesh, Storage Security; Merits and Demerits of Storage: Public, Private, and Hybrid Clouds- A Comparison, Examining the Economics of the Private Cloud, Case study of AWS. ([1] Chapter 5).	15	3
4	Cloud Security: Infrastructure Security: Network Level Security, Host Level Security, Application level Security, Data Security and Storage. Data privacy and security issues, Jurisdictional Issues Raised by Data Location, Authentication in Cloud Computing ([1] Chapter 13).	15	4

Suggested Readings

1. Essentials of Cloud Computing, K Chandrasekaran, CRC Press.
2. Cloud Computing: Principles and Paradigms, Editors: RajkumarBuyya, James Broberg, Andrzej M. Goscinski, Wile, 2011
3. Cloud Computing Bible, Barrie Sosinsky, Wiley-India, 2010

Online Resources

1. https://archive.nptel.ac.in/courses/106/105/106105167/
2. https://archive.nptel.ac.in/courses/106/105/106105223/

PO-PSO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2
CO1	2	2	3	2		3		3	1	3		2	1	2
CO2	2	1	2	3		3	1	3	1	3		2	1	2
CO3	2	1	3	2		3	1	3	2	3		2	1	2
CO4	2	2	3	3		3	3	3	2	3	2	2	2	2

Program	B.Sc. (Hons./ Hons. with Research) Mathematics				
Year	1	Semester	1		
Course Name	Descriptive Statistics				
Code	RBMS2101				
Course Type	SEC	L	T	P	Credit
Pre-Requisite	10+2 Mathematics	2	1	0	3
Course Objectives	The objective of the course is to understand Statistics, its scope and importance in various fields. Learn difference between sample, population, data and its types. Understand graphical representation of different types of data. Differentiate between measure of central tendency & dispersion.				
Course Outcomes: After completion of the course, students will be able to:					
CO1	Understand concept of sample vs. Population and difference between different types of data.				
CO2	Describe data with measures of central tendency measure of dispersion				
CO3	Understand, measure of skewness, kurtosis and their utility.				
CO4	Determine the process constructing linear and non-linear curves through the method of least square and understand its usage in binary mixtures.				

Module	Course Contents	Contact Hrs.	Mapped CO
1	Concept of statistical population ([2] Chapter 1); Primary and secondary data ([2] Chapter 3). Presentation of data: Classification, Tabulation ([2] Chapter 5). Diagrammatic and graphical representation of group data. Frequency distributions, cumulative frequency distributions and their graphical representations and ogives ([3] Chapter 3).	11	CO1
2	Measures of central tendency: Average or arithmetic mean, median, mode, Geometric mean, Harmonic mean for grouped and ungrouped data with their merits and demerits. ([3] Chapter 4). Measure of dispersion, merits and demerits of these measures ([1] Chapter 7).	12	CO2
3	Moments: Moments about origin, central moment ([2] Chapter 9), Skewness and kurtosis and their measures ([1] Chapter 8), measures based on quartiles (Quartiles, Deciles, Percentiles). ([1] Chapter 7).	11	CO3
4	Correlation: Concept, types, Scatter diagram, Karl Pearson correlation coefficient and Spearman Rank correlation coefficient. Regression: Concept, regression lines, regression coefficients, method of least squares, Estimation. ([4] Chapter 9).	11	CO4

Suggested Readings:

1. Beri, G.C., Business Statistics (3rd ed.), TMH Education PVT.LTDNew Delhi, 2011.
2. Gupta, S.P., Statistical Methods (41st ed.), SulTan Chand and Sons New Delhi, 2011 .
3. Tusian , P.C. and Tulsian, Bharat, Business Statistics (2nd ed.), Sultan Chand and company ltd. New Delhi, 2019.
4. Gupta, S.C. and Kapoor, V.K., Fundamentals of Mathematical Statistics (10thed.), Sultan
5. Chand and Sons, 2000.

Online Resources:

1. https://swayam.gov.in/explorer?searchText=statistics
2. https://nptel.ac.in/course.html

Course Articulation Matrix														
PO-PSO	**PO1**	**PO2**	**PO3**	**PO4**	**PO5**	**PO6**	**PO7**	**PO8**	**PO9**	**PO10**	**PO11**	**PO12**	**PSO1**	**PSO2**
CO1	2	1	2	1				3				3	1	2
CO2	3	1	3	1		1		3		1		3	1	3
CO3	3	1	3	2		1		3		1		3	1	3
CO4	3	1	3	2		1		3		1		3	2	3

Program	B.Sc. (Hons./ Hons. with Research) Mathematics				
Year	1	Semester	2		
Course Name	Probability & Distributions				
Code	RBMS2202				
Course Type	SEC	L	T	P	Credit
Pre-Requisite	10+2 Mathematics	2	1	0	3
Course Objectives	The objective of the course is to understand understand concept of probability along with basic laws and axioms of probability. Understand Addition & Multiplication theorems of probability. Understand the concept of random variable (discrete and continuous), concept of probability distribution. Knowledge of discrete and continuous distribution.				
Course Outcomes: After completion of the course, students will be able to:					
CO1	Apply the concept of different terms used in probability.				
CO2	Apply basic probability principles to solve real life problems.				
CO3	Understand applications of discrete and continuous distributions to solve the problems.				
CO4	Differentiate and apply different types of distribution.				

Module	Course Contents	Contact Hrs.	Mapped CO
1	Basic concepts of probability, random experiment, trial, sample point, sample space, events, definition of mutually exclusive, exhaustive and equally likely events. Definitions of probability: Classical, relative frequency and axiomatic approaches and their limitations. ([2] Chapter 1).	11	CO1
2	Theorems of probability: Addition theorem of probability for n events, theorem of total probability or n events. Conditional probability and Multiplication theorems of probability for n events, Independent events. Bayes' theorem and its applications. ([2] Chapter 1).	11	CO2
3	Random variable: discrete and continuous ([1] Chapter 10). Probability mass function (PMF), probability density function (PDF), cumulative distribution function (CDF), joint distribution of two random variables, marginal and conditional distributions , independence of random variables ([3] Chapter 5).	12	CO3
4	Expectation of random variables and its properties, expectation of sum of random variables and product of independent random variables ([3] Chapter 6). Probability distributions: Binomial, Poisson, Normal distribution and their properties ([1] Chapter 10).	11	CO4

Suggested Readings

1. Beri, G.C., Business Statistics (3rd ed.), TMH Education PVT.LTD New Delhi, 2011.
2. Gupta, S.P., Statistical Methods (41st ed.), Sultan Chand and Sons New Delhi, 2011.
3. Tulsian , P.C. and Tulsian, Bharat, Business Statistics (2nd ed.), Sultan Chand and company ltd. New Delhi, 2019

Online Resources

1. https://swayam.gov.in/explorer?searchText=statistics
2. https://nptel.ac.in/course.html

Course Articulation Matrix														
PO-PSO	**PO1**	**PO2**	**PO3**	**PO4**	**PO5**	**PO6**	**PO7**	**PO8**	**PO9**	**PO10**	**PO11**	**PO12**	**PSO1**	**PSO2**
CO1	3	1	2	1				3				3	1	3
CO2	3	1	3	1	1			3		1		3	1	3
CO3	3	1	3	2	1	1		3		1		3	2	3
CO4	3	1	3	2	1	1		3		1		3	2	3

Program	**B.Sc. (Hons./ Hons. with Research) Mathematics**				
Year	**2**	**Semester**		**3**	
Course Name	**Statistical Inference**				
Code	**RBMS2303**				
Course Type	**SEC**	**L**	**T**	**P**	**Credit**
Pre-Requisite	**10+2 Mathematics**	**2**	**1**	**0**	**3**
Course Objectives	The objective of the course is to develop an understanding of concepts of difference between parameter & statistic and standard error. Knowledge of the sampling distribution of the sum and mean and practice various methods of estimations of parameters, sample and large sample tests.				
Course Outcomes: After completion of the course, students will be able to:					
CO1	Understand the concept of Point Estimation and discuss characteristics of a good estimator.				
CO2	Understand the concept of MP, UMP tests.				
CO3	Differentiate between the terms like null and alternative hypotheses, two-tailed and one-tailed alternative hypotheses, significant and insignificant, level of significance and confidence, p value etc.				
CO4	Identify the situations where the various sampling techniques shall be used.				

Module	Course Contents	Contact Hrs.	Mapped CO
1	Point estimation. Characteristics of a good estimator: Unbiasedness, consistency, sufficiency, and efficiency. Method of maximum likelihood and properties of maximum likelihood estimators (without proof). ([1] Chapter2).	12	CO1
2	Statistical Hypothesis (simple and composite). Testing of hypothesis, Type I and Type II errors, significance level, p-values, power of a test. Definitions of Most Powerful (MP), Uniformly Most Powerful (UMP) ([1] Chapter9).	11	CO2
3	Neyman-Pearson's lemma and its applications for finding most powerful tests for simple hypothesis against simple alternative. Tests based on t, F and $\chi 2$ distributions. ([1] Chapter9).	11	CO3
4	Sampling vs. complete enumeration: sampling units and frame. ([3] Chapter2). Simple Random sampling with and without replacement. Estimation of population mean and proportion. Derivation of expression for variance of these estimators. Estimation of variances. ([3] Chapter3). Stratified random sampling. ([3] Chapter4).	11	CO4

Suggested Readings

1. Gupta, S.C. and Kapoor, V.K., Fundamentals of Mathematical Statistics (10th ed.), Sultan Chand and Sons, 2000.
2. Goon, A.M., Gupta, M.K. & Dasgupta, B., Fundamentals of Statistics, Vol. I. ,Kolkata, The World Press, 2002 .
3. Des Raj, Sampling Theory. Tata McGraw Hill, New York, 1976.

Online Resources

1. https://swayam.gov.in/explorer?searchText=statistics
2. https://nptel.ac.in/course.html

Course Articulation Matrix														
PO-PSO	**PO1**	**PO2**	**PO3**	**PO4**	**PO5**	**PO6**	**PO7**	**PO8**	**PO9**	**PO10**	**PO11**	**PO12**	**PSO1**	**PSO2**
CO1	3	1	3	3		1		3		1		3	2	3
CO2	3	1	3	3		1		3		1		3	2	3
CO3	3	1	3	3		1		3		1		3	2	3
CO4	3	1	3	2		1		3		1		3	2	3

Program	B.Sc. (Hons./ Hons. with Research) Mathematics				
Year	2	Semester	4		
Course Name	Applied Statistics				
Code	RBMS1404				
Course Type	SEC	L	T	P	Credit
Pre-Requisite	Basic Knowledge of Statistics	2	1	0	3
Course Objectives	The objective of the course is to understand Time Series, its scope and importance in various fields. Knowledge of Index number. Difference between CDR, CVR and GRR. Understand the concept of life table and its construction.				
Course Outcomes: After completion of the course, students will be able to:					
CO1	Understand the concept of Time series along with its different components.				
CO2	Understand the concept of Index numbers and their applications along with different types of Index numbers.				
CO3	Apply different measurement of fertility.				
CO4	Familiarity with various demographic methods and different measures of mortality and life Table.				

Module	Course Contents	Contact Hrs.	Mapped CO
1	Time series: Its different components, Trend, Seasonal fluctuation, cyclical fluctuation and Irregular component, additive model, multiplicative models. Determination of trend: free hand curve fitting method, semi average method, mathematical curve fitting method, method of moving averages, analysis of seasonal fluctuations. ([1] Chapter2).	12	CO1
2	Index number : Its definition, its applications, problem involved in computation of index number, price relative and quantity relatives, use of averages, simple aggregative and weighted average method. Laspeyre's, Paashe's, Fisher's and Marshall-Edgeworth's index number ([1] Chapter3).	11	CO2
3	Demographic methods: Sources of demographic data – census, register, ad-hoc survey, hospital records, Measurement of fertility – crude birth rate, general fertility rate, age-specific birth rate, total fertility rate, gross reproduction rate, net reproduction rate. ([2] Chapter9).	11	CO2
4	Measurement of mortality: crude death rates, age specific death rates, infant mortality rates, standardized death rates, Life tables: complete life table, its main features. ([2] Chapter9).	11	CO2

Suggested Readings:

1. Gupta, S.C. and Kapoor, V.K. Fundamentals of Applied Statistics (4th ed.), Sultan Chand and Sons 2008.
2. Mukhopadhyay, P., Applied Statistics, 2nd edition revised reprint, Books and Allied (P) Ltd, 2011.

Online Resources:

1. https://swayam.gov.in/explorer?searchText=statistics
2. https://nptel.ac.in/course.html

Course Articulation Matrix														
PO-PSO	**PO1**	**PO2**	**PO3**	**PO4**	**PO5**	**PO6**	**PO7**	**PO8**	**PO9**	**PO10**	**PO11**	**PO12**	**PSO1**	**PSO2**
CO1	3	1	3	2	1	1		3		1		3	2	3
CO2	3	1	3	2	1	1		3		1		3	2	3
CO3	3	1	3	2	2	1		3		1		3	2	3
CO4	3	1	3	2	2	1		3		1		3	2	3

Program	**B.Sc. (Hons./ Hons. with research) Mathematics**				
Year	**2**	**Semester**		**3**	
Course Name	**R Programming**				
Code	**RBMV4301**				
Course Type	**VAC**	**L**	**T**	**P**	**Credit**
Pre-Requisite	**Basic Concepts of Programming Principles**	**1**	-	**-**	**1**
Course Objectives	This course introduces R, which is a popular statistical programming language. The coursecovers data reading and its manipulation using R, which is widely used for data analysis internationally.				
Course Outcomes: Upon successful completion of course, a student will be able to:					
CO1	Develop an R script and execute it				
CO2	Read/write data from/in files and extracting data from web-sites, Cleaning and transforming data.				
CO3	Extract data from different sources using API and use it for data analysis				
CO4	Visualize and summarize the data. Design application with database connectivity for data analysis				

Module	Course Contents	Contact Hrs.	Mapped CO
1	**Introduction:** R interpreter, Introduction to major R data structures like vectors, matrices,arrays, list and data frames, Control Structures, vectorized if and multiple selection, functions. **Installing, loading and using packages:** Read/write data from/in files, extracting data from web-sites, Clean data, Transform data by sorting, adding/removing new/existing columns, centering, scaling and normalizing the data values, converting types of values, using string in-builtfunctions, Statistical analysis of data for summarizing and understanding data, Visualizing data using scatter plot, line plot, bar chart, histogram and box plot **Designing GUI:** Building interactive application and connecting it with database, Building Packages.	15	1,2,3,4

Suggested Readings:

1. The book of R, by tilman m. Davies.
2. R Programming for Data Science, by Roger D. Peng.

Online Resources:

1. https://nptel.ac.in/courses/111104100
2. https://www.classcentral.com/course/swayam-introduction-to-r-software-14162

Course Articulation Matrix														
PO-PSO	**PO1**	**PO2**	**PO3**	**PO4**	**PO5**	**PO6**	**PO7**	**PO8**	**PO9**	**PO10**	**PO11**	**PO12**	**PSO1**	**PSO2**
CO1			1	1				1			1			1
CO2			1	1				1			1			1
CO3		1	1	1		1		1			1		1	
CO4		1	1	1		1		1			1		1	1

Program	B.Sc. (Hons./ Hons. with research) Mathematics				
Year	2	Semester		3	
Course Name	R programming Lab				
Code	RBMV4351				
Course Type	VAC	L	T	P	Credit
Pre-Requisite	Basic Concepts of Programming Principles	-	-	2	1
Course Objectives	This course implements statistical methods using R language. The course also applies data reading and its manipulation.				
Course Outcomes: Upon successful completion of course, a student will be able to:					
CO1	Demonstrate proficiency in R programming fundamentals, including variables, data types, operators, vectors, matrices, arrays, and control structures for solving computational problems.				
CO2	Apply R programming techniques to create, manipulate, and analyze data using data frames, user-defined functions, and data handling operations.				
CO3	Develop and implement R programs for mathematical, statistical, and logical problem-solving using appropriate programming constructs and functions.				
CO4	Utilize R for data visualization and statistical analysis by generating graphical representations, computing descriptive statistics, and interpreting analytical results.				

The Lab work based on the course RBMG4551 shall include the problems on the following:

1. **Introduction to R and Basic Operations**
- Create variables of different data types (numeric, character, logical).
- Perform arithmetic operations (+, −, ×, ÷, modulus, exponentiation).
- Display results using print() and cat().
- Calculate the area and circumference of a circle for a given radius.

2. **Working with Vectors**
- Create a vector containing the first 20 natural numbers.
- Find the sum, mean, median, minimum, and maximum values.
- Extract even and odd numbers from the vector.
- Sort the vector in ascending and descending order.

3. Matrices and Arrays

- Create two 3×3 matrices.
- Perform matrix addition, subtraction, and multiplication.
- Find the transpose of a matrix.
- Calculate determinant and inverse of a matrix.

4. Data Frames and Data Handling

- Create a student data frame containing Roll Number, Name, Marks, and Grade.
- Add a new column for Percentage.
- Display students scoring above 75%.
- Sort records based on marks.

5. Control Structures

- Write a program to determine whether a number is positive, negative, or zero.
- Generate the multiplication table of a given number using a loop.
- Calculate factorial using a for loop.
- Print the first 20 Fibonacci numbers.

6. User-Defined Functions

- Write a function to find the largest of three numbers.
- Create a function to check whether a number is prime.
- Develop a function to calculate the sum of digits of an integer.
- Demonstrate function calls with different arguments.

7. Data Visualization

- Create a bar chart showing marks obtained by students.
- Draw a pie chart representing departmental student distribution.
- Generate a histogram of randomly generated data.
- Create a scatter plot showing the relationship between study hours and marks.

8. Statistical Analysis

- Generate 100 random numbers from a normal distribution.
- Compute mean, median, mode, variance, and standard deviation.
- Calculate quartiles and interquartile range.
- Interpret the statistical results.

Course Articulation Matrix														
PO-PSO	**PO1**	**PO2**	**PO3**	**PO4**	**PO5**	**PO6**	**PO7**	**PO8**	**PO9**	**PO10**	**PO11**	**PO12**	**PSO1**	**PSO2**
CO1			2	2				1			2			1
CO2			1	2				2			2			2
CO3		2	2	2		2		2			2		2	
CO4		1	1	1		1		2			1		1	2

Program	B.Sc. (Hons./ Hons. with research) Mathematics				
Year	2	Semester		4	
Course Name	Web Development				
Code	RBMV4401				
Course Type	VAC	L	T	P	Credit
Pre-Requisite	Basic knowledge of HTML and Computer Networking	1	-	-	1
Course Objectives	To provide the concept and the knowledge of web development using PHP Students also will learn to create front end and connectivity with other databases.				
Course Outcomes					
CO1	Student will learn the various elements of Web Pages and protocols.				
CO2	Student will learn the various types of web development strategies.				
CO3	Student will be able to learn PHP basics programming skills.				
CO4	Student will be able to learn connectivity of databases with PHP web pages.				

Module	Course Contents	Contact Hrs.	Mapped CO
1	**Elements of Web Technologies & PHP:** Elements of web page, Web protocols, Development strategies, Web applications, Web project, Web team, Web forms handling, Environment variables, File and directory handling, Identifying data origin and data validation, Redirecting pages, Cookies, Session and user, PHP basics, PHP installation, PHP configuration. Loops, Functions in PHP, PHP E-mail, Function, Syntax, Structure, Strings, Numbers, Variables, flow controls. **PHP in depth:** Arrays in PHP with attributes, Date, Time, Image Uploading, Functions in PHP, PHP functions. Exercise sets on every topic. Validating an application using PHP, Web-services, Data handling and retrieving data from MYSQL using PHP. MYSQL: Data Types, Functions, Conversion, Creation of database table, Constraints etc., Importing and exporting database.	15	1,2,3,4

Suggested Readings:

1. 1. Xavier, C, " Web Technology and Design" , New Age International
2. Ramesh Bangia, "Internet and Web Design" , New Age International
3. PHP: The Complete Reference : Steven Holzner (McGraw-Hill)
4. PHP and MYSQL by Example: Ellie Quigley (PHI)

Online Resources:

1. https://nptel.ac.in/courses/106106156
2. https://www.nptelvideos.com/php/php_video_tutorials.php

Course Articulation Matrix														
PO-PSO	**PO1**	**PO2**	**PO3**	**PO4**	**PO5**	**PO6**	**PO7**	**PO8**	**PO9**	**PO10**	**PO11**	**PO12**	**PSO1**	**PSO2**
CO1			1	1				1			1			1
CO2			1	1				1			1			1
CO3		1	1	1		1		1			1		1	
CO4		1	1	1		1		1			1		1	1

Program	B.Sc. (Hons./ Hons. with research) Mathematics				
Year	2	Semester	4		
Course Name	Web Development Lab				
Code	RBMV4451				
Course Type	VAC	L	T	P	Credit
Pre-Requisite		-	-	2	1
Course Objectives	This course introduces R, which is a popular statistical programming language. The coursecovers data reading and its manipulation using R, which is widely used for data analysis internationally.				
Course Outcomes: Upon successful completion of course, a student will be able to:					
CO1	Demonstrate the use of PHP syntax, variables, operators, strings, functions, and control structures to develop basic server-side programs for solving computational problems.				
CO2	Design and implement PHP-based web applications that process user input through HTML forms, perform validation, and generate dynamic web content.				
CO3	Apply PHP built-in functions and server environment features to manipulate strings, manage date and time information, and retrieve client/server data in web applications.				
CO4	Develop database-driven web applications using PHP and MySQL by establishing database connectivity, executing SQL queries, and managing records efficiently.				

The Lab work based on the course RBMV4451 shall include the problems on the following:

5. **PHP Environment and Configuration**
   Explain the purpose of PHP as a server-side scripting language. Write a PHP program to display the installed PHP version and complete configuration details. Discuss how this information is useful for developers and system administrators.
6. **String Manipulation in PHP**
   Describe different ways of defining strings in PHP. Write a PHP script to display the string:
   "Tomorrow I'll Visit BBD University Lucknow."
   Explain the role of escape characters and the difference between single and double quotes.
3. **Sum of Digits of a Number**
   Explain the algorithm used to find the sum of the digits of an integer. Develop a PHP program that accepts a number from the user and computes the sum of its individual digits. Illustrate the execution with a suitable example.

4. **Palindrome Number Verification**

   Discuss the concept of a palindrome number. Write a PHP script to determine whether a given number is a palindrome. Explain the logic used for reversing a number and comparing it with the original value.

5. **Date and Time Functions in PHP**

   Describe the importance of date and time handling in web applications. Write a PHP program to display the current date, time, and day of the week. Explain the formatting options available in PHP date functions.

6. **Client Information Retrieval**

   Explain the role of server variables in PHP. Write a PHP script to retrieve and display the client's IP address. Discuss scenarios where client IP information is useful in web applications.

7. **Database Connectivity using PHP and MySQL**

   Explain the architecture of PHP–MySQL interaction. Write a PHP program to establish a connection with a MySQL database and display an appropriate success or error message. Discuss the significance of database connectivity in dynamic websites.

8. **Designing a Calculator Application**

   Describe how HTML forms and PHP can be combined to create interactive web applications. Develop a PHP-based calculator that performs addition, subtraction, multiplication, and division on two user-provided numbers. Explain the flow of data from the form to the PHP script.

9. **Form Handling and User Input Processing**

   Explain the GET and POST methods used in form submission. Create an HTML form that accepts a user's name and displays a personalized welcome message using PHP. Compare the advantages and limitations of GET and POST methods.

10. **Database-Driven Student Record Management**

    Design and implement a PHP application connected to a MySQL database to manage student records. The application should allow insertion and display of student information. Explain the database design, SQL queries used, and the interaction between PHP and MySQL.

Course Articulation Matrix														
PO-PSO	**PO1**	**PO2**	**PO3**	**PO4**	**PO5**	**PO6**	**PO7**	**PO8**	**PO9**	**PO10**	**PO11**	**PO12**	**PSO1**	**PSO2**
CO1			2	1				2			2			1
CO2			2	2				1			2			2
CO3		2	1	2		2		2			2		1	
CO4		1	2	2		2		2			2		2	2

Program	B.Sc. (Hons./Hons. with Research) Mathematics				
Year	3	Semester	5		
Course Name	Vedic Mathematics				
Code	RBMV2501				
Course Type	VAC	L	T	P	Credit
Pre-Requisite	10+2	2	0	-	2
Course Objectives	Through Vedic Math we can understand Indian mathematics and do calculations in Arithmetic, Algebra and Geometry for that matter and simplify and speed up calculations. It is a Fun-Filled way to do Math and arises interest. Sharpens your mind, increases mental agility and intelligence with exceptional results.				
Course Outcomes: After completion of the course, students shall be able to					
CO1	Understand the Vedic methods of arithmetic. Vedic mathematics methods are used in technology like, coding and VLSI implementation of encryption. Some sutras like Udharvtriyakbhyam and Nikhilam are used for implementing multiplication methods.				
CO2	Understand the vedic mathematics method of division, exponentiation and multiplication are used in internet security and cryptographic algorithms for making these calculations faster than before. Understand the Vedic methods of Geometry.				

Module	Course Contents	Contact Hrs.	Mapped CO
1	**Vedic Arithmetic**: Multiplication- Ekadhiken purven method (multiplication of two numbers of two digits), Ekununen purven method (multiplication of two numbers of three digits), ([1] Chapter I &II), Urdhvatiragbhyam method (multiplication of two numbers of three digits), ([1]Chapter III), Nikhilam Navtashchramam Dashtaha (multiplication of two numbers of three digits), Combined Operations ([1] Chapter II), Division- Nikhilam Navtashchramam Dashtaha (two digits divisor) ([1] Chapter IV), Paravartya Yojyet method (three digits divisor) ([1] ChapterV), Power- Square and Cube of two digit numbers, ([1]:Chapter XXXII).	15	CO1
2	**Vedic Algebra**: Multiplication (Quadratic Expressions of Single Variable)-Urdhvatiragbhyam Method, ([1] Chapter III), Combined Operations, Division (Divisor: Linear Expression of Single Variable), ([1]: Chapter V). Factorization (Quadratic Expression of Single Variable), ([1] ChapterVII &XII). Solution of Linear Simultaneous Expressions ([1] ChapterXV). Quadratic Equations ([1] Chapter XVII). Partial fractions ([1] Chapter XXIII). **Vedic Geometry**: Concept of Baudhayana Number (BN) - BN of an angle, Multiplication of a constant in a BN, BN of complementary angles, BN of sum and difference of an angle, BN of half angle.	15	CO2

Suggested Readings:

1. Vedic Mathematics, Motilal Banarsi Das, New Delhi.
2. Vedic Ganita: Vihangama Drishti-1, Siksha Sanskriti Uthana Nyasa, New Delhi.
3. Vedic Ganita Praneta, Siksha Sanskriti Uthana Nyasa, New Delhi.
4. Vedic Mathematics: Past, Present and Future, Siksha Sanskriti Uthana Nyasa, New Delhi.
5. Leelavati, ChokhambbaVidyaBhavan, Varanasi.
6. Bhartiya Mathematicians, Sharda Sanskrit Sansthan, Varanasi.
7. Beejganitam, Chokhambba Vidya Bhavan, Varanasi.

Online Resources:

1. https://books.google.com/books?id=k86aDwAAQBAJ
2. https://nptel.ac.in/courses/111101080
3. https://www.vedicmaths.org/
4.https://www.ms.uky.edu/~sohum/ma330/files/manuscripts/Tirthaji_S.B.K.,_Agarwala_V.S.vedic_mathematics_or_sixteen_simple_mathematical_formulae_from_the_Vedas-Orient_Book_Distributors_1981.pdf

Course Articulation Matrix														
PO-PSO	**PO1**	**PO2**	**PO3**	**PO4**	**PO5**	**PO6**	**PO7**	**PO8**	**PO9**	**PO10**	**PO11**	**PO12**	**PSO1**	**PSO2**
CO1	**2**	**1**	**1**		**1**			**2**					**1**	**2**
CO2	**2**	**2**	**1**		**1**			**3**					**1**	**2**