SIR P. T. SARVAJANIK COLLEGE OF SCIENCE (Autonomous)
SURAT-395001
(Affiliated with Veer Narmad South Gujarat University, Surat)

SYLLABUS

FOR

SEM I & II

Program: M. Sc.

Course: Mathematics

From

Academic year

2024-25

Board of studies in Mathematics

Undergraduate and Post graduate

	Name	Designation	Institute/Industry
Head of the Department			
1	Dr. Khagenrai Chauhan	Chairman	Sir. P. T. Sarvajanik College of Science, Surat.
All Faculty Members of the Department			
1	Dr. Janki Vashi	Adhyapak Sahayak	Sir. P. T. Sarvajanik College of Science, Surat.
2	Dr. Jaimikaben Surawala	Adhyapak Sahayak	Sir. P. T. Sarvajanik College of Science, Surat.
Two Subject expert from the Parent University are to be nominated by Academic Council			
1	Prof. Subhash Krishnan	Head & Associate Professor	K.J. Somaiya College of Science and Commerce, Mumbai. ((Autonomous)
2	Dr. Udayan Prajapati	Head & Associate Professor	St. Xavier's College, Ahmedabad. (Autonomous)
One subject expert is to be nominated by Vice-Chancellor form a panel of six recommended by the Autonomous College Principal			
1	Dr. Kasuhal Patel	Associate Professor	Department of Mathematics, Veer Narmad South Gujarat University, Surat.
One representative from Industry/ Corporate Sector/ allied areas to be nominated by Principal			
1	Mr. Dharmesh Patel	Officer	Canara Bank, Surat.
One Alumnus to be nominated by Principal			
1	Dr. Chhaya Desai	Assistant Professor	Department of Mathematics, Dr. S. S. Gandhi Engineering College, Surat.
Experts from outside the Autonomous College, whenever special courses of studies are to be formulated, to be nominated by the Principal.			
1	Dr. Jatin Desai	Retd. Associate Professor	Sir. P. T. Sarvajanik College of Science, Surat.

ACKNOWLEDGEMENT

I express my heartfelt gratitude to our dynamic Principal, Dr. Pruthul R. Desai, for his invaluable guidance and unwavering support throughout the curriculum restructuring process.

I would also like to express my sincere appreciation to the esteemed members of the Board of Studies. Their constructive suggestions and valuable contributions.

Above all, I am profoundly thankful to my dedicated colleagues in the Department, who tirelessly worked on compiling the syllabus.

Dr. Khagenrai J. Chauhan
Chairperson,
Board of Studies in Mathematics.

PROGRAMME OUTCOMES:

PO-1: Master Degree Programme in Mathematics will meet the present day needs of academic and Research, Institutions and Industries.

PO-2: Students may acquire depth knowledge in Algebra, Analysis, Topology, Functional Analysis, Optimization Techniques and Graph Theory which will motivate the students to go for higher studies/research in Mathematics.

PO-3: Inculcate critical thinking to carry out scientific investigation objectively without being biased with preconceived notions.

PO-4: Prepare students for pursuing research or careers in mathematical sciences and applied fields.

PO-5: Equip the student with skills to analyse problems, formulate a hypothesis, evaluate and validate results, and draw reasonable conclusions thereof.

PROGRAMME SPECIFIC OUTCOMES:

PSO-1: Mastery of Fundamental Mathematical Concepts (Algebra, Analysis, Geometry).

PSO-2: Will gain the ability to understand and deal with abstract concepts.

PSO-3: Communicate mathematical concepts effectively.

PSO-4: Ability to think critically and creatively.

PSO-5: Analyse and model real world problems based on mathematical principles.

PSO-6: Ability to solve problems which are modelled.

PSO-7: Communicate the solutions in rigorous mathematical language.

PSO-8: Ability to progress independently and ethically.

Content

M. Sc. (Sem-I & II) Mathematics

Sr. No	Semester	Course	Course Number	Course Code	Course title
1	I	Core Course-I	CC-I	MHMSC-S1P1-4CR24	Advanced Abstract Algebra
2		Core Course-II	CC-II	MHMSC-S1P2-4CR24	Advanced Real Analysis
3		Core Course-III	CC-III	MHMSC-S1P3-4CR24	Advanced Number Theory
4		Elective Course-1	EC-I	MHMSC-S1E1-4CR24	Ordinary Differential Equations
			EC-II	MHMSC-S1E2-4CR24	Optimization Techniques
			EC-III	MHMSC-S1E3-4CR24	Discrete Mathematics
			EC-IV	MHMSC-S1E4-4CR24	Integral Transforms Techniques
5		Skill based elective Course-1	SEC-I	MHMSC-S1SEC1-4CR24	Differential Geometry-1
			SEC-II	MHMSC-S1SEC2-4CR24	Principles of Data Science
			SEC-III	MHMSC-S1SEC3-4CR24	Math with Python-1
			SEC-IV	MHMSC-S1SEC4-4CR24	SWAYAM/MOOC etc.
6		Practical	CCP-I	MHMSC-S1PR1-6CR24	Lab Course-I
1	II	Core Course – IV	CC-IV	MHMSC-S2P4-4CR24	Complex Analysis
2		Core Course – V	CC-V	MHMSC-S2P5-4CR24	Linear Algebra
3		Core Course – VI	CC-VI	MHMSC-S2P6-4CR24	Analytic Number Theory
4		Elective Course – 2	EC-V	MHMSC-S2E5-4CR24	Nonlinear Ordinary Differential Equations
			EC-VI	MHMSC-S2E6-4CR24	Graph Theory
			EC-VII	MHMSC-S2E7-4CR24	Advanced Integral Transforms Techniques
5		Skill based elective Course-2	SEC-V	MHMSC-S2SEC1-4CR24	Differential Geometry-2
			SEC-VI	MHMSC-S2SEC2-4CR24	Math with Python-2
			SEC-VII	MHMSC-S2SEC3-4CR24	SWAYAM/MOOC etc.
6		Practical	CCP-II	MHMSC-S2PR2-6CR24	Lab Course-II

M. Sc. (Mathematics) Syllabus

M. Sc. (Mathematics) Syllabus with effect from the Academic year 2024-25

Course	Course Title	Course Number	Credits	Hour	Module	Lectures per module (1 Hr)	Examination		
							Internal Marks	External Marks	Total Marks
SEMESTER I									
Core Courses									
I	Advanced Abstract Algebra	CC-I	4	60	4	15	30	70	100
II	Advanced Real Analysis	CC-II	4	60	4	15	30	70	100
III	Advanced Number Theory	CC-III	4	60	4	15	30	70	100
Elective Course – 1									
IV	Ordinary Differential Equations	EC-I	4	60	4	15	30	70	100
	Optimization Techniques	EC-II	4	60	4	15	30	70	100
	Discrete Mathematics	EC-III	4	60	4	15	30	70	100
	Integral Transforms Techniques	EC-IV	4	60	4	15	30	70	100
Skill Enhancement Course									
V	Differential Geometry-1	SEC-I	2	30	2	15	20	30	50
	Principles of Data Science	SEC-II	2	30	2	15	20	30	50
	Math with Python-1	SEC-III	2	30	2	15	20	30	50
	SWAYAM/MOOC etc.	SEC-IV							
Core Courses PRACTICAL									
VI	Lab Course-I (CC-I, II, III and Elective)	CCP-I	6	12	--		50	100	150
SEMESTER II									
Core Courses									
I	Complex Analysis	CC-IV	4	60	4	15	30	70	100
II	Linear Algebra	CC-V	4	60	4	15	30	70	100
III	Analytical Number Theory	CC-VI	4	60	4	15	30	70	100
Elective Course – 2									
IV	Nonlinear Ordinary Differential Equations	EC-V	4	60	4	15	30	70	100
	Graph Theory	EC-VI	4	60	4	15	30	70	100
	Advanced Integral Transforms Techniques	EC-VII	4	60	4	15	30	70	100
Skill Enhancement Course									
V	Differential Geometry-2	SEC-V	2	30	2	15	20	30	50
	Math with Python-2	SEC-VI	2	30	2	15	20	30	50
	SWAYAM/MOOC etc.	SEC-VII							
Core Courses PRACTICAL									
VI	Lab Course-II (CC-IV, V, VI and Elective)	CCP-II	6	12	--		50	100	150

Semester- I

Core Course- I (CC-I)

COURSE TITLE: ADVANCED ABSTRACT ALGEBRA

COURSE CODE: MHMSC-S1P1-4CR24 [CREDITS – 04]

Course learning outcome		
At the end of this course, Students will be able to 1. Gain expertise in the basic concepts of set theory and group theory with the help of numerous examples. 2. Discuss in detail about permutation groups and Normal subgroups and discuss on counting tricks in algebra. 3. Bring out the key steps involved in proving Sylow theorems and use Sylow's theorems to classify groups of finite order up to 120. 4. Understand the basic idea of polynomial Rings and inner product spaces.		
Module 1	**Set, Groups and Quotient Groups**	**[15L]**
Learning Objective 1. Students will gain the knowledge on some of the basic concept in set theory and group theory.		
Learning Outcomes: At the end of this module the learner will be able to 1. Gain expertise in the basic concepts of set theory and group theory with the help of numerous examples		
1.1	Set Theory – Mappings: Surjective, Injective, Bijection, Composition, Definitions, Lemmas and Examples, A(S)-The set of 1-1 mappings of S onto itself, Well-Ordering Principle, Euclidean Algorithm.	**[6L]**
1.2	Group: Finite group, abelian group, Definition and Examples, – Subgroups, trivial subgroups, proper subgroups, cyclic subgroups, A counting Principle.	**[6L]**
1.3	Normal Subgroups and Quotient groups: Definitions and Examples.	**[3L]**
Module 2	**Permutation Groups**	**[15L]**
Learning Objective 1. To understand the Cayley's theorem and Sylow's theorem.		
Learning Outcomes: At the end of this module the learner will be able to 1. Discuss in detail about permutation groups and Normal subgroups and discuss on counting tricks in algebra.		
2.1	Homomorphism: First homomorphism theorem, Correspondence theorem, Second theorem, Third homomorphism theorem, Cayley's theorem	**[6L]**
2.2	Symmetric group, Cycle decomposition, Permutation groups, Odd and Even permutations and Examples, Another counting principle – Conjugacy and Sylow's theorem, The Class Equation.	**[9L]**
Module 3	**Rings**	**[15L]**
Learning Objective 1. To provide the knowledge of Ring particularly Euclidean Rings and Homomorphisms.		
Learning Outcomes: At the end of this module the learner will be able to 1. Understand the concept of Ring theory and Homomorphisms -Ideals and quotient rings.		

2. Summarize topic of various types of Rings.		
3.1	Ring, Commutative Ring, Integral Domain, Division Ring, Zero-divisor, Subring, Ideals, Homomorphism and Quotient Rings, Left and Right Ideals, Maximal Ideals, Isomorphism, Automorphism.	**[9L]**
3.2	More ideals and quotient rings, The field of quotients of an Integral Domain, Euclidean Rings, Principal ideal ring, A particular Euclidean Ring.	**[6L]**
Module 4	**Polynomial Rings**	**[15L]**
Learning Objective 1. To make the students aware of Polynomial Rings.		
Learning Outcomes: At the end of this module the learner will be able to 1. Understand the basic idea of polynomial Rings and inner product spaces.		
4.1	Introduction-Rings and examples.	**[2L]**
4.2	Polynomial rings, Properties of polynomial ring, Division Algorithm, Principal Ideal Domain, gcd of Polynomials.	**[7L]**
4.3	Monic Polynomial, Irreducible polynomial, Polynomials over the rational field, Gauss Lemma.	**[6L]**

References:

1. I. N. Herstein, Topics in Algebra, 3/e, Wiley Eastern Limited, 2016
2. David S. Dummit and Richard M. Foote, Abstract Algebra, 3/e, Wiley Student Edition, 2015.
3. John B. Fraleigh and Neal Brand, A First Course in Abstract Algebra, 8/e, Pearson Education Limited, 2020
4. Vijay K. Khanna and S.K. Bhambri, A Course in Abstract Algebra, 5/e, Vikas Publishing House Pvt Limited, 1993.
5. Joseph A. Gallian, Contemporary Abstract Algebra, 4/e, Narosa publishing House, 1999.

Mapping of COs and PSOs

Course Learning Outcomes	Programme Outcomes							
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**
Gain expertise in the basic concepts of set theory and group theory with the help of numerous examples.	**X**	**X**	**X**					
Discuss in detail about permutation groups and Normal subgroups and discuss on counting tricks in algebra.	**X**	**X**	**X**	**X**				
Bring out the key steps involved in proving Sylow theorems and use Sylow's theorems to classify groups of finite order up to 120.	**X**	**X**						
Understand the basic idea of polynomial Rings and inner product spaces.	**X**	**X**	**X**					

Practical:

Practical-1	Examples based on Group – Subgroups – A counting Principle.
Practical-2	Example related Normal Subgroups and Quotient groups.
Practical-3	Example related Cayley's theorem.
Practical-4	Example related Permutation groups – Sylow's theorems.
Practical-5	Example related Ideals and quotient rings.
Practical-6	Example based on Euclidean Rings-A particular Euclidean Ring.
Practical-7	Based on Polynomial rings – Polynomials over the rational field.
Practical-8	Polynomials over commutative Rings -Inner Product spaces.

Core Course- II (CC-II)

COURSE TITLE: ADVANCED REAL ANALYSIS

COURSE CODE: MHMSC-S1P2-4CR24 [CREDITS – 04]

Course learning outcome		
At the end of this course, Students will be able to 1. Describe fundamental properties of the real numbers that lead to the formal development of real analysis. 2. Demonstrate an understanding of limits and how that are used in sequences. 3. Demonstrate an understanding of limits and how that are used in series. 4. Examine and recognize the continuity of real functions. 5. Understand existence and properties of integrals and use them to solve problems.		
Module 1	**Compact sets and Connected sets in a Metric Space**	**[15L]**
Learning Objective 1. To give the knowledge of the real numbers that lead to the formal development of real analysis.		
Learning Outcomes: At the end of this module the learner will be able to 1. Describe fundamental properties of the real numbers that lead to the formal development of real analysis.		
1.1	Ordered sets, Bounded above, Bounded below, lub, glb, Fields, The Real Field, Extended Real Number system, The Complex Field, Euclidean Spaces	**[8L]**
1.2	Finite, Countable and Uncountable sets, Metric Spaces, Compact sets, Open cover, Perfect sets, Cantor sets, Connected sets	**[7L]**
Module 2	**Numerical Sequences**	**[15L]**
Learning Objective 1. To acquire knowledge on some of the basic concepts convergence of sequence & Numerical Series.		
Learning Outcomes: At the end of this module the learner will be able to 1. Handle convergence of series and sequence. 2. To understand limits and how that are used in series and sequences.		
2.1	Convergent Sequences, Sub-sequences, Sequential limit, Cauchy Sequences, Monotonic sequence, Upper and Lower Limits, Some Special Sequences, Series, Series of Non-Negative Terms.	**[7L]**
2.2	Numerical Series: The Number e, The Root test, Ratio Test , Power Series, Summation by Parts, Absolute Convergence, Addition and Multiplication of Series, Rearrangements.	**[8L]**
Module 3	**Continuity and differentiation**	**[15L]**
Learning Objective 1. To learn different types of function and derive a real function using theorem.		
Learning Outcomes: At the end of this module the learner will be able to 1. Examine and recognize the continuity of real functions		
3.1	Limits of Functions, Continuous Functions, Continuity and Compactness,	**[8L]**

	Uniformly continuous, Continuity and Connectedness, Discontinuities, Monotonic Functions, Infinite Limits and Limits at Infinity.	
3.2	The Derivative of a Real Function, Mean Value Theorems, The Continuity of Derivatives, L'Hospital's Rule, Derivatives of Higher Order, Taylor's Theorem, Differentiation of Vector Valued Functions.	**[7L]**
Module 4	**The Riemann-Stieltjes Integral**	**[15L]**
Learning Objective 1. To learn about Riemann-Stieltjes integrals & properties		
Learning Outcomes: At the end of this module the learner will be able to 1. Understand existence and properties of integrals and use them to solve problems.		
4.1	Definition and existence of the Integral, Riemann Integral, Riemann-Stieltjes Integral, Refinement, Properties of the Integral, Change of variables.	**[8L]**
4.2	Integration and Differentiation, The fundamental theorem of calculus, Integration of vector valued functions, Rectifiable curves.	**[7L]**

References:

1. Walter Rudin, Principles of Mathematical Analysis, 3/e, Tata McGraw- Hill, 1985.
2. R. G. Bartle, D. R. Sherbert, Introduction to Real Analysis, 3/e, John Wiley and Sons, New York, 1982.
3. N. L. Carothers, Real Analysis, Cambridge University Press, UK, 2000.
4. S. C. Malik and Savita Arora, Mathematical Analysis, 2/e, New Age International(P) Ltd. Pub., 2005.
5. K. R. Stromberg, An Introduction to Classical Real Analysis, AMS Chelsea Publishing, 2015.
6. H. L. Royden, Real Analysis, 3/e, Pearson Publishing company, New Delhi, 1988.

Mapping of COs and PSOs

Course Learning Outcomes	Programme Outcomes							
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**
Describe fundamental properties of the real numbers that lead to the formal development of real analysis.	**X**	**X**	**X**			**X**		
Demonstrate an understanding of limits and how that are used in sequences.	**X**	**X**	**X**	**X**				
Demonstrate an understanding of limits and how that are used in series.	**X**	**X**	**X**	**X**				
Examine and recognize the continuity of real functions.	**X**	**X**	**X**				**X**	
Understand existence and properties of integrals and use them to solve problems.	**X**	**X**	**X**			**X**	**X**	**X**

Practical:

Practical-1	Examples based on the real and complex field.
Practical-2	Example related Metric Spaces.
Practical-3	Example related sequences and series.
Practical-4	Example related numerical series.
Practical-5	Example based on limits and continuity.
Practical-6	Example based on the Derivative of a Real Function.
Practical-7	Based on the Integral – Properties of the Integral (Riemann-Stieltjes integrals).
Practical-8	Based on Integration and vector valued functions – Rectifiable curves.

Core Course- III (CC-III)

COURSE TITLE: ADVANCED NUMBER THEORY

COURSE CODE: MHMSC-S1P3-4CR24 [CREDITS – 04]

Course learning outcome		
At the end of this course, 1. Students will learn about Primitive roots and Indices 2. Students will be able to understand the logic of the Quadratic Reciprocity Law 3. Students learns about Fibonacci numbers and its various properties. 4. Students will be able to solve various problems and prove various theorems of number theory		
Module 1	**Primitive Roots**	**[15L]**
Learning Objective 1. to get knowledge of key concept in number theory, like primitive roots.		
Learning Outcomes: At the end of this module the learner will be able to 1. Students will learn about Primitive roots		
1.1	Introduction, Congruences, Residues.	**[2L]**
1.2	The order of an integer modulo n, The exponent of a number mod m, Primitive roots for primes, Primitive roots and reduced residue systems, The nonexistence of primitive roots, The existence of primitive roots mod p for odd primes p, Primitive roots and quadratic residues, The existence of primitive roots mod p^a, The existence of primitive roots mod $2p^a$, The number of primitive roots mod m, Composite numbers having primitive roots.	**[13L]**
Module 2	**Indices and Quadratic Congruence**	**[15L]**
Learning Objective 1. To get the knowledge of indices theory and Solution of the congruences.		
Learning Outcomes: At the end of this module the learner will be able to 1. Understand the indices theory and Solution of the congruences, Quadratic Congruence, Euler's criterion and Quadratic residues		
2.1	The theory of indices, The table of Indices, Solution of the congruences of the types $ax^n \equiv b \pmod{p}$ and $x^n \equiv a \pmod{n}$, $\gcd(a, n) = 1$, Decimal representation, Quadratic Congruence, Euler's criterion and examples, Quadratic residues, Legendre symbol, Gauss lemma, Law of quadratic reciprocity, Quadratic residues and primes.	**[15L]**
Module 3	**Quadratic Congruence**	**[15L]**
Learning Objective 1. To get the knowledge of Quadratic Congruence		
Learning Outcomes: At the end of this module the learner will be able to 1. Understand the logic of the Quadratic Congruence		
3.1	Quadratic congruence, Quadratic congruence with composite moduli, Method of solving the congruence $x^2 \equiv a \pmod{2^h}$, The Jacobi symbol, Applications to Diophantine equations, Gauss sums and the quadratic reciprocity law, The reciprocity law for quadratic Gauss sums.	**[15L]**
Module 4	**Numbers of special forms**	**[15L]**
Learning Objective 1. to get familiar with Numbers of special forms like Perfect numbers, Mersenne primes,		

	Amicable numbers, Fermat numbers, Fibonacci numbers.	
Learning Outcomes: At the end of this module the learner will be able to 1. Students will be able to solve various problems of Numbers of special forms and prove various theorems of number theory		
4.1	Perfect numbers, Mersenne primes, Amicable numbers, Fermat numbers, Pepin's test, Fibonacci numbers.	**[15L]**

References:

1. Tom M. Apostol, Introduction to Analytic Number Theory, Springer, International Student Edition, Reprint 2010.
2. David M. Burton, Elementary Number Theory, 7/e, Tata McGraw Hill Edu. (P) Ltd., New Delhi, 2012
3. G. H. Hardy and et al, An Introduction to the Theory of Numbers, 6/e, Oxford University Press, 2009.
4. S. G. Telang: Number Theory, 4/e, The Tata McGraw Hill Co. Ltd., New Delhi, 2003.

Mapping of COs and PSOs

Course Learning Outcomes	Programme Outcomes							
	1	2	3	4	5	6	7	8
Students will learn about Primitive roots and Indices	X	X	X			X		
Students will be able to understand the logic of the Quadratic Reciprocity Low.	X	X	X					
Students learns about Fibonacci numbers and its various properties.	X	X	X	X	X			
Students will be able to solve various problems and prove various theorems of number theory	X	X	X			X	X	

Practical:

Practical-1	Find primitive roots of primes.
Practical-2	Find primitive roots of composite numbers.
Practical-3	Obtain solutions of congruences.
Practical-4	Solve Quadratic Congruence.
Practical-5	Evaluate the Legendre symbol.
Practical-6	Find quadratic residues.
Practical-7	Find perfect numbers.
Practical-8	Based on Mersenne primes, Amicable numbers, Fermat numbers.

Elective Course- 1 (EC-I)

COURSE TITLE: ORDINARY DIFFERENTIAL EQUATIONS

COURSE CODE: MHMSC-S1E1-4CR24 [CREDITS – 04]

Course learning outcome		
At the end of this course, Students will be able to 1. Find the general solution of the first order linear homogeneous equations. 2. Understand the utility of the theory of power series which is studied in Real Analysis course through solving various second order differential equations. 3. Get introduced to the Hypergeometric functions which arises in connection with solutions of the second order ordinary differential equations with regular singular points. 4. Solve the problems arises in Mathematical physics using properties of special functions. 5. Understand the importance of studying well-posedness of the problem namely existence, uniqueness and continuous dependence of first order differential equations through Picard's theorem. 6. Solve ordinary differential equations by numerical methods.		
Module 1	**The general solution of the homogeneous equation**	**[15L]**
Learning Objective 1. Students will learn about the general solution of first order and second order linear equations.		
Learning Outcomes: At the end of this module the learner will be able to 1. Find the general solution of the first order linear homogeneous equations. 2. Understand the utility of the theory of power series which is studied in Real Analysis course through solving various second order differential equations.		
1.1	The general solution of the homogeneous equation– the use of one known solution to find another – The method of variation of parameters	**[5L]**
1.2	Power Series solutions. A review of power series– Series solutions of first order equations	**[5L]**
1.3	Second order linear equations; The General Solution of the Homogeneous Equation, The Use of a Known Solution to find Another, The Homogeneous Equation with Constant Coefficients, Ordinary points.	**[5L]**
Module 2	**Regular Singular Points**	**[15L]**
Learning Objective 1. To learn about Gauss's hypergeometric equation and Legendre Polynomials & Bessel functions		
Learning Outcomes: At the end of this module the learner will be able to 1. Get introduced to the Hypergeometric functions which arises in connection with solutions of the second order ordinary differential equations with regular singular points.		
2.1	Gauss's hypergeometric equation, The Point at infinity, The generating function and Rodrigues' formula, Two convergence proofs.	**[6L]**
2.2	Legendre Polynomials, Bessel functions, Properties of Legendre Polynomials, Legendre series, Least squares approximation, Bessel functions and Gamma function, The definition of the function $Jp(x)$.	**[9L]**
Module 3	**Linear Systems of First Order Equations**	**[15L]**
Learning Objective 1. To get the knowledge of the concepts from linear algebra and analysis in the study of system of first order equations.		

Learning Outcomes: At the end of this module the learner will be able to 1. Understand the importance of studying well-posedness of the problem namely existence, uniqueness and continuous dependence of first order differential equations through Picard's theorem		
3.1	Linear systems, Homogeneous Linear Systems with Constant Coefficients, Distinct real roots, Distinct complex roots, Equal real roots, The Existence and Uniqueness of Solutions of Initial Value Problem for First Order Ordinary Differential Equations	**[9L]**
3.2	The Existence and Uniqueness of Solutions, The Method of Solutions of Successive Approximations and Picard's Theorem.	**[6L]**
Module 4	**Numerical Methods**	**[15L]**
Learning Objective 1. To get the knowledge of the solution of ordinary differential equations by numerical methods.		
Learning Outcomes: At the end of this module the learner will be able to 1. solve ordinary differential equations by numerical methods.		
4.1	Introduction, The Method of Euler, An Improvement to Euler, Higher Order Methods, Simpson's 1/3 rule, Simpson's 3/8 rule, Runge-Kutta method.	**[15L]**

References:

1. G. F. Simmons, Differential Equations with Applications and Historical Notes, 3/e, CRC Press, 2017.
2. Murray D. A., Introductory course in Differential Equations, Longmas, Green & Co., 1/e, 1897, Reprinted 1929, Revised: Khosla Publishing House, 2021.
3. W.T. Reid, Ordinary Differential Equations, 99/e, John Wiley & Sons, New York, 1971.
4. E.A. Coddington and N. Levinson, Theory of Ordinary Differential Equations, McGraw Hill Publishing Company, New York, 1955.
5. Shepley L. Ross, Differential Equations, 3/e, John Wiley & Sons, 2007.

Mapping of COs and PSOs

Course Learning Outcomes	Programme Outcomes							
	1	2	3	4	5	6	7	8
At the end of this course, Students will be able to Find the general solution of the first order linear homogeneous equations	X	X	X			X	X	X
Understand the utility of the theory of power series which is studied in Real Analysis course through solving various second order differential equations.	X	X	X			X	X	X
Get introduced to the Hypergeometric functions which arises in connection with solutions of the second order ordinary differential equations with regular singular points.	X	X	X			X	X	
Solve the problems arises in Mathematical physics using properties of special functions.	X	X	X			X	X	X
Understand the importance of studying well-posedness of the problem namely existence, uniqueness and continuous dependence of first order differential equations through Picard's theorem.	X	X	X					
Solve ordinary differential equations by numerical methods.	X	X				X		

Practical:

Practical-1	Find the general solution of the homogeneous equation-1.
Practical-2	Find the general solution of the homogeneous equation-2.
Practical-3	Obtain solutions of hypergeometric equation.
Practical-4	Examples: Legendre Polynomials – Bessel functions.
Practical-5	Examples: Linear Systems of First Order Equations.
Practical-6	Examples: Picard's method.
Practical-7	Examples: Oscillation Theory.
Practical-8	Based on Sturm Comparison Theorems.

Elective Course- 1 (EC-II)

COURSE TITLE: OPTIMIZATION TECHNIQUES

COURSE CODE: MHMSC-S1E2-4CR24 [CREDITS – 04]

Course learning outcome		
At the end of this course, Students will be able to 1. Do mathematical formulation of a real life problem into a Integer programming problem. 2. Solve integer programming problem using Gromory's constraints, Fractional cut method and Branch & Bound method. 3. Find solutions to linear programming problem by dynamic programming. 4. Construct the Goal programming problem & solved by different methods. 5. Understand the concepts of nonlinear programming problems. 6. Solve nonlinear programming problems using Wolfe's method and Beale's method.		
Module 1	**Linear Programming Problem**	**[15L]**
Learning Objective 1. Student will learn about Integer programming problem.		
Learning Outcomes: At the end of this module the learner will be able to 1. Do mathematical formulation of a real life problem into a Integer programming problem. 2. Solve integer programming problem using Gromory's constraints, Fractional cut method and Branch & Bound method.		
1.1	Pure and Mixed Integer Programming Problems – Gromory's All I.P.P. Method – Construction of Gomory's Constraints - Fractional Cut Method-All Integer LPP – Fractional Cut Method-Mixed Integer LPP – Branch and Bound Method – Applications of Integer Programming	**[15L]**
Module 2	**Dynamic Programming**	**[15L]**
Learning Objective 1. Introduces the Dynamic programming as a part of Operation Research.		
Learning Outcomes: At the end of this module the learner will be able to 1. Find solutions to linear programming problem by dynamic programming		
2.1	The Recursive Equation Approach – Characteristics of Dynamic Programming – Dynamic Programming Algorithm – Solution of Discrete DPP – Applications – Solution of LPP by Dynamic Programming	**[15L]**
Module 3	**Goal Programming**	**[15L]**
Learning Objective 1. Students will learn how to formulate of Linear Goal Programming Problem.		
Learning Outcomes: At the end of this module the learner will be able to 1. Construct the Goal programming problem & solved by different methods like Graphical Method & Simplex Method.		
3.1	Categorization of Goal Programming – Formulation of Linear Goal Programming Problem – Graphical Goal Attainment Method – Simplex Method for Goal Programming Problem	**[15L]**
Module 4	**Non-Linear Programming**	**[15L]**

Learning Objective 1. Introduces Non Linear Programming & formulate the nonlinear programming models.		
Learning Outcomes: At the end of this module the learner will be able to 1. Understand the concepts of Nonlinear Programming Problems & Saddle point problems.		
4.1	Non-Linear Programming - Formulation - constrained optimization - with equaling constraints, with in-equaling constraints - saddle point problems	**[5L]**
4.2	Non-Linear Programming problems Methods - Graphical sign - Kuhn-Tucker conditions with non-negative constrains - quadratic programming - Wolfe's modified simplex method - Beale's method - separable convex programming - separable programming Algorithm	**[10L]**

References:

1. Kanti Swarup, P.K. Gupta, Man Mohan, Operations Research, 20/e, Sultan Chand & sons, New Delhi, 2022.
2. Hamdy A. Taha, Operations Research, 10/e, McGraw Hill Publications, New Delhi, 2019.
3. Bazaara, Jarvis and Sherali, Linear Programming and Network Flows, 4/e, John Wiley, 2010
4. O.L. Mangasarian, Non Linear Programming, McGraw Hill, New York, 1994.
5. Mokther S. Bazaraa and C.M. Shetty, Non Linear Programming, Theory and Algorithms, 3/e, Willy, New York, 2013.

Mapping of COs and PSOs

Course Learning Outcomes	Programme Outcomes							
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**
1. Do mathematical formulation of a real life problem into a Integer programming problem.	**X**	**X**	**X**		**X**	**X**	**X**	**X**
2. Solve integer programming problem using Gromory's constraints, Fractional cut method and Branch & Bound method	**X**	**X**	**X**		**X**	**X**	**X**	**X**
3. Find solutions to linear programming problem by dynamic programming.	**X**	**X**	**X**		**X**	**X**	**X**	**X**
4. Construct the Goal programming problem & solved by different methods.	**X**	**X**	**X**		**X**	**X**	**X**	**X**
5. Understand the concepts of nonlinear programming problems	**X**	**X**	**X**		**X**	**X**	**X**	**X**
6. Solve nonlinear programming problems using Wolfe's method and Beale's method.	**X**	**X**	**X**		**X**	**X**	**X**	**X**

Practical:

Practical-1	Exercise related to Integer Programming Problems-1.
Practical-2	Exercise related to Integer Programming Problems -2.
Practical-3	Solution of LPP by Dynamic Programming-1.
Practical-4	Solution of LPP by Dynamic Programming-1.
Practical-5	Formulation of Linear Goal Programming Problem.
Practical-6	Simplex method for Goal Programming Problem.
Practical-7	Examples based on Non-Linear Programming-1.
Practical-8	Examples based on Non-Linear Programming-2.

Elective Course- 1 (EC-III)

COURSE TITLE: DISCRETE MATHEMATICS

COURSE CODE: MHMSC-S1E3-4CR24 [CREDITS – 04]

Course learning outcome		
At the end of this course, Students will be able to 1. Understand relations and functions and work with them. 2. Understand functions of logic gates and use it to carry out logical operations on single or multiple binary inputs and give one binary output. 3. Work with fundamental concepts and basic laws of Boolean algebra.		
Module 1	**Relations and Functions**	**[15L]**
Learning Objective 1. To learn about different types of relations and functions.		
Learning Outcomes: At the end of this module the learner will be able to 1. Understand relations and functions and work with them.		
1.1	Binary relations, equivalence relations and partitions, Relation matrix, Graph of a relation, partial order relations, inclusion and exclusion principle, Hasse diagram, Pigeon hole principle.	**[8L]**
1.2	Functions, inverse functions, compositions of functions, recursion, recursive functions, Characteristic function of a set.	**[7L]**
Module 2	**Mathematical Logic**	**[15L]**
Learning Objective 1. To get the knowledge of logic operators and theories.		
Learning Outcomes: At the end of this module the learner will be able to 1. Understand functions of logic gates and use it to carry out logical operations on single or multiple binary inputs and give one binary output.		
2.1	Introduction, Statements and natation, Connectives, Logic operators, Statement formulas and Truth tables, Theory of inference and deduction, mathematical calculus, predicate calculus, The statement function, variables and quantifiers, Predicate formulas.	**[15L]**
Module 3	**Lattices**	**[15L]**
Learning Objective 1. To get the basic idea of various types of Lattices.		
Learning Outcomes: At the end of this module the learner will be able to 1. Understand the concept of Lattices and its properties.		
3.1	Definition, Lattices as Partially Ordered Sets, Properties of Lattices, Lattices as algebraic Systems, Sub lattices.	**[7L]**
3.2	Direct Product and homomorphism, Some Special Lattices, Complete, Complemented and Distributive Lattices.	**[8L]**
Module 4	**Boolean algebra**	**[15L]**
Learning Objective 1. To learn about Boolean algebra and coding theory.		

Learning Outcomes: At the end of this module the learner will be able to 1. Work with fundamental concepts and basic laws of Boolean algebra		
4.1	Various Boolean identities, the switching Algebra Example, Sub Algebras, Direct Production and Homomorphism	**[4L]**
4.2	Boolean Forms and their Equivalence, Minterm Boolean forms, Sum of Products canonical forms, Maxterm Boolean forms, Product of sums canonical forms	**[4L]**
4.3	Minimization of Boolean Functions, The Karnuagh Map Method	**[4L]**
4.4	Coding Theory: Coding of binary information and error detection, Group codes, decoding and error correction	**[3L]**

References:

1. Trembly. J.P & Manohar. P., Discrete Mathematical Structures with Applications to Computer Science, 35/e, Tata McGraw-Hill, 2008.
2. Liu, C.L., Elements of Discrete Mathematics, 3/e, Tata McGraw-Hill, 2008
3. K. D. Joshi, Foundations of Discrete Mathematics, John Wiley & Sons.
4. Kolman, Busy & Ross, Discrete Mathematical Structures, 6/e, Pearson Prentice Hall, 2009.
5. Seymour Lipschutz, M. Lipson: Discrete Mathematics, 3/e, McGraw-Hill Edition.

Mapping of COs and PSOs

Course Learning Outcomes	Programme Outcomes							
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**
1. Understand relations and functions and work with them.	**X**	**X**	**X**	**X**				
2. Understand functions of logic gates and use it to carry out logical operations on single or multiple binary inputs and give one binary output.	**X**	**X**	**X**					
3. Work with fundamental concepts and basic laws of Boolean algebra.	**X**	**X**	**X**	**X**		**X**	**X**	

Practical:

Practical-1	Examples based on binary relations.
Practical-2	Examples based on functions.
Practical-3	Exercise on Mathematical Logic-1.
Practical-4	Exercise on Mathematical Logic-2.
Practical-5	Exercise on lattices-1.
Practical-6	Exercise on lattices -2.
Practical-7	Examples: Boolean forms.
Practical-8	Examples: minimization of Boolean forms and coding.

Elective Course- 1 (EC-IV)

COURSE TITLE: INTEGRAL TRANSFORMS TECHNIQUES

COURSE CODE: MHMSC-S1E4-4CR24 [CREDITS – 04]

Course learning outcome		
At the end of this course, Students will be able to 1. Familiar with the basic concepts of Laplace transforms, Inverse Laplace Transform, Finite Laplace Transform, Fourier transform, Fourier sine and cosine transforms. 2. Analyze Sufficient Conditions for the existence of Laplace transform, Linearity property of Laplace transform and learn about the concepts of Laplace Transforms, Inverse Laplace Transforms, Finite Laplace Transforms. 3. Apply Laplace transforms to the Convolution of two functions. 4. Evaluate technique of Inverse Laplace transform. 5. Understand the Laplace inversion of some elementary functions, Method of expansion into partial fractions of the ratio of two. 6. Solve the ordinary and partial differential equations, initial and boundary value problems using Laplace transform using Laplace transforms and Solve integral equations. 7. Know conceptual knowledge of Fourier series and Fourier Integral Formula, Fourier Transforms. 8. Apply Fourier sine and cosine transform, Inverse of Fourier transform and solve boundary value problems using Fourier transforms.		
Module 1	**Laplace Transform**	**[15L]**
Learning Objective 1. To gain the knowledge on some of the basic concept of Laplace transform, its properties and Convolution of two functions.		
Learning Outcomes: At the end of this module the learner will be able to 1. Understand the basic concepts of Laplace transforms. 2. Analyze Sufficient Conditions for the existence of Laplace transform, Linearity property of Laplace transform and learn about the concepts of Laplace Transforms. 3. Apply Laplace transforms to the Convolution of two functions.		
1.1	Introduction, Definitions, Sufficient conditions for existence of Laplace Transform, Basic properties of Laplace transforms Differentiation and integration of Laplace transforms.	**[4L]**
1.2	Laplace Transform of a periodic function, The Initial-Value Theorem and the Final-Value Theorem of Laplace Transform.	**[4L]**
1.3	The convolution of two functions, properties of convolution, Applications.	**[4L]**
1.4	Tauberian theorem, Watson's lemma.	**[3L]**
Module 2	**Inverse Laplace Transform ,** Finite Laplace Transform **and applications**	**[15L]**
Learning Objective 1. Understand the basic concept of Inverse Laplace Transform Method of Partial Fraction and Finite Laplace Transform with its properties.		
Learning Outcomes: At the end of this module the learner will be able to 1. Analyze Inverse Laplace Transforms and Finite Laplace Transforms with their properties. 2. Evaluate technique of Inverse Laplace transform.		

3. Understand the Laplace inversion of some elementary functions, Method of expansion into partial fractions of the ratio of two.		
2.1	Introduction, Calculation of Laplace inversion of some elementary functions.	**[3L]**
2.2	Method of expansion into partial fractions of the ratio of two, The general evaluation technique of Inverse Laplace transform.	**[4L]**
2.3	Finite Laplace Transforms: Introduction, Definition of Finite Laplace Transform and Finite Laplace Transform of elementary functions.	**[4L]**
2.4	Operational Properties, Applications and Tauberian theorems.	**[4L]**
Module 3	**Applications of Laplace Transforms**	**[15L]**
Learning Objective 1. Apply the Laplace Transforms to solve various differential equations.		
Learning Outcomes: At the end of this module the learner will be able to 1. solve the ordinary and partial differential equations, initial and boundary value problems using Laplace transforms and solve integral equations.		
3.1	Application of Laplace transforms	**[3L]**
3.2	Applications of Laplace transforms to ordinary differential equations	**[4L]**
3.3	Applications of Laplace transforms to partial differential equations,	**[4L]**
3.4	Initial and boundary value problems and solutions to Integral equations.	**[4L]**
Module 4	**Fourier Transform**	**[15L]**
Learning Objective 1. Understand the concept of Fourier Series, Fourier Integral and Fourier transforms.		
Learning Outcomes: At the end of this module the learner will be able to 1. Know conceptual knowledge of Fourier series and Fourier Integral Formula, Fourier Transforms. 2. Apply Fourier sine and cosine transform, Inverse of Fourier transform and solve boundary value problems using Fourier transforms.		
4.1	Introduction, classes of functions, Fourier series and Fourier integral formula	**[4L]**
4.2	Fourier transforms of the derivative of a function, Fourier transform of some more useful functions	**[4L]**
4.3	Inversion formula for Fourier transform	**[3L]**
4.4	Fourier sine and cosine integral, Fourier sine and cosine transforms and applications.	**[4L]**

References:

1. L. Debnath and D.D. Bhatta, Integral Transforms and their Applications, 2/e, CRC Pub., 1995.
2. Baidyanath Patra, An Introduction to Integral Transforms, 1/e, CRC Press, Taylor Francis Group, 2018.
3. Poularikas, A. D., The Transforms and Applications, Handbook, 2/e, CRC Press, 1996.
4. M.Ya.Antimirov, A.A.Klyshkin, R. Valliancourt, Applied Integral Transforms, CRM Monograph Series, American mathematical Society, 2007.
5. B. Davies: Integral Transforms and their applications, 3/e, Springer - Verlag, 1978.

6. Ian Sneddon: The use of Integral Transform, TMIH, 1979.
7. A.R.Vasishta and R.K.Guptha, Integral Transforms, Krishna Prakashan Media, 2016
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9. Spiegel, M.R.: Theory and Problems of Laplace transforms, Schaum's series, 2011
10. Boas M. L.: Mathematical Methods in Physical Sciences, 3/e, John Wiley & Sons, 1983.
11. Raisinghania, M. D.: Integral equations and boundary value problems, 10/e, S. Chand Company Ltd., 2021.
12. Andrews, L. G. & Shivamoggi B. K.: Integral Transforms for Engineers, PHI, 2003.

Mapping of COs and PSOs

Course Learning Outcomes	Programme Outcomes							
	1	2	3	4	5	6	7	8
Familiar with the basic concepts of Laplace transforms, Inverse Laplace transform, Finite Laplace transform, Fourier transform, Fourier sine and cosine transforms	X		X			X	X	
Analyze sufficient conditions for the existence of Laplace transform, Linearity property of Laplace transform and learn about the concepts of Laplace Transforms, Inverse Laplace Transforms, Finite Laplace Transforms.	X	X	X			X	X	
Apply Laplace transforms to the Convolution of two functions.	X	X	X			X	X	
Evaluate technique of inverse Laplace transform	X	X	X	X	X	X		
Understand the Laplace inversion of some elementary functions, Method of expansion into partial fractions of the ratio of two.	X		X		X		X	
Solve the ordinary and partial differential equations, initial and boundary value problems using Laplace transform using Laplace transforms and Solve integral equations.	X					X	X	
Know conceptual knowledge of Fourier series and Fourier Integral Formula, Fourier Transforms.	X	X		X	X	X		
Apply Fourier sine and cosine transform, Inverse of Fourier transform and solve boundary value problems using Fourier transforms.	X		X	X		X	X	

Practical:

Practical-1	Practical based on Laplace Transforms-1
Practical-2	Practical based on Laplace Transforms-2
Practical-3	Practical based on Inverse Laplace Transforms
Practical-4	Practical based on Finite Laplace Transforms
Practical-5	Practical based on Applications of Laplace Transforms-1
Practical-6	Practical based on Applications of Laplace Transforms-2
Practical-7	Practical based on Fourier series, Fourier Integral and Transforms
Practical-8	Practical based on sine and cosine of Fourier Transforms

Skill Based Elective/Value Added Course- I (SEC-I)

COURSE TITLE: Differential Geometry-1

COURSE CODE: MHMSC-S1SEC1-4CR24 [CREDITS – 02]

Course learning outcome		
At the end of this course, Students will be able to 1. Formulate and solve problems involving motion of particles along curves, optimization of functions, and analysis of vector fields and differential equations. 2. Compute dot products between vectors, understand their geometric interpretations, and apply them to analyze curves and vector fields. 3. Use covariant derivatives to study the behavior of vector fields along curves, including understanding the Frenet formulas and connection forms.		
Module 1	**Calculus on Euclidean Geometry**	**[15L]**
Learning Objective 1. Apply concepts of tangent vectors, directional derivatives, curves, 1-forms, differential forms, and mappings to solve problems in geometry, physics, and engineering.		
Learning Outcomes: At the end of this module the learner will be able to 1. Formulate and solve problems involving motion of particles along curves, optimization of functions, and analysis of vector fields and differential equations.		
1.1	Euclidean Space, Tangent Vectors and tangent space, The space of differential forms, Directional derivatives, The wedge product, The differential operator d, Curves in E3–1-Forms, Differential Forms, Mappings.	**[15L]**
Module 2	**Frame Fields and Euclidean Geometry**	**[15L]**
Learning Objective 1. Understand the geometric and analytical properties of curves, vector fields, and their interrelations through the concept of the dot product and covariant derivatives.		
Learning Outcomes: At the end of this module the learner will be able to 1. Compute dot products between vectors, understand their geometric interpretations, and apply them to analyze curves and vector fields. 2. Use covariant derivatives to study the behavior of vector fields along curves, including understanding the Frenet formulas and connection forms.		
2.1	Dot product, Curves, Vector field, The Frenet Formulas, Arbitrary speed curves, Cylindrical helix, Covariant Derivatives, Frame fields, Connection Forms, The Structural equations.	**[15L]**

References:

1. J. A. Thorpe, Elementary topics in differential geometry, 2/e, Springer, 2004.
2. A. Pressley, Elementary differential geometry, 2/e, Springer, 2010.
3. Mittal and Agarwal, Differential geometry, 36/e, Meerut: Krishna Prakashan Media (P) Ltd., 2010.
4. K. S. Amur, D. J. Shetty and C. S. Bagewadi, An introduction to differential geometry, Oxford, U.K: Alpha Science International, 2010.

Mapping of COs and PSOs

Course Learning Outcomes	Programme Outcomes							
	1	2	3	4	5	6	7	8
Formulate and solve problems involving motion of particles along curves, optimization of functions, and analysis of vector fields and differential equations.	X	X		X		X	X	X
Compute dot products between vectors, understand their geometric interpretations, and apply them to analyze curves and vector fields.		X		X	X	X	X	X
Use covariant derivatives to study the behavior of vector fields along curves, including understanding the Frenet formulas and connection forms.	X	X				X	X	X

Skill Based Elective/Value Added Course- I (SEC-II)

COURSE TITLE: Principles of Data Science

COURSE CODE: MHMSC-S1SEC2-4CR24 [CREDITS – 02]

Course learning outcome		
At the end of this course, Students will be able to 1. Use the tools and techniques used in Data Science process 2. Analyze data analysis techniques for applications handling large data		
Module 1	**Introduction to Data Science**	**[15L]**
Learning Objective 2. Apply scientific techniques to practical problems.		
Learning Outcomes: At the end of this module the learner will be able to 1. The managerial understanding of the tools and techniques used in Data Science process		
1.1	Definition, Benefits and uses of data science and big data, Facets of data , Big Data and Data Science Hype, Why data science, Getting Past the Hype, The Current Landscape, Who is Data Scientist?	**[8L]**
1.2	Data Science Process Overview, Defining goals, Retrieving data, Data preparation, Data exploration, Data modelling, Presentation.	**[7L]**
Module 2	**Big Data**	**[15L]**
Learning Objective 1. Provides strong foundation for data science and application area related to information technology		
Learning Outcomes: At the end of this module the learner will be able to 1. Analyze data analysis techniques for applications handling large data		
2.1	Problems when handling large data, General techniques for handling large data, Choosing the right algorithm, Choosing the right data structure, Case study.	**[8L]**
2.2	Steps in big data, Distributing data storage and processing with Frameworks, Case study.	**[7L]**

References:

1. D. Cielen, A. D. B. Meysman and M. Ali, Introducing Data Science, Manning Publications Co., 1/e, 2016
2. G. James, D. Witten, T. Hastie and R. Tibshirani, An Introduction to Statistical Learning: with Applications in R, Springer, 1/e, 2013
3. Y. Bengio, A. Courville, Deep Learning, Ian Goodfellow, MIT Press, 1/e, 2016
4. D. J. Patil, H. Mason, M. Loukides, O' Reilly, Ethics and Data Science, 1/e, 2018

Mapping of COs and PSOs

Course Learning Outcomes	Programme Outcomes							
	1	2	3	4	5	6	7	8
Use the tools and techniques used in Data Science process			X	X	X	X		X
Analyze data analysis techniques for applications handling large data			X	X	X	X		X

Skill Based Elective/Value Added Course- I (SEC-III)

COURSE TITLE: Math with Python-1

COURSE CODE: MHMSC-S1SEC3-4CR24 [CREDITS – 02]

Course learning outcome		
At the end of this course, Students will be able to 1. Acquire proficiency in using different functions of Python to compute solutions of basic mathematical problems. 2. Demonstrate the use of Python to solve differential equations along with visualize the solutions.		
Module 1	**Basic of Python**	**[8L]**
Learning Objective 1. Acquire skill in usage of suitable functions/packages of Python to solve mathematical problems.		
Learning Outcomes: At the end of this module the learner will be able to 1. Acquire proficiency in using different functions of Python to compute solutions of basic mathematical problems.		
1.1	Installation, IDE, Variables, Built-in functions, Input and Output, Modules and packages, Data types and data structures	**[4L]**
1.2	Use of mathematical operators and mathematical functions, Programming Structures (Conditional structure, The for loop, The while loop, nested statements)	**[4L]**
Module 2	**Symbolic and Numeric Computations**	**[7L]**
Learning Objective 1. Gain proficiency in using Python to solve problems on Differential equations.		
Learning Outcomes: At the end of this module the learner will be able to 1. Demonstrate the use of Python to solve differential equations along with visualize the solutions.		
2.1	Use of Sympy package, Symbols, Calculus, Differential Equations	**[3L]**
2.2	Series expressions, Linear and Nonlinear equations, List, Tuples and Arrays.	**[4L]**

References:

1. H. P. Langtangen, A Primer on Scientific Programming with Python, 2nd ed., Springer, 2016
2. S. Linge and H. P. Langtangen, Programming for computations- Python - A gentle Introduction to Numerical Simulations with Python 3.6, Springer Open, Second Edm. 2020.
3. H. Fangohr, Introduction to Python for Computational Science and Engineering (A beginner's guide), University of Southampton, 2015. (https://www.southampton.ac.uk/~fangohr/training/python/pdfs/Python-for-Computational-Science-and-Engineering.pdf)
4. E Balagurusamy, Introduction to Computing & Problem Solving using Python, 1st ed., McGraw Hill Education (India) Private Limited, New Delhi

Mapping of COs and PSOs

Course Learning Outcomes	Programme Outcomes							
	1	2	3	4	5	6	7	8
Acquire proficiency in using different functions of Python to compute solutions of basic mathematical problems.			X	X	X	X		X
Demonstrate the use of Python to solve differential equations along with visualize the solutions.			X	X	X	X		X

Practical:

Practical-1	Installation, IDE, and Getting Started
Practical-2	Program to swap the values of two variables.
Practical-3	Program for matrix transposition, determinant calculation, and matrix inversion.
Practical-4	Program to check if the input year is a leap year or not
Practical-5	Program for Model population growth using the logistic equation.
Practical-6	Program of Taylor series to approximate transcendental functions like sine, cosine, exponential, and logarithm.

Semester- II

Core Course- IV (CC-IV)

COURSE TITLE: COMPLEX ANALYSIS

COURSE CODE: MHMSC-S2P4-4CR24 [CREDITS – 04]

Course learning outcome		
At the end of this course, Students will be able to 1. Learn the algebra and geometry of complex numbers. 2. Check differentiability and the analyticity of complex valued function. 3. Understand Cauchy-Riemann relations and harmonic functions. 4. Understand Cauchy integral formula, general form of Cauchy theorem. 5. Learn Fundamental theorem of Algebra, Maximum module Principle 6. Understand Contour integrals related theorem and Examples. 7. Understand series expansion.		
Module 1	**Algebra of Complex Numbers**	**[15L]**
Learning Objective 1. To learn about basic concept of complex numbers.		
Learning Outcomes: At the end of this module the learner will be able to 1. Understand the algebra and geometry of complex numbers.		
1.1	Introduction, Complex Numbers, Properties, Geometric representation, Conjugate, Triangle Inequality and its Applications, Polar and Exponential forms.	**[8L]**
1.2	Powers and Roots, Region in the Complex Plane, Open set, Limit point, Connected set, Pathwise connected set, Bounded set, Extended Complex Plane.	**[7L]**
Module 2	**Analytic Functions**	**[15L]**
Learning Objective 1. To acquire the knowledge of differentiability, limit and continuity of complex function.		
Learning Outcomes: At the end of this module the learner will be able to 1. Check differentiability and the analyticity of complex valued function.		
2.1	Functions of a Complex variables, Limit concept for complex-valued functions, Limit at infinity, Infinite limit, Continuity, Uniform continuity, Differentiability, Chain rule, Cauchy-Riemann Equations, Polar form of C-R equations, Analytic functions, Harmonic functions.	**[15L]**
Module 3	**Elementary Functions**	**[15L]**
Learning Objective 1. To gain the knowledge of various types of complex functions.		
Learning Outcomes: At the end of this module the learner will be able to 1. Understand about complex functions and their properties.		
3.1	Introduction, Periodic functions, Exponential function, Trigonometric functions, Hyperbolic functions, Multivalued function and its branches	**[8L]**
3.2	Logarithmic function, Complex Exponents, Inverse Trigonometric, Inverse Hyperbolic functions.	**[7L]**

Module 4	Complex Integration	[15L]
Learning Objective 1. To learn Contour integrals related theorem and Examples		
Learning Outcomes: At the end of this module the learner will be able to 1. Understand Contour integrals related theorem and Examples.		
4.1	Contour Integral, Primitives, Cauchy-Goursat Theorem, Extension of Cauchy-Goursat Theorem, Winding Number, Cauchy Integral formula, Consequences of Cauchy Integral formula, Concept of Maximum Moduli of functions.	**[8L]**
4.2	Series Expansions: Power Series, Uniform convergence of power series, Taylor series, Zeros of Analytic functions, Laurent Series.	**[7L]**

References:

1. H. S. Kasana: Complex Variables – Theory and Applications, 2nd Edition (2006), PHI, N. Delhi.
2. James Ward Brown & Ruel V. Churchill: complex Variables and Applications, McGraw-Hill, 8th Edition.
3. S. Ponnuswamy: Foundation of Complex Analysis, Narosa Publishing House, 1997.
4. J. N. Sharma: Functions of a Complex Variable, Krishna Prakashan, 2014
5. S. Lang: Complex Analysis, Addition Wesley, 4th Edition, 1997.
6. H. A. Priestly: Introduction to Complex Analysis, Clarendon Press, 1990
7. J. B. Conway: Functions of one Complex Variable, Springer-Verlag, 1980

Mapping of COs and PSOs

Course Learning Outcomes	Programme Outcomes							
	1	2	3	4	5	6	7	8
Learn the algebra and geometry of complex numbers.	X	X	X					
Check differentiability and the analyticity of complex valued function.	X	X	X			X	X	
Understand Cauchy-Riemann relations and harmonic functions.	X	X	X	X		X	X	
Understand Cauchy integral formula, general form of Cauchy theorem.	X	X			X	X	X	
Learn Fundamental theorem of Algebra, Maximum module Principle	X	X			X	X	X	
Understand Contour integrals related theorem and Examples.	X	X	X			X	X	
Understand series expansion.	X	X	X					

Practical:

Practical-1	Examples based on Triangle Inequality, Polar and Exponential forms.
Practical-2	Finding roots in complex plane.
Practical-3	Exercise on Limits, Continuity, Differentiability.
Practical-4	Examples based on Cauchy-Riemann Equations, Analytic functions, Harmonic functions.
Practical-5	Examples on Exponential function, Trigonometric functions, Hyperbolic functions, Multivalued function.
Practical-6	Examples on Logarithmic function, Complex Exponents, Inverse Trigonometric and Hyperbolic functions.
Practical-7	Examples based on Cauchy-Goursat Theorem, Extension of Cauchy-Goursat Theorem, Cauchy Integral formula.
Practical-8	Examples on Series Expansions.

Core Course- V (CC-V)

COURSE TITLE: LINEAR ALGEBRA

COURSE CODE: MHMSC-S2P5-4CR24 [CREDITS – 04]

Course learning outcome		
At the end of this course, Students will be able to 1. Discuss in detail the basic concepts of Linear dependence, basis and dimension of a vector space. The students will be able to demonstrate how the geometric ideas turn into rigorous proofs. 2. Capture the idea of producing lot of structure preserving maps (Linear transformations). Further the study of algebras of linear maps would be accomplished. 3. Having got trained in numerous examples the student realizes the isomorphic theory of linear transformations and matrices. 4. Understand the Linear polynomial and Eigenvalues-vector and algebra of polynomials. 5. Understand real and complex inner product space and theorems and to solve the examples using the theorems		
Module 1	**Vector Space and Linear Transformations**	**[15L]**
Learning Objective 1. To learn about concepts of a vector space and Linear Transformations.		
Learning Outcomes: At the end of this module the learner will be able to 1. Discuss in detail the basic concepts of Linear dependence, basis and dimension of a vector space. 2. Capture the idea of producing lot of structure preserving maps (Linear transformations). Further the study of algebras of linear maps would be accomplished.		
1.1	Vector Spaces, Subspaces, Direct Sums, Spanning Sets and Linear Independence, The Dimension of a Vector Space, Ordered Bases and Coordinate Matrices, The Row and Column Spaces of a Matrix.	**[7L]**
1.2	Linear Transformations: Isomorphisms, The Kernel and Image of a Linear Transformation, Rank-Nullity Theorem, The Matrix of a Linear Transformation, Change of Bases for Linear Transformations, Equivalence of Matrices, Similarity of Matrices, Similarity of Operators, Invariant Subspaces.	**[8L]**
Module 2	**Isomorphism Theorems**	**[15L]**
Learning Objective 1. To learn about Isomorphism of linear transforms.		
Learning Outcomes: At the end of this module the learner will be able to 1. Having got trained in numerous examples the student realizes the isomorphic theory of linear transformations and matrices.		
2.1	The Isomorphism Theorems: Quotient Spaces, The Universal Property of Quotients and the First Isomorphism Theorem, Quotient Spaces, Complements and Co-dimension, Additional Isomorphism Theorems, Linear Functional, Dual Bases, Reflexivity, Annihilators	**[15L]**

Module 3	Eigenvalues and Eigenvectors	[15L]
Learning Objective 1. To acquire the knowledge of linear operators, Eigenvalues and Eigenvectors. 2. To understand Triangularizability Diagonalizable Operators, Projections, Algebra of Projections, Projections and Invariance.		
Learning Outcomes: At the end of this module the learner will be able to 1. Understand the Linear polynomial and Eigenvalues-vector and algebra of polynomials.		
3.1	Linear Operator, Characteristic Polynomial and Minimal Polynomial of an Operator, Eigenvalues and Eigenvectors, Geometric and Algebraic Multiplicities, The Jordan Canonical Form, Triangularizability Diagonalizable Operators, Projections, Algebra of Projections, Projections and Invariance.	**[15L]**
Module 4	**Inner Product Space**	**[15L]**
Learning Objective 1. To make students aware inner product space, The Projection Theorem and Best Approximations, Orthogonal Direct Sums, The Riesz Representation Theorem and make them able to solve the examples of it.		
Learning Outcomes: At the end of this module the learner will be able to 1. Understand real and complex inner product space and theorems. 2. To solve the examples using the theorems.		
4.1	Real and Complex Inner Product Spaces, Norm and Distance, Isometries, Orthogonality, Orthogonal and Orthonormal Sets, The Projection Theorem and Best Approximations, Orthogonal Direct Sums, The Riesz Representation Theorem	**[15L]**

References:

1. Kenneth Hoffman and Ray Alden Kunze, Linear Algebra, 2/e, Prentice Hall of India Private Limited, New Delhi, 1975
2. V. Krishnamurthy, V.P. Mainra, J. L. Arora, Introduction to Linear Algebra, East West Press Ltd, 1985 (Reprint 2019)
3. S. Kumaresan, Linear Algebra: A Geometric Approach, Prentice-Hall of India Ltd, 2004.
4. A.R. Rao, P. Bhimashankaram, Linear Algebra, 2/e, Tata McGraw Hill, 2000.
5. Edgar G. Goodaire, Linear Algebra-Pure & Applied World Scientific, Cambridge University Press India Ltd, 2014.

Mapping of COs and PSOs

Course Learning Outcomes	Programme Outcomes							
	1	2	3	4	5	6	7	8
Discuss in detail the basic concepts of Linear dependence, basis and dimension of a vector space. The students will be able to demonstrate how the geometric ideas turn into rigorous proofs.	X	X	X		X		X	X
Capture the idea of producing lot of structure preserving maps (Linear transformations). Further the study of algebras of linear maps would be accomplished.	X	X	X				X	
Having got trained in numerous examples the student realizes the isomorphic theory of linear transformations and matrices.	X	X	X	X		X	X	
Understand the Linear polynomial and Eigenvalues-vector and algebra of polynomials.	X	X	X		X	X		
Understand real and complex inner product space and theorems and to solve the examples using the theorems	X	X			X	X	X	

Practical:

Practical-1	Examples on vector space.
Practical-2	Examples on linear transformations.
Practical-3	Exercise on isomorphism theorems-1.
Practical-4	Exercise on isomorphism theorems-2.
Practical-5	Examples on Linear Operator.
Practical-6	Examples on Eigenvalues and Eigenvectors.
Practical-7	Examples based on Inner Product Spaces.
Practical-8	Examples on Orthogonality.

Core Course- VI (CC-VI)

COURSE TITLE: ANALYTIC NUMBER THEORY

COURSE CODE: MHMSC-S2P6-4CR24 [CREDITS – 04]

Course learning outcome		
At the end of this course, Students will be able to 1. Know about Arithmetic functions, Dirichlet multiplication and elementary theorems on Prime numbers. 2. Learn about Chebyshev's functions, divisor functions $d(n)$, Mangöldt function, Abel's identity 3. Analyze the number theoretic problems		
Module 1	**Arithmetical functions and Dirichlet multiplication**	**[15L]**
Learning Objective 1. To learn about various functions in Number theory.		
Learning Outcomes: At the end of this module the learner will be able to 1. Understand the Möbius function, Mangöldt function and its properties.		
1.1	Basic introduction of the Möbius function $\mu(n)$ and the Euler totient function $\phi(n)$, relation connecting μ and ϕ, the Dirichlet product of two arithmetical functions (a.f.) and group structure w.r.t. this product, the Mangöldt function $\Lambda(n)$, Multiplicative arithmetical functions, the inverse of a completely multiplicative arithmetical functions.	**[15L]**
Module 2	**Dirichlet multiplication and averages of Arithmetical functions**	**[15L]**
Learning Objective 1. To gain the knowledge of Arithmetic functions.		
Learning Outcomes: At the end of this module the learner will be able to 1. Understand Arithmetic functions, Dirichlet multiplication and elementary theorems on Prime numbers		
2.1	Liouville's function $\lambda(n)$, the divisor functions $d(n)$and $\sigma\alpha(n)$, the generalized convolutions, the big oh notation, Euler's summation formula, some elementary asymptotic formulas, the average order of divisor functions $d(n)$and $\sigma\alpha(n)$, the average order of functions $\phi(n)$, $\mu(n)$, $\Lambda(n)$.	**[15L]**
Module 3	**Averages of Arithmetical Functions and Chebyshev's functions**	**[15L]**
Learning Objective 1. To make students aware about various types of the functions in number theory.		
Learning Outcomes: At the end of this module the learner will be able to 1. Understand lattice points and functions and relation between two functions in number theory.		
3.1	Euler's summation formula, Distribution of lattice points visible from the origin, the partial sums of a Dirichlet product, applications to $\mu(n)$ and $\Lambda(n)$, Chebyshev's functions $\psi(x)$ and $\vartheta(x)$, relation between $\psi(x)$, $\pi(x)$and $\vartheta(x)$, Abel's identity.	**[15L]**

Module 4	Elementary theorems on the distribution of prime numbers	[15L]
Learning Objective 1. To learn about elementary theorems on distributions of prime numbers.		
Learning Outcomes: At the end of this module the learner will be able to 1. Understand prime number theorems and partial sums of the functions.		
4.1	Some equivalent forms of prime number theorem, lower and upper bounds for $\pi(n)$ and pn, Shapiro's Tauberian theorem and its applications, an asymptotic formula for the partial sums $\sum_{p\leq x}(1/p)$, the partial sums of function $\mu(n)$.	**[15L]**

References:

1. Tom M. Apostol: Introduction to Analytic Number Theory, Narosa Pub. House, New Delhi, 1998.
2. Mc Carthy P. J.: Introduction to Arithmetical function, Springer-Verlag, New York, 1986.
3. K. Chandrashekharan: Introduction to Analytic Number Theory, Springer-Verlag, New York, 1968.
4. Hua L. K.: Introduction to Number Theory, Springer-Verlag, New York, 1982.

Mapping of COs and PSOs

Course Learning Outcomes	Programme Outcomes							
	1	2	3	4	5	6	7	8
Know about Arithmetic functions, Dirichlet multiplication and elementary theorems on Prime numbers.	X	X	X				X	
Learn about Chebyshev's functions, divisor functions $d(n)$, Mangöldt function, Abel's identity	X	X	X		X		X	
Analyse the number theoretic problems	X	X	X		X	X	X	

Practical:

Practical-1	Exercise on Möbius function $\mu(n)$, Euler totient function $\phi(n)$.
Practical-2	Exercise on Mangöldt function $\Lambda(n)$, Multiplicative a.f..
Practical-3	Exercise on Liouville's function $\lambda(n)$, the divisor functions $d(n)$and $\sigma\alpha(n)$.
Practical-4	Exercise on the average order of divisor functions $d(n)$and $\sigma\alpha(n)$, the average order of functions $\phi(n)$, $\mu(n)$, $\Lambda(n)$.
Practical-5	Examples on Distribution of lattice points visible from the origin, the partial sums of a Dirichlet product.
Practical-6	Examples on Chebyshev's functions $\psi(x)$ and $\vartheta(x)$, relation between $\psi(x)$, $\pi(x)$and $\vartheta(x)$, Abel's identity.
Practical-7	Examples based on Equivalent forms of prime number theorem, lower and upper bounds for $\pi(n)$ and pn.
Practical-8	Examples on Shapiro's Tauberian theorem.

Elective Course- 2 (EC-V)

COURSE TITLE: NON-LINEAR ORDINARY DIFFERENTIAL EQUATIONS

COURSE CODE: MHMSC-S2E5-4CR24 [CREDITS – 04]

Course learning outcome		
At the end of this course, Students will be able to 1. Find linear approximation at equilibrium points 2. Solve simple nonlinear differential equation using averaging methods. 3. Solve some nonlinear differential equation using perturbation methods. 4. Understand different types of linear systems and their solutions. 5. Solve linear systems by various methods like Poincare stability solutions.		
Module 1	**First order systems in two variables**	**[15L]**
Learning Objective 1. To learn about system of differential equations of first order in two variables and solution of it.		
Learning Outcomes: At the end of this module the learner will be able to 1. Understand and solve First order systems in two variables and linearization.		
1.1	First order systems in two variables and linearization: The general phase plane, Equilibrium points, Constant solutions, some population models, Linear approximation at equilibrium points, Linear systems in matrix form.	**[15L]**
Module 2	**Averaging Methods**	**[15L]**
Learning Objective 1. To gain the knowledge of solution of an energy balance method for limit cycles and periodic solutions.		
Learning Outcomes: At the end of this module the learner will be able to 1. Solve simple nonlinear differential equation using averaging methods.		
2.1	An energy balance method for limit cycles, Amplitude and frequency estimates, slowly varying amplitudes, nearly periodic solutions, periodic solutions.	**[8L]**
2.2	Harmony balance, Equivalent linear equation by harmonic balance, Accuracy of a period estimate.	**[7L]**
Module 3	**Perturbation Methods**	**[15L]**
Learning Objective 1. To get the knowledge of how to solve non linear differential equations by direct methods.		
Learning Outcomes: At the end of this module the learner will be able to 1. Solve some nonlinear differential equation using perturbation methods.		
3.1	Outline of the direct method, Forced Oscillations far from resonance, Forced Oscillations near resonance with Weak excitation.	**[7L]**
3.2	The amplitude equation for undamped pendulum, Amplitude Perturbation for the pendulum equation, Lindstedt's Method, Forced oscillation of a self–excited equation, The Perturbation Method and Fourier series.	**[8L]**

Module 4	Linear Systems	[15L]
Learning Objective 1. To get the knowledge of different types of linear systems.		
Learning Outcomes: At the end of this module the learner will be able to 1. Understand different types of linear systems and their solutions.		
4.1	Time Varying Systems, Constant coefficient System, Periodic Coefficients, Floquet Theory, Wronskian.	**[7L]**
4.2	Stability: Poincare stability, solutions, paths and norms, Liapunov stability Stability of linear systems, Comparison theorem for the zero solutions of nearly, linear systems.	**[8L]**

References:

1. D.W. Jordan & P. Smith, Nonlinear Ordinary Differential Equations, 4/e, Oxford University Press, 2007.
2. G. F. Simmons, Differential Equations with Applications and Historical Notes, 3/e, CRC Press, 2017.
3. D.A.Sanchez, Ordinary Differential Equations and Stability Theory, 1/e, Dover Publications, 2012.
4. J.K.Aggarwal, Notes on Nonlinear Systems, D. Van Nostrand, 1972.

Mapping of COs and PSOs

Course Learning Outcomes	Programme Outcomes							
	1	2	3	4	5	6	7	8
Find linear approximation at equilibrium points.	X	X	X		X		X	X
Solve simple nonlinear differential equation using averaging methods.	X	X	X				X	
Solve some nonlinear differential equation using perturbation methods.	X	X	X			X	X	
Understand different types of linear systems and their solutions.	X	X		X		X		X
Solve linear systems by various methods like Poincare stability solutions.	X	X	X		X	X	X	

Practical:

Practical-1	Exercise on First order systems in two variables-1.
Practical-2	Exercise on First order systems in two variables-2.
Practical-3	Examples on An energy balance method for limit cycles.
Practical-4	Examples based on Harmony balance – Equivalent linear equation by harmonic balance.
Practical-5	Solve some nonlinear differential equation using perturbation methods.
Practical-6	Examples based on Lindstedt's Method.
Practical-7	Examples based on Linear Systems-1.
Practical-8	Examples based on Linear Systems-2.

Elective Course-2 (EC-VI)

COURSE TITLE: GRAPH THEORY

COURSE CODE: MHMSC-S2E6-4CR24 [CREDITS – 04]

Course learning outcome		
At the end of this course, Students will be able to 1. Understand and work on the fundamental concepts of graphs. 2. Apply graph theory based tools in solving practical problems. 3. Understand basic concepts in Trees and discuss matching problems and its applications elsewhere.		
Module 1	**Introductory concepts**	**[15L]**
Learning Objective 1. To learn about fundamental concepts of graphs.		
Learning Outcomes: At the end of this module the learner will be able to 1. Understand and work on the fundamental concepts of graphs		
1.1	Basic Concepts, Diagrammatic Representation of a Graph, Finite graph, Infinite graph, Isomorphism, Simple Graphs and Isomorphism, Subgraphs, Degrees of Vertices, Paths and Connectedness, Operations on Graphs, Directed Graphs: Basic Concepts, Tournaments.	**[15L]**
Module 2	**Connectivity**	**[15L]**
Learning Objective 1. To gain the knowledge of connectivity and basic concept of Counting the Number of Spanning Trees.		
Learning Outcomes: At the end of this module the learner will be able to 1. Understand basic concepts in Trees and discuss matching problems and its applications elsewhere.		
2.1	Vertex Cuts and Edge Cuts, Connectivity and Edge Connectivity, r-connected, Blocks, Ear decomposition of a block, Cyclical Edge Connectivity of a Graph.	**[8L]**
2.2	Definition, Characterization and Simple Properties, Centers and Centroids, Counting the Number of Spanning Trees, Cayley's Formula.	**[7L]**
Module 3	**Matching , Eulerian and Hamilton Graphs**	**[15L]**
Learning Objective 1. To learn about Matching problems and Eulerian Graphs & Hamiltonian Graphs.		
Learning Outcomes: At the end of this module the learner will be able to 1. Understand the matching problems and its applications elsewhere. 2. Understand Eulerian Graphs and Hamiltonian Graphs.		
3.1	Vertex Independent Sets and Vertex Coverings, Edge Independent Sets, Matchings in Bipartite Graphs, Matchings and Factors.	**[8L]**
3.2	Eulerian Graphs, Euler trail, Euler tour, Hamiltonian Graphs.	**[4L]**
Module 4	**Graph Colorings**	**[15L]**
Learning Objective 1. To get the knowledge of Graph Colouring.		
Learning Outcomes: At the end of this module the learner will be able to 1. Understand Colorings of Graphs like Vertex Coloring, Edge Colorings.		
4.1	Vertex Colorings, Application of Graph colorings, Critical Graphs, Brook's theorem, Triangle-Free Graphs.	**[8L]**

4.2	Edge Colorings of Graphs, Vizing's theorem, Snarks, Kirkman's Schoolgirl Problem, Chromatic Polynomials.	**[7L]**

References:

1. R. Balakrishnan, K. Ranganathan, A Textbook of Graph Theory, 2/e, Springer International Edition, New Delhi, 2008.
2. J.A. Bondy, U.S.R. Murty, Graph Theory with Applications, 5/e, Macmillan Press Ltd., 1982.
3. Gary Chartrand, Linda Lesniak, Ping Zhang, Graphs and Digraph, 6/e, CRC press, 2016.
4. Douglas B. West, Introduction to Graph Theory, 2/e, Pearson Edu. (P) Ltd., 2002.

Mapping of COs and PSOs

Course Learning Outcomes	Programme Outcomes							
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**
Understand and work on the fundamental concepts of graphs.	**X**	**X**	**X**	**X**	**X**	**X**		
Apply graph theory based tools in solving practical problems.	**X**	**X**	**X**	**X**	**X**	**X**		**X**
Understand basic concepts in Trees and discuss matching problems and its applications elsewhere.	**X**	**X**	**X**	**X**	**X**			**X**

Practical:

Practical-1	Examples based on fundamental concepts of graphs -1.
Practical-2	Examples based on fundamental concepts of graphs -2.
Practical-3	Exercise on Vertex Cuts and Edge Cuts - Connectivity and Edge – Connectivity, Blocks.
Practical-4	Examples: Counting the Number of Spanning Trees - Cayley's Formula.
Practical-5	Based on Independent Sets -Matchings and Factors.
Practical-6	Examples: Eulerian Graphs - Hamiltonian Graphs.
Practical-7	Examples: Vertex Coloring.
Practical-8	Examples: Edge Coloring.

Elective Course-2 (EC-VII)

COURSE TITLE: ADVANCED INTEGRAL TRANSFORMS TECHNIQUES

COURSE CODE: MHMSC-S2E7-4CR24 [CREDITS – 04]

Course learning outcome		
At the end of this course, Students will be able to 1. Familiar with the basic concepts of Students will be able to learn about Hankel transform, Finite Hankel transforms. 2. Understand applications of Hankel transforms. 3. Solve the partial differential equations using Hankel transforms. 4. Learn about Hilbert and Stieltjes transforms. 5. Solve differential equations using Hilbert and Stieltjes transforms. 6. Know conceptual knowledge of Z-transforms and properties of Z- transforms. 7. Analyze Mellin Transform of derivative of a function, Mellin Transform of Integral of a function.		
Module 1	**Hankel Transforms**	**[15L]**
Learning Objective 1. To gain the knowledge on some of the basic concept of Hankel transform and finite Hankel transform.		
Learning Outcomes: At the end of this module the learner will be able to 1. learn the concepts of Hankel transform and its properties and Finite Hankel transforms with its properties.		
1.1	Introduction, Hankel transform and Examples, operational properties of the Hankel transform.	**[3L]**
1.2	Introduction, Definition of the finite Hankel transform and its examples.	**[4L]**
1.3	Finite Hankel transforms of some elementary functions.	**[4L]**
1.4	Basic operational properties of the finite Hankel transform.	**[4L]**
Module 2	**Applications of Hankel transforms**	**[15L]**
Learning Objective 1. know and understand the applications of Hankel Transform.		
Learning Outcomes: At the end of this module the learner will be able to 1. solve various differential equations using Hankel transform and Finite Hankel transforms.		
2.1	Applications of Hankel transforms to partial differential equations	**[7L]**
2.2	Applications of finite Hankel transforms	**[8L]**
Module 3	**Hilbert and Stieltjes Transforms**	**[15L]**
Learning Objective 1. Understand concept and use of Hilbert and Stieltjes Transform.		
Learning Outcomes: At the end of this module the learner will be able to 1. solve differential equations using Hilbert and Stieltjes Transform.		
3.1	Introduction and definition of Hilbert transform and examples, Basic properties of Hilbert transform	**[3L]**
3.2	Definition of Stieltjes transforms and examples, Basic properties of Stieltjes transforms	**[4L]**

3.3	Inverse theorem for Stieltjes transforms, Applications of Stieltjes transforms	**[4L]**
3.4	The generalized Stieltjes transform, Basic properties of the generalized Stieltjes transform	**[4L]**
Module 4	Z-transform and Mellin Transform	**[15L]**
Learning Objective 1. Understand concept of Z-transform and Mellin Transform.		
Learning Outcomes: At the end of this module the learner will be able to 1. know conceptual knowledge of Z-transforms and properties of Z- transforms. 2. analyze Mellin transform of derivative of a function and Mellin transform of Integral of a function.		
4.1	Definition and properties, Z-transform of some standard functions, initial and final value theorems.	**[5L]**
4.2	Convolution theorem, Some operational properties of Z-Transform, Application of Z-Transforms.	**[5L]**
4.3	Definition of Mellin transform, Mellin Transform of derivative of a function, Mellin transform of Integral of a function.	**[5L]**

References:

1. L. Debnath and D.D. Bhatta, Integral Transforms and their Applications, 2/e, CRC Pub., 1995.
2. Baidyanath Patra, An Introduction to Integral Transforms, 1/e, CRC Press, Taylor Francis Group, 2018.
3. Poularikas, A. D., The Transforms and Applications, Handbook, 2/e, CRC Press, 1996.
4. M.Ya.Antimirov, A.A.Klyshkin, R. Valliancourt, Applied Integral Transforms, CRM Monograph Series, American mathematical Society, 2007.
5. B. Davies: Integral Transforms and their applications, 3/e, Springer - Verlag, 1978.
6. Ian Sneddon: The use of Integral Transform, TMIH, 1979.
7. A.R.Vasishta and R.K.Guptha, Integral Transforms, Krishna Prakashan Media, 2016
8. Kanwal, R.P. and Sneddon, I.N, Fourier Transforms, Dover publication, 2010.
9. Spiegel, M.R.: Theory and Problems of Laplace transforms, Schaum's series, 2011
10. Boas M. L.: Mathematical Methods in Physical Sciences, 3/e, John Wiley & Sons, 1983.
11. Raisinghania, M. D.: Integral equations and boundary value problems, 10/e, S. Chand Company Ltd., 2021.
12. Andrews, L. G. & Shivamoggi B. K.: Integral Transforms for Engineers, PHI, 2003.

Mapping of COs and PSOs

Course Learning Outcomes	Programme Outcomes							
	1	2	3	4	5	6	7	
Familiar with the basic concepts of Students will be able to learn about Hankel transform, Finite Hankel transforms.	X		X			X	X	
Understand applications of Hankel transforms.	X	X	X			X	X	
Solve the partial differential equations using Hankel transforms.	X	X	X			X	X	
Learn about Hilbert and Stieltjes transforms.	X	X		X		X		X
Solve differential equations using Hilbert and Stieltjes transforms.	X	X		X		X		X
Know Conceptual Knowledge of Z-transforms and properties of Z- transforms.	X	X		X	X	X		
Analyze Mellin Transform of derivative of a function, Mellin Transform of Integral of a function.	X		X		X	X	X	

Practical:

Practical-1	Practical based on Hankel Transform-1
Practical-2	Practical based on Finite Hankel Transform-1
Practical-3	Practical based on Applications of Hankel transform-1
Practical-4	Practical based on Applications of Hankel transform-1
Practical-5	Practical based on Hilbert Z-transform
Practical-6	Practical based on Stieltjes Transform
Practical-7	Practical based on Z-transform
Practical-8	Practical based on Mellin Transform

Skill based elective/Value Added Course- 2 (SEC-V)

COURSE TITLE: Differential Geometry-2

COURSE CODE: MHMSC-S2SEC1-4CR24 [CREDITS – 02]

Course learning outcome		
At the end of this course, Students will be able to 1. Interpret the geometric meaning of the angle of intersection in terms of curvature and orientation. 2. Analyze the behavior of curves in a family, including geodesics and curvature lines.		
Module 1	**Intrinsic geometry of Surface**	**[15L]**
Learning Objective 1. Explore the geometric properties of surfaces, including curvature, normal vectors, and tangential planes.		
Learning Outcomes: At the end of this module the learner will be able to 1. Interpret the geometric meaning of the angle of intersection in terms of curvature and orientation.		
1.1	First fundamental quadratic form of a surface, Angle of two intersecting curves in a surface, element of area, Family of curves in a surface, principle directions, isometric surfaces, The Riemannian curvature tensor, the Gaussian curvature of a surface.	**[15L]**
Module 2	**Surfaces in Space**	**[15L]**
Learning Objective 1. Explore applications of families of curves in surface mapping and differential geometry.		
Learning Outcomes: At the end of this module the learner will be able to 1. Analyze the behavior of curves in a family, including geodesics and curvature lines.		
2.1	Second fundamental form of a surface, Equation of Gauss and equations of Codazzi, Normal curvature of surface, lines of curvature of a surface, Isometric conjugate nets, Dupin indicatrix.	**[15L]**

References:

1. J. A. Thorpe, Elementary topics in differential geometry, 2/e, Springer, 2004.
2. A. Pressley, Elementary differential geometry, 2/e, Springer, 2010.
3. Mittal and Agarwal, Differential geometry, 36/e, Meerut: Krishna Prakashan Media (P) Ltd., 2010.
4. K. S. Amur, D. J. Shetty and C. S. Bagewadi, An introduction to differential geometry, Oxford, U.K: Alpha Science International, 2010.

Mapping of COs and PSOs

Course Learning Outcomes	Programme Outcomes							
	1	2	3	4	5	6	7	8
Interpret the geometric meaning of the angle of intersection in terms of curvature and orientation.				X	X	X		X
Analyze the behavior of curves in a family, including geodesics and curvature lines.				X	X	X		X

Skill Based Elective/Value Added Course- 2 (SEC-VI)

COURSE TITLE: Math with Python-2

COURSE CODE: MHMSC-S2SEC2-4CR24 [CREDITS – 02]

Course learning outcome		
At the end of this course, Students will be able to 1. Be familiar with the built-in functions to deal with Graphs and Digraphs. 2. The built in functions required to deal with creating and visualizing Graphs, Digraphs, Multi Graph.		
Module 1	**Data Visualization Fundamentals**	**[7L]**
Learning Objective 1. be aware of different types of plots in Python.		
Learning Outcomes: At the end of this module the learner will be able to 1. deal with Graphs and Digraphs.		
1.1	Standard plots (2D and 3D), Plotting with Matplotlib, pyplot interface, Scatter plots, Slope fields, Vector fields, Plotting more than one curve.	**[7L]**
Module 2	**Advanced Data Visualization and Analysis**	**[8L]**
Learning Objective 1. acquire the skill of creating graphs using functions of Python.		
Learning Outcomes: At the end of this module the learner will be able to 1. Deal with creating and visualizing Graphs, Digraphs, Multi Graph using the built in functions.		
2.1	Contour plots, stream lines, Manipulating and data visualizing data with Pandas, various examples using Pandas series.	**[8L]**

References:

1. H. P. Langtangen, A Primer on Scientific Programming with Python, 2/e., Springer, 2016.
2. S. Linge and H. P. Langtangen, Programming for computations- Python - A Gentle Introduction to Numerical Simulations with Python 3.6, 2/e, Springer Open, Second Edm., 2020.
3. H. Fangohr, Introduction to Python for Computational Science and Engineering (A beginner's guide), University of Southampton, 2015. (https://www.southampton.ac.uk/~fangohr/training/python/pdfs/Python-for-Computational-Science-and-Engineering.pdf)
4. E Balagurusamy, Introduction to Computing & Problem Solving using Python, 1st ed., McGraw Hill Education (India) Private Limited, New Delhi.

Mapping of COs and PSOs

Course Learning Outcomes	Programme Outcomes							
	1	2	3	4	5	6	7	8
Be familiar with the built-in functions to deal with Graphs and Digraphs.			X	X	X	X		X
The built in functions required to deal with creating and visualizing Graphs, Digraphs, Multi Graph.			X	X	X	X		X

Practical:

Practical-1	Examples include line plots, bar charts, and histograms.
Practical-2	Scatter plots display individual data points on a two-dimensional plane.
Practical-3	Examples of velocity,
Practical-4	Examples of force, or electric field
Practical-5	Example of contour plot
Practical-6	Example of data visualization using pandas

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