M.Sc. Mathematics

Course Structure and Syllabus

University Campus

(Based on Choice Based Credit System)

2018 onwards

DEPARTMENT OF MATHEMATICAL SCIENCES

VISION

To be a knowledge nerve center in Mathematics, Pure and Applied Research and industry requirements for creating sustainable infrastructure and enhancing quality of life.

MISSION

1. To offer globally-relevant, industry-linked, research-focused, technology-enabled seamless education at the graduate, postgraduate and research levels in various areas of Mathematical sciences keeping in mind that the manpower so spawned is excellent in quality, is relevant to the global scientific and technological needs, is motivated to give its best and is committed to the growth of the Nation;
2. To develop and conduct continuing education programs for Science graduates with a view to update their fundamental knowledge base and problem-solving capabilities in the various areas of core specialization of the University;
3. To develop comprehensive linkages with premier academic and research institutions within the country and abroad for mutual benefit.

M.Sc. (Mathematics) Program

The main objective of this program is to cultivate a mathematical aptitude and nurture the interests of the students towards problem solving aptitude. Further, it aims at motivating the young minds for research in mathematical sciences and to train computational scientists who can work on real life challenging problems.

Duration: M.Sc. Mathematics is a postgraduate level program offered by the Department of Mathematical Sciences. This is a 2-years program, consisting of four semesters with two semesters per year.

Program Code: MSM (Masters of Science in Mathematics)

Eligibility: B.A./B.Sc. or equivalent from a recognized university with Mathematics as one of the major subjects with at least 50% marks in aggregate.

PROGRAM OBJECTIVES: The Program Objectives are the knowledge skills and attributes which the students have at the time of post-graduation. At the end of the program, the student will be able to:

1	To provide comprehensive curriculum to groom the students into qualitative scientific manpower
2	Enable students to enhance mathematical skills and understand the fundamental concepts of pure and applied mathematics.
3	To provide qualitative education through effective teaching learning processes by introducing projects, participative learning and latest software tools.
4	To inculcate innovative skills, team work, ethical practices among students so as to meet societal expectations.
5	To encourage collaborative learning and application of mathematics to real life situations.
6	To inculcate the curiosity for mathematics in students and to prepare them for future research.

PROGRAM SPECIFIC OUTCOMES: At the end of the program, the student will be able to:

PSO1	Apply the knowledge of mathematical concepts in interdisciplinary fields.
PSO2	Understand the nature of abstract mathematics and explore the concepts in further details.
PSO3	Model the real-world problems in to mathematical equations and draw the inferences by finding appropriate solutions.
PSO4	Identify challenging problems in mathematics and find appropriate solutions.
PSO5	Pursue research in challenging areas of pure/applied mathematics.
PSO6	Employ confidently the knowledge of mathematical software and tools for treating the complex mathematical problems and scientific investigations.
PSO7	Continue to acquire mathematical knowledge and skills appropriate to professional activities and demonstrate highest standards of ethical issues in mathematics.
PSO8	Comprehend and write effective reports and design documentation related to mathematical research and literature, make effective presentations.
PSO9	Qualify national level tests like NET/GATE etc.
PSO10	Effectively communicate and explore ideas of mathematics for propagation of knowledge and popularization of mathematics in society.

Scheme of the Program:

First Semester **Contact Hours: 28 Hrs.**

Course Code	Course Title	Load Allocation			Marks Distribution			Credits
		L	T	P	Internal	External	Total	
UC-MSM-101-18	Algebra-I	4	1	0	40	60	100	4
UC-MSM-102-18	Real Analysis-I	4	1	0	40	60	100	4
UC-MSM-103-18	Complex Analysis	4	1	0	40	60	100	4
UC-MSM-104-18	Ordinary Differential Equations and Special Functions	4	1	0	40	60	100	4
UC-MSM-105-18	Mathematical Methods	4	1	0	40	60	100	4
UC-MSM-106-18	Introduction to Computer Algebra System (Lab)	0	0	3	50	25	75	3
Total		20	05	03	250	325	575	23

Second Semester **Contact Hours: 28 Hrs.**

Course Code	Course Title	Load Allocation			Marks Distribution			Credits
		L	T	P	Internal	External	Total	
UC-MSM-201-18	Algebra-II	4	1	0	40	60	100	4
UC-MSM-202-18	Real Analysis-II	4	1	0	40	60	100	4
UC-MSM-203-18	Mechanics-I	4	1	0	40	60	100	4

UC-MSM-204-18	Partial Differential Equations	4	1	0	40	60	100	4
UC-MSM-205-18	Numerical Analysis	4	1	0	40	60	100	4
UC-MSM-206-18	Numerical Analysis (Lab)	0	0	3	50	25	75	3
Total		20	05	03	250	325	575	23

Third Semester **Contact Hours: 25 Hrs.**

Course Code	Course Title	Load Allocation			Marks Distribution			Credits
		L	T	P	Internal	External	Total	
UC-MSM-301-18	Topology	4	1	0	40	60	100	4
UC-MSM-302-18	Number Theory and Cryptography	4	1	0	40	60	100	4
UC-MSM-303-18	Mathematical Statistics	4	1	0	40	60	100	4
UC-MSM-304-18	Functional Analysis	4	1	0	40	60	100	4
UC-MSM-305-18	Mechanics-II	4	1	0	40	60	100	4
UC-MSM-311-18	Seminar	0	0	2	50	0	50	2
Total		20	05	00	200	300	500	22

Fourth Semester **Contact Hours: 27 Hrs.**

S.No.	Course Code	Course Title	Load Allocation			Marks Distribution			Credits
			L	T	P	Internal	External	Total	
1.	UC-MSM-401-18	Differential Geometry	4	1	0	40	60	100	4
2.	UC-MSM-WWW-18	Elective	4	1	0	40	60	100	4
3.*	UC-MSM-XXX-18 UC-MSM-YYY-18 UC-MSM-ZZZ-18	Elective	4	1	0	40	60	100	12
	UC-MSM-411-18	Dissertation	-	-	12	200	100	300	
4.	UC-MSM-412-18	Seminar	0	0	2	50	0	50	2
	Total							550	22

TOTAL NUMBER OF CREDITS = 90

Note*: Students may opt either three Elective Theories or Dissertation.

LIST OF DEPARTMENTAL/INTERDISCIPLINARY ELECTIVES

Elective- UC-MSM-WWW-18, UC-MSM-XXX-18, UC-MSM-YYY-18, UC-MSM-ZZZ-18 (Any one subject to be opted)

MSM-501-18 Discrete Mathematics

MSM-502-18 Coding Theory

MSM-503-18 Operations Research

MSM-504-18 Advanced Number Theory

MSM-505-18 Advanced Complex Analysis

MSM-506-18 Advanced Operations Research

MSM-507-18 Advanced Fluid Mechanics

MSM-508-18 Advanced Solid Mechanics

MSM-509-18 Theory of Linear Operators

MSM-510-18 Advanced Numerical Methods

MSM-511-18 Topological Vector Spaces

MSM-512-18 Fractional Calculus

Examination and Evaluation

Theory			
S. No.	**Evaluation criteria**	**Weightage in Marks**	**Remarks**
1	Mid term/sessional Tests	24	Internal evaluation (40 Marks)
2	Attendance	6	MSTs, Quizzes, assignments, attendance, etc., constitute internal evaluation. Average of two mid semester test will be considered for evaluation.
3	Assignments	10	
4	End semester examination	60	External evaluation

5	Total	100	Marks may be rounded off to nearest integer.
Practical			
1	Evaluation of practical record/ Viva Voice/Attendance/Seminar/ Presentation	30	Internal evaluation
2	Final Practical Performance + Viva-Voce	20	External evaluation
3	Total	50	Marks may be rounded off to nearest integer.
Seminar			
1	Content	15	Internal evaluation
2	Queries	15	
3	Communication skills	10	
4	Visual effects	10	
5	Total	50	Marks may be rounded off to nearest integer.

<table>
<tr><td colspan="7">Dissertation</td></tr>
<tr><td></td><td colspan="4">Internal Assessment</td><td></td><td></td></tr>
<tr><td rowspan="2">Departmental Presentation</td><td colspan="2">Communication and presentation</td><td colspan="2">Response to queries</td><td>Maximum Marks</td><td>Evaluated by</td></tr>
<tr><td colspan="2">20</td><td colspan="2">30</td><td>50</td><td>Committee Member:
1.Head
2.Supervisor
3.One of Faculty Member</td></tr>
<tr><td rowspan="2">Dissertation</td><td>Plagiarism</td><td>Subject Matter</td><td>Usage of Language</td><td>Publication/Presentation in Conference</td><td rowspan="2">150</td><td rowspan="2"></td></tr>
<tr><td>25</td><td>70</td><td>25</td><td>30</td></tr>
<tr><td></td><td colspan="4">External Assessment</td><td></td><td></td></tr>
<tr><td rowspan="2">External Examiner</td><td colspan="4">Subject Matter</td><td rowspan="2">50</td><td rowspan="2">Committee Member:
1.Head
2.External Expert
3.Supervisor
4. Director (MC) nominee</td></tr>
<tr><td colspan="4">50</td></tr>
<tr><td rowspan="2">Viva Voce</td><td colspan="2">Communication and Presentation</td><td colspan="2">Response to queries</td><td rowspan="2">50</td><td rowspan="2"></td></tr>
<tr><td colspan="2">20</td><td colspan="2">30</td></tr>
<tr><td colspan="5">Total</td><td>300</td><td></td></tr>
</table>

Evaluation Process:

1. The subject matter evaluation can further be defined on the basis of Title, Review of literature/Motivation, Objectives, Methodology, Results and discussions, and Conclusion.
2. The usage of language and the subject matter shall be evaluated by the supervisor. Out of 300 marks, 95 marks are to be evaluated by the concerned supervisor.
3. Total 15% Plagiarism is admissible for submission of the dissertation. For (0-5)%of plagiarism, candidate should be awarded 25 marks. For >5%-10% candidate should be awarded 15 marks and for the range of > 10% to < 15%, candidate should be awarded 5 marks.
4. For publication candidate should be awarded full 30 marks and for presenting the work related to dissertation, candidate should be awarded 25 marks.

Instructions for Paper-Setter in M. Sc (Hons.) Mathematics

A. Scope

1. The question papers should be prepared strictly in accordance with the prescribed syllabus and pattern of question paper of the University.

2. The question paper should cover the entire syllabus with uniform distribution among each units and Weightage of marks for each question.

3. The language of questions should be simple, direct, and documented clearly and unequivocally so that the candidates may have no difficulty in appreciating the scope and purpose of the questions. The length of the expected answer should be specified as far as possible in the question itself.

4. The distribution of marks to each question/answer should be indicated in the question paper properly.

B. Type and difficulty level of question papers

1. Questions should be framed in such a way as to test the students intelligent grasp of broad principles and understanding of the applied aspects of the subject. The Weightage of the marks as per the difficulty level of the question paper shall be as follows:

i)	Easy question	30%
ii)	Average questions	50%
iii)	Difficult questions	20%

2. The numerical content of the question paper should be up to 40%.

C. Format of question paper

1. Paper code and Paper-ID should be mentioned properly.
2. The question paper will consist of three sections: Sections-A, B and C.
3. Section-A is COMPULSORY consisting of TEN SHORT questions carrying two marks each (total 20 marks) covering the entire syllabus.
4. The Section-B consists of FOUR questions of eight marks each covering Unit I & II of syllabus (Taking two questions from each unit I & II).
5. The Section-C consists of FOUR questions of eight marks each covering Unit III & IV of syllabus (Taking two questions from each unit III & IV).
6. Sub-parts of the questions in Section B and C should be preferred for numerical/conceptual questions.
7. Attempt any five questions from Section-B and Section-C, selecting at least two questions from each of the two sections.

Question paper pattern for MST:

Roll No:		**No of pages:**
IK Gujral Punjab Technical University- Jalandhar		
Department of Mathematical Sciences		
Academic Session:		
Mid-Semester Test: I/II/III (Regular/reappear)	**Date:**	
Programme: B.Sc. (Hons.) Mathematics	**Semester:**	
Course Code:	**Course:**	
Maximum Marks: 24	**Time: 1 hour 30 minutes**	

❖ Note: Section A is compulsory; Attempt any two questions from Section B and one question from Section C.

Section: A		**Marks**	**Cos**
1		2	
2		2	
3		2	
4		2	
Section: B			
5		4	
6		4	
7		4	
Section: C			
8		8	
9		8	

Details of Course Objectives

CO1	
CO2	
CO3	
CO4	
CO5	

SEMESTER-I

UC-MSM-101-18	**Algebra-I**	**L-4, T-1, P-0**	**4 Credits**
Pre-requisite: Discrete Structures			
Course Objectives: This course is designed to give students a foundation for all future mathematics courses. The fundamentals of algebraic problem-solving are explained. Students will explore: foundations of Algebraic structures, Groups, Rings, Ideals, Fields, Homomorphisms etc. The course also fulfills the objective to make students aware of the applicability of abstract mathematics in real world problems.			
Course Outcomes: At the end of the course, the students will be able to			

CO1	Apply the knowledge of Algebra to attain a good mathematical maturity and enables to build mathematical thinking and skill.
CO2	Utilize the class equation and Sylow theorems to solve different related problems.
CO3	Identify and analyze different types of algebraic structures such as Solvable groups, Simple groups, Alternate groups to understand and use the fundamental results in Algebra.
CO4	Design, analyze and implement the concepts of homomorphism and isomorphism between groups and rings for solving different types of problems, for example, Isomorphism theorems, quotient groups, conjugacy etc.
CO5	Create, select and apply appropriate algebraic structures such as finitely generated abelian groups, Ideals, Fields to explore the existing results.
CO6	Identify the challenging problems in modern mathematics and find their appropriate solutions.

Mapping of course outcomes with the program outcomes

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10
CO1	√	√	-	√	√	-	√	-	√	√
CO2	√	√	-	√	-	-	√	-	√	√
CO3	√	√	-	√	√	-	√	-	√	√
CO4	√	√	-	√	√	-	√	-	√	√
CO5	√	√	-	√	-	-	√	-	√	√
CO6	√	√	-	√	-	-	√	-	√	√

Course Title: Algebra-I
Course Code: UC-MSM-101-18

UNIT-I

Groups: Groups, homomorphisms, Subgroups and Cosets, Cyclic groups, Permutation groups, Normal subgroups and quotient groups, Isomorphism theorems, Automorphisms, Symmetric groups, Conjugacy. [Ref 2: Unit 1]

UNIT-II

Normal series, Derived Series, Composition Series, Solvable Groups, Simple groups and their examples, Alternating group A_n, Simplicity of A_n. [Ref 2: Unit 1]

UNIT-III

Direct Products, Finite Abelian Groups, Fundamental Theorem on Finitely generated Abelian Groups, Invariants of a finite abelian groups, Sylow's Theorems and their applications, Groups of order p^2, pq. [Ref 2: Unit 1]

UNIT-IV

Rings: Ring, Subring, Ideals, Homomorphism and Algebra of Ideals, Maximal and prime ideals, Ideals in quotient rings, Nilpotent and nil ideals. [Ref 2: Unit 2]

RECOMMENDED BOOKS:

1. Bhattacharya, P. B., Jain, S.K. and Nagpaul, S.R., *Basic Abstract Algebra, 2nd Edition.* U.K.: Cambridge University Press, 2004.
2. Dummit, David. S., and Foote, Richard M., *Abstract Algebra, 3rd Edition*. New Delhi: Wiley, 2011.
3. Herstein, I.N., *Topics in Algebra, 2nd Edition*. New Delhi: Wiley, 2006.
4. Singh, Surjeet, and Zameeruddin, Q., *Modern Algebra, 7th Edition*. New Delhi: Vikas Publishing House, 1993.
5. Artin, M., *Algebra, 2nd Edition*. Pearson Publications, 2010.

UC-MSM-102-18	**Real Analysis-I**	**L-4, T-1, P-0**	**4 Credits**
Pre-requisite: Basic Calculus			
Course Objectives: This course is designed to provide a deeper and rigorous understanding of fundamental concepts viz. metric spaces, continuous functions, sequences and series of numbers as well as functions, and the Riemann-Stieltjes integral etc. The main focus of this course will be on theoretical foundation of the above said concepts and it will cultivate the rigorous mathematical logics and skills in the students.			
Course Outcomes: At the end of the course, the students will be able to			

CO1	Apply the knowledge of concepts of real analysis in order to study theoretical development of different mathematical techniques and their applications.
CO2	Understand the nature of abstract mathematics and explore the concepts in further details.
CO3	Identify challenging problems in real variable theory and find their appropriate solutions.
CO4	Deal with axiomatic structure of metric spaces and generalize the concepts of sequences and series, and continuous functions in metric spaces.
CO5	Use theory of Riemann-Stieltjes integral in solving definite integrals arising in different fields of science and engineering.
CO6	Extend their knowledge of real variable theory for further exploration of the subject for going into research.

Mapping of course outcomes with the program outcomes

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10
CO1	√	-	-	-	-	-	√	-	√	√
CO2	-	√	-	-	-	-	√	-	√	√
CO3	-	-	-	√	-	-	√	-	√	√
CO4	-	√	-	-	-	-	√	-	√	√
CO5	√	-	-	-	-	-	√	-	√	√
CO6	-	-	-	-	√	-	√	-	√	√

Course Title: Real Analysis-I
Course Code: UC-MSM-102-18

UNIT-I

Finite, Countable and Uncountable sets, Metric spaces, Compact sets, Perfect sets, Connected sets, Convergent sequences, Sub sequences, Cauchy sequences, Power series, Absolute convergence, Algebra of series, Rearrangements of elements in a series.

UNIT-II

Limits of functions, Continuous functions, Compactness, Connectedness, Monotonic functions, Infinite limits and Limits at infinity.

UNIT-III

The Riemann-Stieltjes integral: Definition and existence of the Riemann-Stieltjes integral, Properties of the integral, Integration and differentiation, Integration of vector-valued functions, Rectifiable curves.

UNIT-IV

Sequences and series of functions: Interchanging order of limits for sequences of functions, Uniform convergence, Uniform convergence and continuity, Uniform convergence and integration, Uniform convergence and differentiation, Equicontinuous families of functions, Stone Weierstrass Theorem.

RECOMMENDED BOOKS:

1. Rudin, W., *Principles of Mathematical Analysis, 3rd Edition*. New Delhi: McGraw-Hill Inc., 2013.
2. Royden, H.L. and Fitzpatrick, P.M., *Real Analysis, 4th Edition.* New Delhi: Pearson, 2010.
3. Carothers, N. L., *Real Analysis*, Cambridge University Press, 2000.
4. Apostol, T.M., *Mathematical Analysis –A modern approach to Advanced Calculus*. New Delhi: Narosa Publishing House, 1957.
5. Abbott, S., *Understanding Analysis, 2nd Edition.* Springer, 2016.

UC-MSM-103-18	**Complex Analysis**	**L-4, T-1, P-0**	**4 Credits**

Pre-requisite: Calculus of several variables and complex number system.

Course Objectives: The objective of this course is to introduce and develop a clear understanding of the fundamental concepts of Complex Analysis such as analytic functions, Cauchy-Riemann relations and harmonic functions and to make students equipped with the understanding of the fundamental concepts of complex variable theory. In particular, to enable students to acquire skill of contour integration to evaluate complicated real integrals via residue calculus.

Course Outcomes: At the end of the course, the students will be able to

CO1	Know the fundamental concepts of complex analysis.
CO2	Evaluate complex integrals and apply Cauchy integral theorem and formula.
CO3	Evaluate limits and checking the continuity of complex function & apply the concept of analyticity and the Cauchy-Riemann equations.
CO4	Solve the problems using complex analysis techniques applied to different situations in engineering and other mathematical contexts.
CO5	Establish the capacity for mathematical reasoning through analysing, proving and explaining concepts from complex analysis
CO6	Extend their knowledge to pursue research in this field.

Mapping of course outcomes with the program outcomes

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10
CO1	√	√	-	-	√	-	√	-	√	√
CO2	√	√	-	√	√	-	√	-	√	√
CO3	√	√	-	√	√	-	√	-	√	√
CO4	√	√	√	√	√	-	√	-	√	√
CO5	√	√	√	√	√	-	√	-	√	√
CO6	√	√	√	√	√	-	√	-	√	√

Course Title: Complex Analysis

Course Code: UC-MSM-103-18

UNIT-I

Function of complex variable, continuity and differentiability, Analytic functions, Cauchy Riemann equation (Cartesian and polar form). Harmonic functions, Harmonic conjugate, Construction of analytic functions. Exponential function, Trigonometric and inverse trigonometric functions, Logarithmic function, Complex powers, Branches of multivalued functions with reference to arg(z), log(z), z^c. Stereographic projection and the spherical representation of the extended complex plane.

Unit-II

Complex line integral, Cauchy-Goursat theorem, independence of path; Cauchy’s integral formulas and their consequences, Cauchy inequality, Liouville's theorem, Fundamental theorem of algebra, Morera's theorem, Maximum modulus principle, Schwarz lemma, Poisson’s integral formula.

Unit-III

Power series: circle of convergence, radius of convergence. Taylor’s series and Taylor’s theorem, Laurent’z series and Laurent theorem, Zeros and singularities of complex functions, classification of singularities: removable singularity, poles, essential singularities, Residue at a pole and at infinity, Cauchy's Residue theorem and its applications in evaluation of real integrals: integration around unit circle, integration over semi-circular contours (with and without real poles), integration around rectangular contours, Argument principle, Rouche’s theorem

Unit-IV

Conformal transformations, Bilinear transformations, Critical points, Fixed points, Problems on cross-ratio and bilinear transformation.

RECOMMENDED BOOKS:

1. Ahlfors, L.V., *Complex Analysis, 2nd Edition*. McGraw-Hill International Student Edition, 1990.
2. Kumar, R.R., Complex Analysis, Pearson Education, 2015.
3. Churchill, R. and Brown, J.W., *Complex Variables and Applications*, *6th Edition*. New- York: McGraw-Hill, 1996.

UC-MSM-104-18	Ordinary Differential Equations and Special Functions	L-4, T-1, P-0	4 Credits

Pre-requisite: Differential Calculus, Integral Calculus and some introduction to linear algebra.

Course Objectives: The Objective of this course is to introduce ordinary differential equations and fundamental theorems for existence and uniqueness. This course further explains the analytic techniques in computing the solutions of various ordinary differential equations appearing in various fields of science and technology.

Course Outcomes: At the end of the course, the 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 and applications of eigen value problems.
CO3	Understand differential equations of Strum Liouville type.
CO4	Apply various power series methods to obtain series solutions of differential equations.
CO5	Discuss various kinds of special functions in detail, their properties and relations.
CO6	Solve problems of ordinary differential equations arising in various fields.

Mapping of course outcomes with the program outcomes

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10
CO1	√	-	√	√	√	-	√	-	√	√
CO2	√	-	√	√	√	-	√	-	√	√
CO3	√	-	√	√	√	-	√	-	√	√
CO4	√	-	√	√	√	-	√	-	√	√
CO5	√	-	√	√	√	-	√	-	√	√
CO6	√	-	√	√	√	-	√	-	√	√

Course Title: Ordinary Differential Equations and Special Functions

Course Code: UC-MSM-104-18

UNIT-I

Review of linear differential equations with constant & variable coefficients, Fundamental existence and uniqueness theorem for system and higher order equations (Picard's and Piano theorems), System of linear differential equations, an operator method for linear system with constant coefficients, Phase plane method.

UNIT-II

Homogeneous linear system with constant coefficients, Eigenvalues and eigen functions, orthogonality of eigen functions, Complex eigenvalues, repeated eigenvalues, Ordinary differential equations of the Sturm-Liouville problems, Expansion theorem, Extrema properties of the eigen values of linear differential operators, Formulation of the eigen value problem of a differential operator as a problem of integral equation, Linear homogeneous boundary value problems

UNIT-III

Power series solution of differential equations: about an ordinary point, solution about regular singular points, the method of Frobenius, Bessel equation and Bessel functions, Recurrence relations and orthogonal properties., Series expansion of Bessel Coefficients, Integral expression, Integral involving Bessel functions, Modified Bessel function, Ber and Bei functions, Asymptotic expansion of Bessel Functions, Legendre's differential equations, Legendre Polynomials , Rodrigue's formula, Recurrence relations and orthogonal properties.

UNIT-IV

The Hermite polynomials, Chebyshev's polynomial, Laugrre's polynomial: Recurrence relations, generating functions and orthogonal properties.

RECOMMENDED BOOKS:

1. Ross, S.L., *Differential Equations, 3rd Edition.* John Wiley & Sons, 2004.
2. Boyce, W.E. and Diprima, R.C., *Elementary Differential Equations and Boundary Value problems, 4th Edition*. John Wiley and Sons, 1986.
3. Sneddon, I.N., *Special Functions of Mathematical Physics and Chemistry.* Edinburg: Oliver & Boyd, 1956.
4. Bell, W.W., *Special Functions for Scientists and Engineers.* Dover, 1986.

UC-MSM-105-18	Mathematical Methods	L-4, T-1, P-0	4 Credits

Pre-requisite: Basic Calculus and Linear Algebra

Course Objectives: The objective of the course is to acquaint the students with the knowledge of mathematical techniques frequently applied in various branches of engineering and sciences. Also, one of the objectives of this course is to equip the students with the mathematical background required for the development of such techniques.

Course Outcomes: At the end of the course, the students will be able to

CO1	Understand the theory and applications of integral transforms.
CO2	Explain how integral transforms can be used to solve a variety of differential equations.
CO3	Solve integro-differential equations of Fredholm and Volterra type.
CO4	Understand the properties of various kinds of integral equations.
CO5	Develop their attitude towards problem solving.

Mapping of course outcomes with the program outcomes

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10
CO1	√	-	√	√	√	-	-	-	√	√
CO2	√	-	√	√	√	-	-	-	√	√
CO3	√	-	√	√	√	-	-	-	√	√
CO4	√	√	-	√	√	-	-	-	√	√
CO5	√	-	√	√	√	-	-	-	√	√

Course Title: Mathematical Methods
Course Code: UC-MSM-105-18

UNIT I

Laplace Transforms: Laplace Transform, Properties of Laplace Transform, Inverse Laplace Transform, Convolution theorem, Laplace transform of periodic functions, unit step function and impulsive function, Application of Laplace Transform in solving ordinary and partial differential equations and Simultaneous linear equations;

UNIT II

Fourier Transforms: Fourier transform, properties of Fourier transform, inversion formula, convolution, Parseval's equality, Fourier transform of generalized functions, application of Fourier transforms in solving heat, wave and Laplace equation. Fast Fourier transform.

UNIT III

Integral Equations: Relations between differential and integral equations, Green's function, Linear equations in cause and effect, Integral equations of Fredholm and Volterra type, solution by successive substitution and successive approximation, integral equations with degenerate kernels.

UNIT IV

Integral equations of convolution type and their solutions by Laplace transform, Fredholm's theorems, integral equations with symmetric kernel, Solutions with separable kernels, Characteristic numbers, Resolvent kernel, Eigen values and Eigen functions of integral equations and their simple properties.

Text and Reference Books:

1. Sneddon, I.N., *The Use of Integral Transforms*. McGraw Hill, 1985.
2. Goldberg, R.R., *Fourier Transforms.* Cambridge University Press, 1970.
3. Smith, M.G., *Laplace Transform Theory*. Van Nostrand Inc., 2000.
4. Elsegolc, L., *Calculus of Variation*. Dover Publications, 2010.
5. Kenwal, R.P., *Linear Integral Equation; Theory and Techniques*. Academic Press, 1971.
6. Hildebrand, F.B., *Methods of Applied Mathematics* ***(Latest Reprint)***. Dover Publications.
7. Pal, S. and Bhunia, S.C., *Engineering Mathematics*. Oxford University Press, 2015.

UC-MSM-106-18	**Introduction to Computer Algebra System**	**L-0, T-0, P-3**	**3 Credits**
Pre-requisite: Basic knowledge of computer			
Course Objectives: This course provides an introduction to Computer Algebra System (CAS) viz. MATLAB and MATHEMATICA that are widely used in scientific computing. The major objective of this course is to enable students to make use of symbol tools of these CAS and also develop programming skills for solving problems of real world more efficiently and accurately			
Course Outcomes: At the end of the course, the students will be able to			

CO1	Apply the knowledge of mathematical software viz. MATLAB and MATHEMATICA to solve real world problems efficiently.
CO2	Utilize the symbolic tools of these CAS for handling different mathematical problems for example, solution of equations, differentiation, integration etc.
CO3	Design and analyze their own computer codes of mathematical methods.
CO4	Understand and modify existing codes in scientific computing based on the use of different loops and conditional structures.
CO5	Use these CAS with the understanding of limitations of the systems.
CO6	Identify the challenging problems in mathematics and find their appropriate solutions accurately and efficiently using Computer Algebra System.

Mapping of course outcomes with the program outcomes

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10
CO1	√	-	-	-	-	√	-	-	√	√
CO2	√	-	-	-	-	√	-	-	√	√
CO3	√	-	-	-	-	√	-	-	√	√
CO4	-	-	-	-	-	√	-	-	√	√
CO5	√	-	-	-	-	√	-	-	√	√
CO6	-	-	-	√	-	-	-	-	√	√

Course Title: Introduction to Computer Algebra System
Course Code: UC-MSM-106-18

UNIT-I

The MATLAB environment, scalars, variables, arrays, mathematical operations with arrays, built-in and user defined functions, graphics: two-dimensional and three-dimensional, m-files: script and function files, functions: input; disp and fprintf, relational and logical operators, symbolic math: symbolic objects and expressions; collect; expand; factor; simplify; simple; pretty; solve; diff and int commands, Programming: if-end structure; if-else-end structure; if-elseif-else-end structure; loops: for-end and while-end

UNIT-II

The structure of MATHEMATICA, notebook interfaces, constants, variables, algebraic calculations, four kinds of brackets, lists, tables, expressions, functions, built-in functions, functional operations, graphics, patterns, manipulating lists, transformation rules, evaluation of expressions, modularity, manipulating notebooks, relational and logical operators, symbolic math commands: D; Integrate; Sum; Product; Solve; Eliminate; Reduce; Series; Limit; Minimize; basic numerical mathematics, Programming: conditionals; loops: Do; For and While.

Text and Reference Books:

1. Higham, D.J. and Higham, N.J., MATLAB Guide, 2nd Edition. Society for Industrial and Applied Mathematics (SIAM), 2005.
2. Gilat, A., MATLAB: An Introduction with Applications, 5th Edition. John Wiley & Sons, 2014.
3. Wolfram, S., The MATHEMATICA Book, 5th revised edition. Wolfram Media Inc, 2004.
4. Abell, M. and Braselton, J., Mathematica by Example, 5th Edition. Academic Press, 2017.

SEMESTER-II

UC-MSM-202-18	Real Analysis-II	L-4, T-1, P-0	4 Credits

Pre-requisite: Calculus of several variables and Real Analysis-I

Course Objectives: This course is designed to consider theoretical foundations of concepts of mathematical analysis, viz. derivative, MVTs, functions of several variables, measure theory and integration that have many important applications in different branches of pure and applied mathematics. Further, the objective is enable students familiar with these concepts and their fruitful applications.

Course Outcomes: At the end of the course, the students will be able to

CO1	Apply the knowledge of concepts of functions of several variables and measure theory in order to study theoretical development of different mathematical concepts and their applications.
CO2	Understand the nature of abstract mathematics and explore the concepts in further details
CO3	Utilize the concepts of derivative, MVTS for vector-valued functions in applications different fields for example management, industry and economics etc.
CO4	Recognize the need of concept of measure from a practical view point.
CO5	Understand measure theory and integration from theoretical point of view and apply its tools in different fields of applications.
CO6	Extend their knowledge of Lebesgue theory of integration by selecting and applying its tools for further research in this and other related areas

Mapping of course outcomes with the program outcomes

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10
CO1	√	-	-	√	√	-	-	-	√	√
CO2	-	√	-	√	√	-	-	-	√	√
CO3	√	-	-	√	√	-	-	-	√	√
CO4	-	√	-	√	√	-	-	-	√	√
CO5	-	√	-	√	√	-	-	-	√	√
CO6	-	-	-	√	√	-	-	-	√	√

Course Title: Real Analysis-II

Course Code: UC-MSM-202-18

UNIT-I

Differentiation of Real functions, Mean value theorems, Taylor's theorem, Differentiation of vector-valued functions, Functions of several variables: Linear transformations, Differentiation, Contraction principle, The Inverse function theorem, The implicit function theorem. [Ref. 3]

UNIT-II

Lebesgue Measure: Introduction, Lebesgue outer measure, Measurable sets and Lebesgue measure, non-measurable set, Measurable functions, Borel and Lebesgue measurability, Littlewood's three principles.

UNIT-III

Lebesgue Integral: The Riemann integral, The Lebesgue integral of a bounded function over a set of finite measure, the integral of a nonnegative function, The general Lebesgue integral, Convergence in measure.

UNIT-IV

Differentiation and Integration: Differentiation of monotone functions, The Four derivatives, Functions of bounded variation, differentiation of an integral, Lebesgue Differentiation Theorem. Absolute continuity. Convex Functions.

RECOMMENDED BOOKS:

1. Royden, H.L. and Fitzpatrick, P.M., *Real Analysis, 4th Edition.* New Delhi: Pearson, 2010.
2. Barra, G. de., *Measure Theory and Integration*, New Delhi: Woodhead Publishing, 2011.
3. Rudin, W., *Principles of Mathematical Analysis, 3rd Edition*. New Delhi: McGraw-Hill Inc., 2013.
4. Carothers, N. L., *Real Analysis*, Cambridge University Press, 2000.
5. Apostol, T.M., *Mathematical Analysis –A modern approach to Advanced Calculus*. New Delhi: Narosa Publishing House, 1957.

UC-MSM-203-18	**Mechanics-I**	**L-4, T-1, P-0**	**4 Credits**

Pre-requisite: Basic Mechanics and Calculus of several variables

Course Objectives: To demonstrate knowledge of functional and extremum path and the application of the knowledge in solving some fundamental problems. To demonstrate the knowledge and understanding of the fundamental concepts in the dynamics of system of particles and Lagrangian and Hamiltonian formulation of mechanics. To represent the equations of motion for complicated mechanical systems using the Lagrangian and Hamiltonian formulation of classical mechanics.

Course Outcomes: At the end of the course, the students will be able to

CO1	Understand the concept of functional and determine stationary paths of a functional to deduce the differential equation for stationary paths.
CO2	Use Euler-Lagrange equation to find stationary paths and its applications in some classical fundamental problems.
CO3	Define and understand basic mechanical concepts related to discrete and continuous mechanical systems.
CO4	describe and understand the motion of a mechanical system using Lagrange-Hamilton formalism.
CO5	Connect concepts and mathematical rigor in order to enhance understanding.

Mapping of course outcomes with the program outcomes

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10
CO1	-	√	-	√	√	-	-	-	√	√
CO2	√	-	√	√	√	-	-	-	√	√
CO3	√	-	√	√	√	-	-	-	√	√
CO4	√	√	-	√	√	-	-	-	√	√
CO5	√	-	√	√	√	-	-	-	√	√

Course Title: Mechanics-I

Course Code: UC-MSM-203-18

UNIT-I

Functional and its properties, Variation of a functional, Motivating problems: Brachistochrone, isoperimetric, Geodesics. Fundamental lemma of calculus of variation, Euler's equation for one dependent function of one and several variables. Generalization to n dependent functions and dependence on several derivatives. Invariance of Euler's equation, Moving end points problem, extremum under constraints.

UNIT-II

Constraints, Generalized coordinates, Generalized velocity, Generalized force, Generalized potential, D'Alembert principle, Lagrange's equation of first kind and second kind, uniqueness of solution, Energy equation for conservative field. Examples based on solving Lagrange's equation.

UNIT-III

Legendre transformation, Hamilton canonical equation, cyclic coordinates, Routhian procedure, Poisson bracket, Poisson's identity, Jacobi-Poisson theorem, Hamilton's principle, Principle of Least action, Small oscillations of conservative system, Lagrange's equation for small oscillations, Nature of roots of frequency equation, Principle oscillations. Normal coordinates.

UNIT-IV

Canonical transformations, Hamilton-Jacobi equation. Method of Separation of variables, Lagrange's bracket, Hamilton's equations in Poisson bracket, Canonical character of transformation through Poisson bracket. Invariance of Lagrange's bracket and Poisson's bracket. Action-Angle Variables.

RECOMMENDED BOOKS:

1. Elsegolc, L.D., *Calculus of Variation*, Dover Publication, 2007.
2. Gantmacher, F., *Lectures in Analytic Mechanics,* Moscow: Mir Publisher, 1975.
3. Goldstien, H., Poole, C. and Safco, J.L., *Classical Mechanics, 3rd Edition*. Addison Wesely, 2002.
4. Landau, L.D. and Lipshitz, E.M., *Mechanics*, Oxford: Pergamon Press, 1976.
5. Marsden, J.E., *Lectures on Mechanics*, Cambridge University Press, 1992.
6. Biswas, S. N., *Classical Mechanics,* Books and Applied (P) Ltd., 1999.

UC-MSM-204-18	**Partial Differential Equations**	**L-4, T-1, P-0**	**4 Credits**

Pre-requisite: Calculus of several variables and ODE

Course Objectives: The Objective of this course is to introduce first and higher order partial differential equations and their classification. This course explains various analytic methods for computing the solutions of various partial differential equations. It also explains various applications of partial differential equations in real physical phenomenon like wave equation of string, diffusion equations and heat flow equation to students.

Course Outcomes: At the end of the course, the students will be able to

CO1	Understand partial differential equations of first order (linear and nonlinear), second and higher order.
CO2	Apply various analytic methods for computing solutions of various PDEs.
CO3	Determine integral surfaces passing through a curve, characteristic curves of second order PDE and compatible systems.
CO4	Understand the formation and solution of some significant PDEs like wave equation, heat equation and diffusion equation.
CO5	Apply the knowledge of PDEs and their solutions in order to understand physical phenomena.

Mapping of course outcomes with the program outcomes

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10
CO1	√	-	√	√	√	-	-	-	√	√
CO2	√	-	√	√	√	-	-	-	√	√
CO3	√	-	√	√	√	-	-	-	√	√
CO4	√	-	√	√	√	-	-	-	√	√
CO5	√	-	√	√	√	-	-	-	√	√

Course Title: Partial Differential Equations

Course Code: UC-MSM-204-18

UNIT-I

First Order PDE: Partial differential equations; its order and degree; origin of first-order PDE; determination of integral surfaces of linear first order partial differential equations passing through a given curve; surfaces orthogonal to given system of surfaces; non-linear PDE of first order, Cauchy's method of characteristic; compatible system of first order PDE; Charpit's method of solution, solutions satisfying given conditions, Jacobi's method of solution.

UNIT-II

Second and Higher Order PDE: Origin of second order PDE; linear second and higher order PDE with constant and variable coefficients; characteristic curves of the second order PDE; Monge's method of solution of non-linear PDE of second order.

UNIT-III

Separation of Variable Method: Separation of variables for PDE; wave, diffusion and Laplace equations and their solutions by Separation of variables method; Elementary solutions of Laplace equations.

UNIT-IV

Applications of PDE: Vibrations governed by one and two-dimensional wave equations; vibrations of string and membranes; three dimensional problems; diffusion equation; resolution of boundary value problems for diffusion equations and elementary solutions of diffusion equations.

RECOMMENDED BOOKS:

1. Sneddon, I.N., *Elements of Partial Differential Equation, 3rd Edition.* McGraw Hill Book Company, 1998.
2. Copson, E.T., *Partial Differential Equations, 2nd Edition.* Cambridge University Press, 1995.
3. Strauss, W.A., *Partial Differential Equations: An Introduction, 2nd Edition*. 2007.
4. Sharma, J.N. and Singh, K., *Partial differential equations for engineers and scientists, 2nd Edition*. New Delhi: Narosa Publication House, 2009.

UC-MSM-205-18	**Numerical Analysis**	**L-4, T-1, P-0**	**4 Credits**

Pre-requisite: Basic Calculus, analysis and linear algebra

Course Objectives: This course is designed to introduce the basic concepts of Numerical Mathematics in order to solve the problems arising in various fields of application, for example in science, engineering and economics etc. that do not possess analytical solutions or difficult to deal with analytically. This course addresses development, analysis and application of different numerical methods to solve the problems, viz. system of linear & nonlinear equations, numerical initial and boundary value problems of ordinary differential equations etc.

Course Outcomes: At the end of the course, the students will be able to

CO1	Identity and analyze different types of errors encountered in numerical computing.
CO2	Apply the knowledge of Numerical Mathematics to solve problems efficiently arising in science, engineering and economics etc.
CO3	Utilize the tools of the Numerical Mathematics in order to formulate the real-world problems from the view point of numerical mathematics.
CO4	Design, analyze and implement of numerical methods for solving different types of problems, viz. initial and boundary value problems of ordinary differential equations etc.
CO5	Create, select and apply appropriate numerical techniques with the understanding of their limitations so that any possible modification in these techniques could be carried out in further research.
CO6	Identify the challenging problems in continuous mathematics (which are difficult to deal with analytically) and find their appropriate solutions accurately and efficiently.

Mapping of course outcomes with the program outcomes

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10
CO1	-	-	-	√	-	-	-	-	√	√
CO2	√	-	-	-	-	-	-	-	√	√
CO3	√	-	-	-	-	-	-	-	√	√
CO4	√	-	-	-	-	-	-	-	√	√
CO5	√	√	-	-	-	√	-	-	√	√
CO6	-	-	-	√	-	-	-	-	√	√

Course Title: Numerical Analysis
Course Code: UC-MSM-205-18

UNIT-I

Numerical computation and Error analysis: Numbers and their accuracy, Floating point arithmetic, Errors in numbers, Error estimation, General error formulae, Error propagation in computation. Inverse problem of error analysis and Numerical instability. Algebraic and transcendental equations: Bisection method, Iteration method, Regula-Falsi method, Secant method, Newton-Raphson's method. Convergence of these methods. Lin-Bairstow's method, Muller's method, Graeffe's root squaring method, Solution of system of nonlinear equations, Complex roots by Newton-Raphson's method.

UNIT-II

System of linear algebraic equations: Gauss elimination method without pivoting and with pivoting, Gauss-Jordon method, LU-factorization method, Jacobi and Gauss-Seidal methods, Convergence of iteration methods, Round-off errors and refinement, ill-conditioning, Partitioning method, Inverse of matrices. Eigen values and eigen vectors: Rayleigh Power method, Given's method and Householder's method.

UNIT-III

Interpolation: Finite differences, Newton's interpolation formulae, Gauss, Stirling's and Bessel's formulae, Lagrange's, Hermite's and Newton's divided difference formulae. Numerical differentiation and integration: differentiation at tabulated and non-tabulated points, Maximum and minimum values of tabulated function, Newton-Cotes Formulae-Trapezoidal, Simpson's, Boole's and Weddle' rules of integration with errors, Romberg integration, Gaussian integration, Double integration by Trapezoidal and Simpson's rules.

UNIT-IV

Ordinary differential equations: Taylor series and Picard's methods, Euler's and modified Euler methods, Runge-Kutta methods, Predictor-Corrector methods: Adams-Bashforth's and Milne's methods. Error analysis and accuracy of these methods. Solution of simultaneous and higher order equations, Boundary value problems: Finite difference and Shooting methods.

RECOMMENDED BOOKS:

1. Sharma, J.N., *Numerical Methods for Engineers and Scientists, 2nd Edition*. Narosa Publ. House New Delhi/Alpha Science International Ltd., Oxford UK, 2007, Reprint 2010.
2. Jain, M.K., Iyengar, S.R.K. and Jain, R.K., *Numerical Methods for Scientific and Engineering Computation, 5th Edition. New Age International Publ.* New Delhi, 2010
3. Bradie, B., *A Friendly Introduction to Numerical Analysis*. Pearson Prentice Hall, 2006.
4. Atkinson, K.E., *Introduction to Numerical Analysis, 2nd Edition*. John Wiley, 1989.
5. Scarborough, J.B., *Numerical Mathematical Analysis.* Oxford & IBH Publishing Co., 2001.

UC-MSM-206-18	Numerical Analysis (Lab)	L-0, T-0, P-3	3 Credits

Pre-requisite: Basic knowledge of Computer programming and Computer Algebra System (CAS): MATLAB or MATHEMATICA

Course Objectives: This course is designed to provide understanding of implementation of basic numerical methods for solving different problems viz. nonlinear equations, system of linear equations, interpolation and extrapolation, numerical differentiation and integration, numerical initial and boundary value problems of ordinary differential equations etc. Further, this course will develop programming skills in the students in order to write and implement their own computer programs for solving problems arising in science, engineering and economics.

Course Outcomes: At the end of the course, the students will be able to

CO1	Apply their knowledge of computer programming to develop and implement their own computer codes of numerical methods for solving different types of complex problems viz. nonlinear equations, system of linear equations, interpolation and extrapolation, numerical differentiation and integration, numerical initial and boundary value problems of ordinary differential equations etc.
CO2	Understand different implementation modes of a numerical method in order to solve a given problem efficiently.
CO3	Analyze and modify computer codes available in the scientific literature.
CO4	Utilize the symbolic tools of Computer Algebra System (CAS) for example MATLAB, MATHEMATICA and MAPLE independently and in their computer codes for solving a given problem.
CO5	Develop, select and apply numerical methods as a computer code with the understanding of their limitations so that they can be implemented in order to get acceptable results.
CO6	Identify the challenging problems in continuous mathematics (which are difficult to deal with analytically) and find their appropriate solutions accurately and efficiently using computer codes.

Mapping of course outcomes with the program outcomes

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10
CO1	√	-	-	-	-	-	-	-	√	√
CO2	-	√	-	-	-	-	-	-	√	√
CO3	√	√	-	-	-	-	-	-	√	√

CO4	√	-	-	-	-	-	-	-	√	√
CO5	√	√	-	-	-	-	-	-	√	√
CO6	-	-	-	√	-	-	-	-	√	√

Course Title: Numerical Analysis (LAB)

Course Code: UC-MSM-206-18

The following programs of following methods are to be practiced:

1. To find a real root of an algebraic/ transcendental equation by using Bisection method.
2. To find a real root of an algebraic/ transcendental equation by using Regula-Falsi method.
3. To find a real root of an algebraic/ transcendental equation by using Newton-Raphson method.
4. To find a real root of an algebraic/ transcendental equation by using Iteration method.
5. Implementation of Gauss- Elimination method to solve a system of linear algebraic equations.
6. Implementation of Jacobi's method to solve a system of linear algebraic equations.
7. Implementation of Gauss-Seidel method to solve a system of linear algebraic equations.
8. To find differential coefficients of 1st and 2nd orders using interpolation formulae.
9. To evaluate definite integrals by using Newton - Cotes integral formulae.
10. To evaluate definite integrals by using Gaussian Quadrature.
11. To evaluate double integrals by using Trapezoidal and Simpson method.
12. To compute the solution of ordinary differential equations with Taylor's series method.
13. To compute the solution of ordinary differential equations by using Euler's method.
14. To compute the solution of ordinary differential equations by using Runge -Kutta methods.
15. To compute the solution of ordinary differential equations by using Milne-Simpson method.
16. To compute the solution of Boundary value problems of Ordinary Differential Equations by using Finite Difference method.
17. To compute the solution of Boundary value problems of Ordinary Differential Equations by using Shooting method.

RECOMMENDED BOOKS:

1. Fausett, L.V., *Applied Numerical Analysis using MATLAB, 2nd Edition.* Pearson Prentice Hall, 2007.
2. Mathews, J.H. and Fink, K.D., *Numerical Methods using MATLAB, 4th Edition.* Pearson Prentice Hall, 2004.
3. Balagurusamy, E., Object Oriented Programming with C++. New Delhi: Tata McGraw Hill, 1999.
4. Conte, S.D. and Boor, C.D., *Numerical Analysis*. New York: McGraw Hill, 1990.

SEMESTER-III

UC-MSM-301-18	**Topology**	**L-4, T-1, P-0**	**4 Credits**

Pre-requisite: Real Analysis-I

Course Objectives: The objective of the course on **Topology** is to provide the knowledge of Topological Spaces and their importance. To acquaint students with the concept of Homeomorphism and the topological properties and important mathematical concepts which can be generalized in topological spaces, so that students may learn and appreciate the nature of abstract Mathematics.

Course Outcomes: At the end of the course, the 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 Bases and Subbases, create new topological spaces by using subspace.
CO3	Understand continuity, compactness, connectedness, homeomorphism and topological properties.
CO4	Understand how points of space are separated by open sets, Housdroff spaces and their importance.
CO5	Understand regular and normal spaces and some important theorems in these spaces.

Mapping of course outcomes with the program outcomes

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10
CO1	√	√	-	√	√	-	-	-	√	√
CO2	√	√	√	√	√	-	-	-	√	√
CO3	√	√	-	√	√	-	-	-	√	√
CO4	√	√	-	√	√	-	-	-	√	√
CO5	√	√	-	√	√	-	-	-	√	√

Course Title: Topology

Course Code: UC-MSM-301-18

UNIT-I

Introduction topological spaces, closed sets, Closure, Dense subsets, neighborhoods, interior, exterior and boundary, Accumulation points and derived sets.
Bases and subbases, Subspaces and relative Topology, Alternative methods of defining a Topology in terms of Kuratowski closure operator and neighborhood systems.

UNIT-II

Open mappings and closed mappings, Continues functions and homomorphism's, Compactness and local Compactness. One-point compactification, connected and arc-wise connected spaces, Components and Locally connected spaces.

UNIT-III

T0 and T1 spaces, T2 spaces and sequences. Hausdorffness of one-point compactification, Axioms of Countability and Seperability, Equivalence of Separable, second Axiom and Lindel of properties in a metricspaces. Equivalence of compact and countably compact sets in metric spaces.

UNIT-IV

Regular and completely regular, Normal and completely normal spaces. Metric spaces as T2, completely normal and first axiom spaces, Urysohn's Lemma, Tietze Extension Theorem.

BOOKS RECOMMENDED

1. Munkres, J. R., *Topology, a first course,* Prentice-Hall of India Ltd., New Delhi, 2000.
2. Joshi, K. D., *An introduction to general topology, 2nd edition,* Wiley Eastern Ltd., New Delhi, 2002.
3. Simmons, G.F., *Introduction to topology and Modern Analysis*, McGraw Hill Publications, 2017.
4. Kelley, J. L., *General Topology*, Springer Verlag, New York, 1990.
5. Armstrong, M.A., *Basic Topology,* Springer International Ed., 2005.

UC-MSM-302-18	**Number Theory and Cryptography**	**L-4, T-1, P-0**	**4 Credits**

Pre-requisite: Congruences, Number System

Course Objectives: This course is designed to provide students an introduction to classical number theory and enable them to study higher courses in number theory, and to apply the learnt concepts of number theory using public-key cryptography.

Course Outcomes: At the end of the course, the students will be able to

CO1	Apply the knowledge of Number theory and Cryptography to attain a good mathematical maturity and enables to build mathematical thinking and skill.
CO2	Utilize the congruences, Chinese remainder theorem, indices, residue classes, Legendre symbols to solve different related problems.
CO3	Identify and analyze different types of divisibility tests, Euler's theorem, Wilson theorem, Mobius inversion formula to formulate and solve various related problems.
CO4	Design, analyze and implement the concepts of Diophantine equations for solving different types of problems, for example, sum of two and four squares.
CO5	Create, select and apply appropriate number theoretic techniques such as primes, greatest integer functions in Cryptography to use in real life problems.
CO6	Identify the challenging problems in modern mathematics and find their appropriate solutions.

Mapping of course outcomes with the program outcomes

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10
CO1	√	√	-	√	√	-	-	-	√	√
CO2	√	√	-	√	√	-	-	-	√	√
CO3	√	√	√	√	√	-	-	-	√	√
CO4	√	√	-	√	√	-	-	-	√	√
CO5	√	√	-	√	√	-	-	-	√	√
CO6	√	-	√	√	-	-	-	-	√	√

Course Title: Number Theory and Cryptography
Course Code: UC-MSM-302-18

UNIT-I

Divisibility, Greatest common divisor, Euclidean Algorithm, Least Common Multiplier, divisibility of product of r consecutive integers, The Fundamental Theorem of arithmetic, congruences and its properties, Special divisibility tests, Solvability of linear diophantine equations ($ax + by = c$) and congruence equations ($an \equiv b(mod\ c)$), Chinese remainder theorem.

UNIT-II

Arithmetic functions $\phi(n)$, d(n), $\sigma(n)$, $\mu(n)$, Multiplicative functions, Mobius inversion Formula, Complete residue system, Fermat's little theorem, Wilson's theorem, Euler's theorem, Power residue, order of $a(mod\ m)$, Primitive root, Reduced residue system, Euler's solvability criterion, Lagrange's theorem for the number of incongruent solutions of a polynomial.

UNIT-III

Indices and its properties, The greatest integer function, Legendre's formula, Quadratic residues, Legendre symbol, Gauss's Lemma, Quadratic reciprocity law, perfect numbers, Mersenne primes and Fermat prime numbers. [Ref. 2]

UNIT-IV

Cryptography: some simple cryptosystems, need of the cryptosystems, the idea of public key cryptography, RSA cryptosystem. [Ref. 4]

RECOMMENDED BOOKS:

1. Burton, D.M., *Elementary Number Theory, 7th Edition*. McGraw-Hill Education, 2010.
2. Hardy, G.H. and Wright, E.M., *An introduction to the Theory of Numbers, 4th Edition*. Oxford University Press, 1975.
3. Niven, I., Zuckerman, H.S. and Montgomery, H.L., *Introduction to Theory of Numbers, 5th Edition*. John Wiley & Sons, 1991.
4. Koblitz N., *A Course in Number Theory and Cryptography, Graduate Texts in Mathematics, No.114*. New-York: Springer-Verlag, 1987.
5. Stallings, W., *Cryptography and Network Security, 5th Edition.* Pearson, 2010.

UC-MSM-303-18	Mathematical Statistics	L-4, T-1, P-0	4 Credits

Pre-requisite: Basic Statistics and Calculus of several variables

Course Objectives: The aim of the course is to enable the students with understanding of various types of probability distributions and testing of hypothesis problems. It aims to equip the students with standard concepts of statistical techniques and their utilization.

Course Outcomes: At the end of the course, the students will be able to

CO1	Understand and utilize the concept of probability.
CO2	Explain the concept of random variable and its applications.
CO3	Explore the different types of discrete and continuous distributions and their utilization.
CO4	Deal with formulation of hypotheses as per situations and their testing.
CO5	Apply the knowledge of statistical techniques in various experimental and industrial requirements.

Mapping of course outcomes with the program outcomes

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10
CO1	√	-	√	√	√	-	-	-	√	√
CO2	√	-	√	√	√	-	-	-	√	√
CO3	√	-	√	√	√	-	-	-	√	√
CO4	√	-	√	√	√	-	-	-	√	√
CO5	√	-	√	√	√	-	-	-	√	√

Course Title: Mathematical Statistics

Course Code: UC-MSM-303-18

Unit I

Classical and axiomatic approach to the theory of probability, additive and multiplicative law of probability, conditional probability and Bayes theorem.Random variable, function of random variable, and their distributions, probability mass function, probability density function, cumulative distribution function.

Unit II

Two dimensional random variables, joint, marginal and conditional distributions, independence of random variables, expectation, conditional expectation, moments, product moments, probability generating functions, moment generating function and its properties. Chebyshev's, Markov, Jenson, Techebyshey's, inequalities, stochastic convergence, central limit theorem. characteristic function and its elementary properties.

Unit III

Study of various discrete and continuous distributions, Binomial, Poisson, Geometric, Hyper geometric, Multinomial. Uniform, Exponential, Normal distributions, Gamma distribution, Cauchy, exponential, Beta and gamma distributions, Bivariate normal distribution and distribution of order statistics and range.

Unit IV

Concept of sampling distribution and its standard error, Derivation of sampling distributions of χ^2, t and F distribution of sample mean and sample variance Testing of hypotheses, fundamental notions important tests based on normal distributions, Tests of significance: tests based on normal distribution, χ^2, t and F statistic. Analysis of variance: One way and two-way classifications.

BOOKS RECOMMENDED:

1. Hogg R. V., McKean J. W. and Craig A. T., *Introduction to Mathematical Statistics*, Pearson, 2005, Sixth Edition.
2. Gupta S. C. and Kapoor V. K., *Fundamentals of Mathematical Statistics, 11th Edition.* Sultan Chand & Sons, 2014.
3. Fisz M., *Probability Theory and Mathematical Statistics*, *3rd Edition.* John Wiley & Sons, 1967.
4. Gun A.M., Gupta, M.K. and Dasgupta B., *Fundamentals of Statistics (Vol-I)*, World Press, 2013.
5. Feller W., *An Introduction to Probability Theory and Its Applications (Vol-I), 3rd Edition.* John Wiley & Sons, 2003.

UC-MSM-304-18	Functional Analysis	L-4, T-1, P-0	4 Credits

Pre-requisite: Real analysis and Linear Algebra

Course Objectives: This course will develop a deeper and rigorous understanding of fundamental concepts of functional analysis, their properties and related theorems.

Course Outcomes: At the end of the course, the students will be able to

CO1	Explain the fundamental concepts of functional analysis and their role in modern mathematics.
CO2	Utilize the concepts of functional analysis, for example continuous and bounded operators, normed spaces, Hilbert spaces and to study the behavior of different mathematical expressions arising in science and engineering.
CO3	Understand and apply fundamental theorems from the theory of normed and Banach spaces including the Hahn-Banach theorem, the open mapping theorem, the closed graph theorem and uniform boundedness theorem.
CO4	Understand the nature of abstract mathematics and explore the concepts in further details.
CO5	Explain the concept of projection on Hilbert and Banach spaces.

Mapping of course outcomes with the program outcomes

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10
CO1	√	√	-	√	√	-	-	-	√	√
CO2	√	√	√	√	√	-	-	-	√	√
CO3	√	√	√	√	√	-	-	-	√	√
CO4	√	√	-	√	√	-	-	-	√	√
CO5	√	√	-	√	√	-	-	-	√	√

Course Title: Functional Analysis

Course Code: UC-MSM-304-18

UNIT-I

Normed Spaces with examples $l^p, l^\infty, C[a,b]$ etc, Banach Spaces, Incomplete normed spaces, Finite Dimensional Normed Spaces and Subspaces, Equivalent norms, Compactness of Metric/ Normed spaces, Riesz's Lemma for two subspaces of a Normed space.

UNIT-II

Linear Operators- definition and examples, Range and Null space, Inverse Operator, Bounded and Continuous linear operators in a Normed Space, Bounded Linear Functionals in a Normed space with examples, Concept of Reflexive space, Dual basis, Dual spaces with examples.

UNIT-III

Inner Product and Hilbert space, Further properties of Inner product spaces, Projection Theorem, Orthonormal Sets, Representation of functionals on a Hilbert Spaces (Riesz's Lemma and Representation), Hilbert Adjoint Operator, Self-adjoint, Unitary & Normal Operators.

UNIT-IV

Fundamental Theorems for Normed & Banach Spaces: Partially Ordered Set and Zorn's Lemma, Hahn Banach Theorem for Real Vector Spaces, Hahn Banach Theorem for Complex Vector Spaces and Normed Spaces, Uniform Boundedness Theorems (Banach-Steinhaus Theorem), Open Mapping Theorem, Closed Graph Theorem.

RECOMMENDED BOOKS:

1. Kreyzig, E., *Introductory Functional Analysis with Applications*. New York: John Willey and Sons, 1989.
2. Limaye, B. V., *Functional Analysis.* New Delhi: New Age International (P) Ltd, 1996.
3. Simmons, G. F., *Introduction to topology and modern analysis.* New Delhi: Tata McGraw-Hill Education Private Limited, 2012.
4. Nair, M. T., *Functional Analysis-A First Course*. New Delhi: Prentice- Hall of India Private Limited, 2008.
5. Rudin, W., *Functional Analysis*, Tata-McGraw Hill Pub. Co.

UC-MSM-305-18	Mechanics-II	L-4, T-1, P-0	4 Credits

Pre-requisites: Linear Algebra, Vector Calculus and Basic Mechanics

Course Objectives: The objective of the course on Mechanics-II is to equip the students with the knowledge of Tensors and their applications. To make students understand the notion of continuum and the basic concepts of strain, stretch and rotation and the applications of tensors in understanding these concepts. One of the objectives is to make students understand the applications of Mathematical concepts in real world problems related to Mechanics.

Course Outcomes: At the end of the course, the students will be able to

CO1	Understand the concept of Tensor and their properties.
CO2	Understand the effect of co-ordinate transformations and visualize the tensor as a linear transformation.
CO3	Understand the conventions like summation convention and comma notations. Also, students shall learn the concepts of tensor calculus.
CO4	Understand continuum hypothesis, spatial an material co-ordinates and their applications.
CO5	Understand the concepts of strain, stretch, rotation and shall be able to apply the knowledge in solving real world problems related to continuum mechanics.

Mapping of course outcomes with the program outcomes

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10
CO1	√	-	√	√	√	-	-	-	√	√
CO2	√	-	√	√	√	-	-	-	√	√
CO3	√	-	√	√	√	-	-	-	√	√
CO4	√	-	√	√	√	-	-	-	√	√
CO5	√	-	√	√	√	-	-	-	√	√

Course Title: Mechanics-II

Course Code: UC-MSM-305-18

Unit I

Tensors: Introduction, Range and Summation Conventions, Free and dummy suffixes, results in vector algebra and matrix, the symbol δ_{ij} & ε_{ijk} , Coordinate transformations, cartesian tensors, Properties of tensors, Isotropic tensors, Isotropic tensor of order four, Tensors as linear operators, Transpose of a tensor.

Unit II

Tensor Continued: Symmetric and skew tensors, Dual vector of a skew tensor, Invariants of a tensor, Deviatoric tensors, Eigenvalues and eigenvectors, Polar decomposition

Unit III

Scalar, vector and tensor functions, Comma notation, Gradient of a scalar, divergence and curl of a vector, Gradient of a vector, divergence and curl of a tensor, Integral theorems for vectors and tensors.

Unit IV

Continuum Hypothesis: Notation of a continuum, Configuration of a continuum, Mass and density, Descriptions of motion, Deformation: Material and special coordinates, Deformation gradient tensor, Stretch and rotation, Strain tensors, Strain-displacement relations, Infinitesimal strain tensor, Infinitesimal stretch and rotation, Compatibility conditions., Principal strains, Strain-deviator.

BOOKS RECOMMENDED:

1. Jog, C.S., *Foundations and Applications of Mechanics: Volume-I Continuum Mechanics.* Narosa Publishing House, New delhi.
2. Chandrasekharaiah, D.S. and Lokenath, D., *Continuum Mechanics,* Academic Press, London (Prism Books Pvt. Ltd., Bangalore-India).

SEMESTER-IV

UC-MSM-401-18	**Differential Geometry**	**L-4, T-1, P-0**	**4 Credits**
Pre-requisite: Basic calculus and vector calculus			
Course Objectives: The objective of this course is to make students familiar with basic concepts of differential geometry so as to deal with geometry of curves and spaces using the methods of differential calculus.			
Course Outcomes: At the end of the course, the studentts will be able to			
CO1	Understand the basic concepts and results related to space curves, tangents, normals and surfaces.		
CO2	Explain the geometry of different types of curves and spaces.		
CO3	Explain the physical properties of different curves and spaces.		
CO4	Understand principal directions and curvatures, asymptotic lines and then apply their important theorems and results to study various properties of curves and surfaces.		
CO5	Utilize Geodesics, it's all related terms, properties and theorems.		

Mapping of course outcomes with the program outcomes

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10
CO1	√	√	-	√	√	-	-	-	√	√
CO2	√	√	√	√	-	-	-	-	√	√
CO3	√	-	√	√	√	-	√	-	√	√
CO4	√	√	√	√	√	-	√	-	√	√
CO5	√	√	√	√	√	-	√	-	√	√

Course Title: Differential Geometry

Course Code: UC-MSM-401-18

Unit I

Theory of Space Curves: Tangent, principal normal, bi-normal, curvature and torsion. Serretfrenet formulae, Contact between curves and surfaces. Locus of centre of curvature, spherical curvature, Helices.

Unit II

Spherical indicatrix, Bertrand curves, surfaces, envelopes, edge of regression, developable surfaces, two fundamental forms.

Unit III

Curves on a surface, Conjugate Direction, Principle Directions, Lines of Curvature, Principal Curvatures, Asymptotic Lines. Theorem of Beltrami and Enneper, Mainardi- Codazzi equations.

Unit IV

Geodesics, Differential Equation of Geodesic, torsion of Geodesic, Geodesic Curvature, Clairaut's theorem, Gauss- Bonnet theorem, Joachimsthal's theorem, Geodesic Mapping, Tissot's theorem.

BOOKS RECOMMENDED:

1. Weatherburn, C.E., *Differential Geometry of Three Dimensions*, Cambridge University Press, 2016.
2. Willmore, T.J., *Introduction to Differential Geometry*, Dover Publications Inc., United States, 2012.
3. Bansi Lal, *Differential Geometry, 4th Edition.* Atma Ram & Sons, India, 1976.

ELECTIVE SUBJECTS

UC-MSM-501-18	**Discrete Mathematics**	**L-4, T-1, P-0**	**4 Credits**

Pre-requisite: Set Theory, Relations, functions.

Course Objectives: Prepare students to develop mathematical foundations to understand and create mathematical arguments require in learning many mathematics and computer sciences courses. To motivate students how to solve practical problems using discrete mathematics. Also, in this course basic concepts of Graph theory such as Trees, Eulerian Graphs, Matching, Vertex colourings, Edge colourings, Planarity, are introduced.

Course Outcomes: At the end of the course, the students will be able to

CO1	construct mathematical arguments using logical connectives and quantifiers.
CO2	understand how lattices and Boolean algebra are used as tools and mathematical models in the study of networks.
CO3	validate the correctness of an argument using statement and predicate calculus.
CO4	learn how to work with some of the discrete structures which include sets, relations, functions, graphs and recurrence relation.
CO5	understand the concepts Planarity including Euler identity.
CO6	discuss and understand the importance of the concepts Matching's and Colourings'.

Mapping of course outcomes with the program outcomes

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10
CO1	✓	✓	✓	✓	✓	-	-	-	✓	✓
CO2	✓	✓	✓	✓	✓	-	-	-	✓	✓
CO3	✓	✓	✓	✓	✓	-	-	-	✓	✓
CO4	✓	✓	✓	✓	✓	-	-	-	✓	✓
CO5	✓	✓	✓	✓	✓	-	-	-	✓	✓
CO6	✓	✓	✓	✓	✓	-	-	-	✓	✓

Course Title: Discrete Mathematics
Course Code: UC-MSM-501-18

Unit-I

Mathematical Logic: Basic logical operations, conditional and bi-conditional statements, tautologies, contradiction, predicate calculus.

Recursion and Recurrence Relations: Polynomial expressions, telescopic form, recursion theorem, closed form expression, generating function, solution of recurrence relation using generating function, recursion.

Unit-II

Lattices and Boolean Algebra: Introduction to Binary relations, equivalence relations and partitions, Partial order relations, Hasse diagram. Lattices as partially ordered sets, properties, lattices as algebraic systems, sub lattices. Boolean algebra as lattices, Boolean identities, sub-algebra, Boolean forms and their equivalence, Applications of Boolean algebra to circuit theory.

Unit-III

Graph Theory: Directed graphs, undirected graphs, paths, circuits, cycles, sub-graphs, induced Sub graphs, degree of vertex, connectivity, planner graph, complete, Eulerian paths and circuits, Trees and Coloring of the graph, Rooted tree, spanning trees, minimal spanning trees, Kruskal's algorithm. Chromatic number, four-color problem (statement only).

Unit-IV

Algebraic Structures: Review of groups, codes and group codes, encoders and decoders, hamming matrices, parity checks, decoding and error correction.

BOOKS RECOMMENDED:

1. Tremblay, J.P. and Manohar, R.P., *Discrete Mathematics with Applications to Computer Science*, Tata McGraw Hill, 2008.
2. Ram, Babu, *Discrete Mathematics*, Pearson Education, 2007.
3. Harary, F., *Graph Theory*, Narosa, 1995
4. Anami, B.S and Madalli, V.S., *Discrete Mathematics*, University Press, 2016.
5. Liu, C.L, *Elements of Discrete Mathematics*, 3rd Edition, Tata McGraw Hill, 2008.
6. Grimaldi, R.P and Ramana, B.V., *Discrete and Combinatorial Mathematics-An Applied Introduction*, Pearson education, 5th Edition, 2004..

UC-MSM-502-18	**Coding Theory**	**L-4, T-1, P-0**	**4 Credits**
Pre-requisite: Linear Algebra, Probability theory			

Course Objectives: Coding Theory helps to detects errors in Transmission of messages. In this course we introduce the basic concepts of Coding Theory such as, Double Error-Correcting B.C.H. code, Cyclic codes, The Group of a code, Quadratic residue codes and Bose-Chaudhuri- Hocquenghem codes.

Course Outcomes: At the end of the course, the students will be able to

CO1	understand the concept of Maximum-Likelihood Decoding and Syndrome Decoding.
CO2	analyze Double Error-Correcting B.C.H. code and Finite Fields Polynomials.
CO3	understand Cyclic Codes.
CO4	study the concept of Bose-Chaudhuri-Hocquenghem (*B.C.H.*) Codes and Weight Distributions.
CO5	learn about basic techniques of algebraic coding theory like matrix encoding, polynomial encoding, and decoding by coset leaders etc.
CO6	learn how algebraic coding theory is applicable in real world problems.

Mapping of course outcomes with the program outcomes

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10
CO1	✓	✓	✓	✓	✓	-	-	-	✓	✓
CO2	✓	✓	✓	✓	✓	-	-	-	✓	✓
CO3	✓	✓	✓	✓	✓	-	-	-	✓	✓
CO4	✓	✓	✓	✓	✓	-	-	-	✓	✓
CO5	✓	✓	✓	✓	✓	-	-	-	✓	✓
CO6	✓	✓	✓	✓	✓		-	-	✓	✓

Course Title: Coding Theory

Course Code: UC-MSM-502-18

Unit-I

Introduction to Coding Theory: Code words, distance and weight function, Nearest-neighbour decoding principle, Error detection and correction, Matrix encoding techniques, Matrix codes, Group codes, decoding by coset leaders, Generator and parity check matrices, Syndrome decoding procedure, Dual codes.

Unit-II

Linear Codes: Linear codes, Matrix description of linear codes, Equivalence of linear codes, Minimum distance of linear codes, Dual code of a linear code, Weight distribution of the dual code of a binary linear code, Hamming codes.

Unit-III

BCH Codes: Polynomial codes, Finite fields, Minimal and primitive polynomials, Bose-Chaudhuri-Hocquenghem codes.

Unit-IV

Cyclic Codes: Cyclic codes, Algebraic description of cyclic codes, Check polynomial, BCH and Hamming codes as cyclic codes. Maximum distance separable codes, Necessary and sufficient conditions for MDS codes, Weight distribution of MDS codes, An existence problem, Reed-Solomon codes.

BOOKS RECOMMENDED

1. Vermani L R, *Elements of Algebraic Coding Theory*, Chapman and Hall, 1996.
2. Vera P.**,** *Introduction to the Theory of Error Correcting Codes*, John Wiley and Sons, 1998.
3. Roman Steven, *Coding and Information Theory*, Springer Verlag, 1992.
4. Garrett Paul, *The Mathematics of Coding Theory*, Pearson Education, 2004.

UC-MSM-503-18	**Operations Research**	**L-4, T-1, P-0**	**4 Credits**
Pre-requisite: Basic Calculus, analysis and linear algebra			
Course Objectives: This course is designed to introduce basic optimization techniques in order to get best results from a set of several possible solutions of different problems viz. linear programming problems, transportation problem, assignment problem and unconstrained and constrained problems etc. The major focus will be on formulation of real world phenomena from its physical considerations and implementation of optimization algorithms for solving these problems.			
Course Outcomes: At the end of the course, the students will be able to			

CO1	Apply the knowledge of basic optimization techniques in order to get best possible results from a set of several possible solution of different problems viz. linear programming problems, transportation problem, assignment problem and unconstrained and constrained problems etc.
CO2	Formulate an optimization problem from its physical consideration.
CO3	Select and implement an appropriate optimization technique keeping in mind its limitations in order to solve a particular optimization problem.
CO4	Understand theoretical foundation and implementation of similar type optimization techniques available in the scientific literature.
CO5	Continue to acquire knowledge and skills of optimization techniques that are appropriate to professional activities
CO6	Extend their knowledge of basic optimization techniques to do interesting research work on these types of optimization techniques.

Mapping of course outcomes with the program outcomes

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10
CO1	✓	-	-	-	-	-	-	-	✓	✓
CO2	-	-	✓	-	-	-	-	-	✓	✓
CO3	✓	✓	-	-	-	-	-	-	✓	✓
CO4	-	✓	-	-	-	-	-	-	✓	✓
CO5	-	-	-	-	-	-	✓	-	✓	✓
CO6	-	-	-	-	✓	-	-	-	✓	✓

Course Title: Operations Research

Course Code: UC-MSM-503-18

UNIT-I

Formulation of linear programming problem (LPP) -graphical method, Basic Feasible Solution, Extreme Points, Convex set, Convex linear combination, optimal solution of LPP using Simplex, Big-M and two-phase methods, Exceptional cases in LPP i.e., Infeasible, unbounded, alternate and degenerate solutions.

UNIT-II

General Primal-Dual pair, Formulating a dual problem, Weak and strong duality theorems, Complementary slackness theorem, Dual simplex method, Economic interpretation of primal-Dual problems. Sensitivity analysis: change in right hand side of constraints, change in the objective function and coefficient matrix addition and deletion of constraint and variables.

UNIT-III

Initial basic Feasible solution of transportation problem, Balanced and unbalanced transportation problems, Optimal solutions of transportation problem using U-V /MODI methods, Assignment problems; Mathematical formulation of assignment problem, typical assignment problem, the traveling salesman problem, Test for optimality, degeneracy, Project management with critical path method.

UNIT-IV

Concept of convexity and concavity, Maxima and minima of convex functions, Single and multivariate unconstrained problems, constrained programming problems, Kuhn-Tucker conditions for constrained programming problems, Quadratic programming, Wolfe's method.

BOOKS RECOMMENDED

1. Taha, H.A., *Operations Research-An Introduction*, PHI, 2007.
2. Kanti Swarup, Gupta, P.K. and Man Mohan, *Operations Research*, Sultan Chand & Sons, Ninth Edition, 2002.
3. Hillier, F.S. and Lieberman, G.J., *Operations Research, Second Edition,* Holden-Day Inc, USA, 1974.
4. Bazaraa, M.S., Sherali, H.D., Shetty, C.M., *Nonlinear Programming: Theory and Algorithms,* John Wiley and Sons, 1993.
5. Chandra, S., Jayadeva, and Mehra, A., *Numerical Optimization and Applications,* Narosa Publishing House, 2013.

UC-MSM-504-18	**Advanced Number Theory**	**L-4, T-1, P-0**	**4 Credits**

Pre-requisite: Elementary Number Theory

Course Objectives: This Course helps the students to understand the concept of Partitions and Compositions. In this course we introduce the concepts of various identities like Jacobi's triple product identity, Gollnitz-Gordon identities, Rogers-Ramanujan type identities for n-colour partitions, and their applications. Also, the weak and strong versions of various important theorems.

Course Outcomes: At the end of the course, the student will be able to

CO1	understand the different types of partitions & compositions.
CO2	students will have a working knowledge of the various types of identities
CO3	work with congruence's, solve congruence equations and systems of equations with one and more variables.
CO4	be literate in the language and notation of number theory.
CO5	understand the concept of for n-colour partitions

Mapping of course outcomes with the program outcomes

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10
CO1	✓	✓	✓	✓	✓	-	-	-	✓	✓
CO2	✓	✓	✓	✓	✓	-	-	-	✓	✓
CO3	✓	✓	✓	✓	✓	-	-	-	✓	✓
CO4	✓	✓	✓	✓	✓	-	-	-	✓	✓
CO5	✓	✓	✓	✓	✓	-	-	-	✓	✓

Course Title: Advanced Number Theory

Course Code: UC-MSM-504-18

UNIT-I

Partitions, Compositions, Ferrers graphs, Jacobi's triple product identity, Congruence properties of $p(n)$, Rogers-Ramanujan identities, Basic hypergeometric series, q-binomial theorem, Sylvester's theorem (Statement only), Heine's transformation (Statement only).

UNIT-II

Restricted partitions, q-Gauss theorem, Gaussian polynomials, Bailey's lemma (weak version) (Statement only), Rogers lemma, q-Saalschutz's theorem (Statement only), Finite version of q-Saalschutz's theorem.

UNIT-III

Schur's theorem, Gollnitz-Gordon identities, Generalization and various analogues of Rogers-Ramanujan identities, Bailey's lemma (strong version) (Statement only), Watson's q-analogue of Whipple's theorem (Statement only) and its applications in deriving Rogers-Ramanujan identities and Gollnitz-Gordon identities.

UNIT-IV

Rank & Crank of a partition, n-colour partitions, Conjugate and self-conjugate n-colour partitions, Restricted n-colour partitions, Rogers-Ramanujan type identities for n-colour partitions.

RECOMMENDED BOOKS:

1. Agarwal, A.K., Padmavathamma and Subbarao, M.V., *Partition Theory,* Atma Ram & Sons, Chandigarh, 2005.
2. Andrews, G.E., *The Theory of Partitions, Encyclopedia of Mathematics and its Applications* (Addison-Wesley), 1976, Re-issued: Cambridge University Press, Cambridge, 1988.
3. Gasper, G. and Rahman, M., *Basic Hypergeometric Series, Encyclopedia of Mathematics and its Applications,* Vol. 35, Cambridge University Press, Cambridge, 1990.
4. Agarwal, R.P., *Resonance of Ramanujan Mathematics*, Vol. 1 (New Age International), 1996.
5. Gupta, H., *Selected Topics in Number Theory*, ABACUS Press, 1980.
6. N.J. Fine, *Basic Hypergeometric Series and Applications*, Mathematical Surveys and Monographs, No. 27, American Mathematical Society, 1988.

UC-MSM-505-18	**Advanced Complex Analysis**	**L-4, T-1, P-0**	**4 Credits**

Pre-requisite: Complex Analysis, Real Analysis

Course Objectives: This course is designed to enable the readers to understand further deeper topics of Complex Analysis and will provide basic topics needed for students to pursue research in pure Mathematics.

Course Outcomes: At the end of the course, the students will be able to

CO1	equip with necessary knowledge and skills to enable them handle mathematical operations, analyses and problem solving involving complex numbers.
CO2	understanding of topological and geometric properties of the complex plane
CO3	analyze how complex numbers provide a satisfying extension of the real numbers
CO4	learn techniques of complex analysis that make practical problems easy (e.g. graphical rotation and scaling as an example of complex multiplication);
CO5	continue to develop proof techniques.

Mapping of course outcomes with the program outcomes

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10
CO1	✓	✓	✓	✓	✓	-	-	-	✓	✓
CO2	✓	✓	✓	✓	✓	-	-	-	✓	✓
CO3	✓	✓	✓	✓	✓	-	-	-	✓	✓
CO4	✓	✓	✓	✓	✓	-	-	-	✓	✓
CO5	✓	✓	✓	✓	✓	-	-	-	✓	✓

Course Title: Advanced Complex Analysis

Course Code: UC-MSM-505-18

Unit-I

Analytic continuation, Analytic continuation by power series method, Natural boundary, Schwarz reflection principle, Analytic continuation along a path, Monodromy theorem, Runge's theorem, simple connectedness, Mittag-Leffler's theorem.

Unit-II

Maximum principle, Schwarz's Lemma, Hadamard's three circle theorem, Phragmen-Lindelof theorem, Weierstrass factorization theorem, Factorization of sine function, Gamma function. Entire functions, Jensen's formula, the genus and order of an entire function, Hadamard factorization theorem.

Unit-III

Harmonic functions, Basic properties, Harmonic functions on a disc, Subharmonic and Superharmonic functions, The Dirichlet problem, Green's function.

Unit-IV

Normal families of analytic functions, Montel's theorem, Hurwitz's theorem, Riemann mapping theorem, Univalent function, Distortion and Growth theorem for the class of normalized univalent functions, Covering theorem, starlike functions, convex functions, Subordination principle.

BOOKS RECOMMENDED

1. Nihari, Z., Conformal Mapping, Conformal Mapping, McGraw-Hill,1952.
2. Conway, J.B., Functions of One Complex Variable, Springer-Verlag,1973
3. Gamelin, T.W., Complex Analysis, Springer, 2004.
4. Tutschke, W. and Vasudeva, H.L., An Introduction to Complex Analysis- Classical and Modern Approaches, Chapman & Hall/CRC, 2005
5. Copson, E.T., An Introduction to Theory of Functions of a Complex Variable.

UC-MSM-506-18	**Advanced Operations Research**	**L-4, T-1, P-0**	**4 Credits**

Pre-requisite: Basic Calculus, analysis, linear algebra and operations research.

Course Objectives: This course is designed to provide a theoretical introduction and implementation of advanced optimization techniques in order to get best results from a set of several possible solutions of different problems viz. advanced linear programming problem, goal programming problem, game theory, dynamic programming and inventory models. The major focus of this course will be on formulation of real-world phenomena from its physical consideration and implementation of optimization techniques for solving these problems.

Course Outcomes: At the end of the course, the student will be able to

CO1	Apply the knowledge of advanced optimization techniques in order to get best possible results from a set of several possible solutions of a given problem.
CO2	Formulate an optimization problem from its physical considerations.
CO3	Select and implement an appropriate optimization technique keeping in mind its limitations in order to solve a particular optimization problem.
CO4	Understand and analyze similar types of other optimization techniques available in the scientific literature.
CO5	Continue to acquire knowledge and skills of optimization techniques that are appropriate to professional activities.
CO6	Extend their knowledge of advanced optimization techniques in order to do interesting research work on these and similar types of optimization techniques.

Mapping of course outcomes with the program outcomes

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10
CO1	✓	-	-	-	-	-	-	-	✓	✓
CO2	-	-	✓	-	-	-	-	-	✓	✓
CO3	✓	✓	-	-	-	-	-	-	✓	✓
CO4	-	✓	-	-	-	-	-	-	✓	✓
CO5	-	-	-	-	-	-	✓	-	✓	✓
CO6	-	-	-	-	✓	-	-	-	✓	✓

Course Title: Advanced Operations Research

Course Code: UC-MSM-506-18

Unit I

Advanced Linear Programming: Revised simplex method, Sensitivity analysis, Parametric programming, Integer programming branch and bond algorithm, Goal programming, Standard form of LGPP, Partitioning algorithm.

Unit II

Game Theory: Two-person zero sum games pure strategies (minmax and maximum principles), Game with saddle point, Mixed strategies: Game without saddle point, Rule of Dominance, Solution methods for games without saddle point: Graphical method, Linear programming method.

Unit III

Dynamic Programming: Characteristics of dynamic programming, Recursive relations, continuous and discrete cases, forward recursion, linear programming versus dynamic programming, Dynamic programming approach for Priority Management employment smoothening, capital budgeting, Stage Coach/Shortest Path, cargo loading and Reliability problems.

Unit IV

Inventory Models: Deterministic models: Classic EOQ (Economic order quantity) models, EOQ with price brakes, Multi item EOQ with storage limitation, Dynamic EOQ models(b) Probabilistic models: Probabilistic EOQ models, Single period models and multiperiod models.

Books Recommended

1. Taha, H.A., *Operations Research- An introduction*, 8th Edition, PHI, 2007.
2. Sharma, J.K, *Operation research: Theory & Applications*, 3rd Edition, Macmillan India, 2007.
3. Kasana, H.S and Kumar K.D, *Introductory Operations Research: Theory & Applications*, Springer, 2005.
4. Pant, J.C, Introduction to Optimization and Operations Research, Jain Brothers, 2004.

UC-MSM-507-18	**Advanced Fluid Mechanics**	**L-4, T-1, P-0**	**4 Credits**
Pre-requisite: Fluid Mechanics and Continuum Mechanics			
Course Objectives: This course is intended to provide a treatment of advanced topics in fluid mechanics where the students will be able to apply the techniques used in deriving arrange of important results and in research problems. The objective is to provide the student with knowledge of the fluid mechanics and an appreciation of their application to real world problems.			
Course Outcomes: At the end of the course, the students will be able to			

CO1	Understand the concept of rotational and irrotational flow, stream functions, velocity potential, sink, source, vortex etc.
CO2	analyze simple fluid flow problems (flow between parallel plates, flow through pipe etc.) with Navier-Stoke's equation of motion.
CO3	understand the phenomenon of flow separation and boundary layer theory
CO4	understand the concept of thermal conductivity.
CO5	learn about the fundamental equations of the flow and energy

Mapping of course outcomes with the program outcomes

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10
CO1	✓	-	✓	✓	✓	-	-	-	✓	✓
CO2	✓	-	✓	✓	✓	-	-	-	✓	✓
CO3	✓	-	✓	✓	✓	-	-	-	✓	✓
CO4	✓	-	✓	✓	✓	-	-	-	✓	✓
CO5	✓	-	✓	✓	✓	-	-	-	✓	✓

Course Title: Advanced Fluid Mechanics

Course Code: UC-MSM-507-18

UNIT-I

Basic Concepts: Continuum Hypothesis, Viscosity, Most general motion of a fluid element, Rate of strain quadric, stress at a point, Tensor character of stress matrix, Symmetry of stress matrix, stress quadric, Stress in a fluid at rest, stress in a fluid in motion, Relation between stress and rate of strain components (Stoke's law of friction), Thermal conductivity, Generalized law of heat conduction, Fundamental equations of the flow of viscous fluids: Equation of state, equation of continuity - Conservation of mass, Equation of motion- Navier-Stoke's equations, Equation of energy- Conservation of energy, Symmetry of fundamental equations, Vorticity and circulation in a viscous incompressible fluid motion, (a) velocity transport equation, Circulation

UNIT-II

Dynamical similarity and Dynamical Analysis: Dynamical similarity, Reynold's law, Inspection analysis, Dimensional analysis, Buckingham π-theorem. Method of finding out the pi-products, Application of pi- theorem to viscous and compressible fluid. Physical importance of non-dimensional parameters. Reynolds number, Eckert Number, Froude Number, Mach Number, Pecklet Number, Grashoff Number, Prandtl Number, Brinkman Number, Nussel Number. Exact Solution of Navier-Stoke's equations of motion- Flow between parallel plates (Velocity and temperature distributions), (i) Plane Couette flows (ii) Plane Poiseulle Flow and (iii) Generalized Couette flow.

UNIT-III

Flow in a circular pipe (Hagen Poiseuille flow) -Velocity and temperature distribution, Flow through tubes of uniform cross section in the form of circle, annulus, ellipse and equilateral triangle under constant pressure gradient. Flow between two concentric rotating cylinders (Couette flow), Flow in convergent and divergent channels,

UNIT-IV

Steady incompressible flow with variable viscosity: Variable viscosity plane Couette flow and plane poiseulle flow. Unsteady incompressible flow with constant fluid properties: Flow due to a plane wall suddenly set in motion, flow due to an oscillating plane wall, starting flow in plane Couette motion, Starting flow in pipes, Plane coquette flow with transpiration cooling.

Books Recommended

1. Bansal, J L, *Viscous Fluid Dynamics*, OXFORD & IBH Publishing Company Pvt. Ltd., New Delhi, 1992.
2. Chorlton, F., *Textbook of Fluid Dynamics*, C.B.S. Publishers, Delhi, 1985.
3. Schlichting, H., *Boundary Layer Theory*, McGraw Hill Book Company, New York, 1979.
4. Young, A. D., *Boundary Layers*, AIAA Education Series, Washington DC, 1989.
5. Yuan, S.W., *Foundations of Fluid Mechanics*, Prentice Hall of India Private Limited, New Delhi, 1976

UC-MSM-508-18	Advanced Solid Mechanics	L-4, T-1, P-0	4 Credits

Pre-requisite: Mechanics-I and Continuum Mechanics

Course Objectives: The primary course objective is to solve advanced solid mechanics problems using classical methods and equip the students with the tools necessary to solve mechanics problems, which involves (a) static analysis of a component to find the internal actions (forces and moments), and determine stresses, strains and deformation due to internal actions.

Course Outcomes: At the end of the course, the students will be able to

CO1	understand the theory of elasticity including strain/displacement and Hooke's law relationships.
CO2	analyze solid mechanics problems using classical methods and energy methods.
CO3	solve for stresses and deflections of beams under unsymmetrical loading.
CO4	obtain stresses and deflections of beams on elastic foundations.
CO5	solve torsion problems in bars and thin walled members.

Mapping of course outcomes with the program outcomes

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10
CO1	✓	-	✓	✓	✓	-	-	-	-	✓
CO2	✓	-	✓	✓	✓	-	-	-	-	✓
CO3	✓	-	✓	✓	✓	-	-	-	-	✓
CO4	✓	-	✓	✓	✓	-	-	-	-	✓
CO5	✓	-	✓	✓	✓	-	-	-	-	✓

Course Title: Advanced Solid Mechanics

Course Code: UC-MSM-508-18

Unit-I

Basics and Extension of Beams: Hooke's law, generalized Hooke's law, Elastic moduli and their relationship, strain-energy density function and its connection with Hooke's law, Saint-Venant's principle. Extension of beams: extension of beams by longitudinal forces, beam stretched by its own weight and bending of beams by terminal couples.

Unit-II

Torsion and flexure of beams: Torsion of a circular shaft, cylindrical bars, and elliptic cylinder. Stress function, conformal mapping, solution of torsion problem by conformal mapping. Flexure of beams by terminal loads, bending of rectangular beams.

Unit-III

Two-and Three-dimensional Problems: Plane deformation, plane stress, plane elastostatic problems, Airy's stress function, solution of the bi-harmonic equation, stress and displacement formulae basic problems of circular region: uniform pressure, uniform radial displacement and concentrated loads. Spherical shell under external and internal pressures.

Unit-IV

Thermoelastic problems and Variational Methods: Thermal stresses in spherical bodies, two-dimensional thermoelastic problems. Variational methods: Theorems of potential energy, minimum complementary energy, work and reciprocity, Ritz method for one- and two-dimensional problems and Galerkin's method. Kantorovich and Trefftz methods. Application of Treffz method.

Books Recommended

1. Sokolnikoff, I.S., *Mathematical Theory of Elasticity*, TMH, New Delhi 1978.
2. Timoshenko.S. and Young D.H., *Elements of strength of materials Vol. I & Vol. II*, T. Van Nostrand Co-Inc Princeton, N.J., 1990.
3. Love, A.E.H, *A Treatise on the Mathematical theory of Elasticity,* Cambridge University Press, 1963.

UC-MSM-509-18	**Theory of Linear Operators**	**L-4, T-1, P-0**	**4 Credits**
Pre-requisite: Real Analysis, Topology, Integral Equations			
Course Objectives: To teach the fundamentals of Banach Algebras and Spectral Operator Theory which are necessary for a deeper understanding of many adjacent mathematical fields (integral and differential equations, mathematical physics, harmonic analysis, operator theory etc.)			
Course Outcomes: At the end of the course, the students will be able to			

CO1	have understanding of main topics of Banach Algebras and Spectral Theory.
CO2	terminology, notation and the basic results and concepts of Banach and Hilbert spaces.
CO3	understand the concept of spectrum and resolvent, adjoint operators, compact operators, self-adjoint and normal operators, Gelfand Representation, Riesz-Fredholm Theory.
CO4	relation of the subject with other branches of mathematics (Fourier analysis, complex functions, differential equations)
CO5	prepare the students for reading the literature of a wide variety of subjects in which Hilbert space ideas are used.

Mapping of course outcomes with the program outcomes

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10
CO1	✓	✓	-	✓	✓	-	-	-	-	✓
CO2	✓	✓	-	✓	✓	-	-	-	-	✓
CO3	✓	✓	-	✓	✓	-	-	-	-	✓
CO4	✓	✓	✓	✓	✓	-	-	-	-	✓
CO5	✓	✓	-	✓	✓	-	-	-	-	✓

Course Title: Theory of Linear Operators

Course Code: UC-MSM-509-18

Unit I

Spectral theory in normed linear spaces, resolvent set and spectrum, spectral properties of bounded linear operators. Properties of resolvent and spectrum. Spectral mapping theorem for polynomials.

Unit II

Elementary theory banach algebra, Spectral radius of a bounded linear operator on a complex banach space.

Unit III

General properties of compact linear operators. Spectral properties of compact linear operators on normed spaces. Behaviors of compact linear operators with respect to solvability of operator equations. Fredholm type theorems. Fredholm alternative theorem. Fredholm alternative for integral equations.

Unit IV

Spectral properties of bounded self-adjoint linear operators on a complex Hilbert space. Positive operators. Monotone Sequences theorem for bounded self-adjoint operators on a complex Hilbert space, Square roots of a positive operator.

Books Recommended

1. Kreyszig E., *Introductory functional analysis with applications,* Johan-Wiley & Sons, New York, 1978.
2. Halmos P.R., *Introduction to Hilbert space and the theory of spectral multiplicity*, 2nd Edition. Chelsea Pub., Co., N.Y. 1957.
3. Dunford N. and Schwartz, J.T., *Linear operators-3 parts,* Inter-science Wiley, New York, 1958-71.
4. Bachman G. and Narici, L., *Functional analysis,* Academic Press, New York, 1998.

UC-MSM-510-18	**Advanced Numerical Methods**	**L-4, T-1, P-0**	**4 Credits**

Pre-requisite: Basic Calculus and analysis. Basic numerical analysis

Course Objectives: This course is designed to provide a theoretical introduction and application of advanced numerical methods for solving different types of problems viz. linear systems, eigenvalues problems, ordinary and partial differential equations arising in various field of applications, for example in science, engineering and economics etc. The major focus will be on development, analysis and implementation of numerical methods keeping in mind advantages & limitations of these methods.

Course Outcomes: At the end of the course, the student will be able to

CO1	Apply the knowledge of advanced numerical methods in order to solve different types of problems viz. linear systems, eigenvalues problems, ordinary and partial differential equation arising in various field of applications for example in science, engineering and economics etc.
CO2	Understand advantages and limitations of advanced numerical methods.
CO3	Select and implement an appropriate numerical method for solving a given problem keeping in mind nature of the problem.
CO4	Use theoretical basis of these methods in order to study their counterparts existing in the scientific literature.
CO5	Identify the challenging problems in continuous mathematics (which are difficult to deal with analytically) and find their appropriate solutions accurately and efficiently.
CO6	Extend their knowledge to do research work on these methods and similar type of other methods.

Mapping of course outcomes with the program outcomes

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10
CO1	✓	-	-	-	-	-	-	-	✓	✓
CO2	-	✓	-	-	-	-	-	-	✓	✓
CO3	✓	✓	-	-	-	-	-	-	✓	✓
CO4	-	✓	-	-	-	-	-	-	✓	✓
CO5	-	-	-	✓	-	-	-	-	✓	✓
CO6	-	-	-	-	✓	-	-	-	✓	✓

Course Title: Advanced Numerical Methods
Course Code: UC-MSM-510-18

Unit-I

Iterative Methods for Linear Systems & Eigenvalue problem: The classical iterative methods: Jacobi, Gauss-Seidel and Successive Over Relaxation (SOR) methods. Conjugate gradient method. Eigenvalues & eigenvectors: Rayleigh power method & Givens method.

Unit-II

Finite Difference Methods: Explicit and implicit schemes, consistency, stability and convergence, Lax equivalence theorem, numerical solutions to elliptic, parabolic and hyperbolic partial differential equations.

Unit-III

Approximate methods of solution: Rayleigh-Ritz, collocation and Galerkin methods, properties of Galerkin approximations, Petrov-Galerkin method, Generalized Galerkin method.

Unit-IV

Finite Element Method (FEM): FEM for second order problems, One- and two-dimensional problems, The finite elements (elements with a triangular mesh and a rectangular mesh and three-dimensional finite elements), Fourth-order problems, Hermite families of elements, iso-parametric elements, numerical integration.

BOOKS RECOMMENDED:

1. Jain, M.K, Iyengar, S.R.K. and Jain, R.K., *Numerical Methods for Scientific and Engineering Computation,* 5th Edition, New Age international, 2008.
2. Hoffman Joe D., *Numerical methods for Engineers and Scientists*, McGrow-Hill, 1993.
3. Atkinson, K.E, *An Introduction to Numerical Analysis,* 2nd Edition, *John Wiley*, 2004.
4. Gupta R.S., *Elements of Numerical Analysis,* McMillan India, 2009
5. Seshu P., *Textbook of Finite Element Analysis*, Prentice Hall India, 2003.

UC-MSM-511-18	**Topological Vector Spaces**	**L-4, T-1, P-0**	**4 Credits**

Pre-requisite: Linear Algebra, Real Analysis, Topology

Course Objectives: The aim of this course is to give an overview of the most important concepts and results of the theory of topological vector spaces (TVS). As the name suggests, this theory beautifully connects topological and algebraic structures. The main focus will be the study of TVS over the reals and particular attention will be given to locally convex spaces (e.g. normed, seminormed and nuclear spaces).

Course Outcomes: At the end of the course, the student will be able to

CO1	understand the general theory of topological vector spaces.
CO2	learn the basic properties of topological vector spaces.
CO3	define the structure of locally-convex topological vector spaces.
CO4	understanding and analyzing inductive and projective limits.
CO5	understand the structure of, Frechet spaces, Montel, Schwartz, and nuclear spaces.

Mapping of course outcomes with the program outcomes

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10
CO1	✓	✓	✓	✓	✓	-	-	-	✓	✓
CO2	✓	✓	✓	✓	✓	-	-	-	✓	✓
CO3	✓	✓	✓	✓	✓	-	-	-	✓	✓
CO4	✓	✓	✓	✓	✓	-	-	-	✓	✓
CO5	✓	✓	✓	✓	✓	-	-	-	✓	✓

Course Title: Topological Vector Spaces

Course Title: Topological Vector Spaces
Course Code: UC-MSM-511-18

Unit-I

Review of basic concepts of topological spaces and vector spaces. Prodect topological spaces, projection maps, compactness of prodect topological spaces-Tichonov's theorem.

Topological vector spaces (TVSs), examples of TVSs, Normed vector spaces as TVSs, Translation and multiplication maps, Neighborhood of 0, separated TVS, linear maps between TVSs, Bounded subsets of a topological vector space.

Unit-II

Locally convex topological spaces, normable and metrizable topological vector spaces, complete topological vector spaces

Unit-III

Frechet spaces, Uniform boundedness principle, open mapping and closed graph theorems for Frechet spaces.

Unit-IV

Banach-Alaoglu theorem, Variational inequalities, Lion-Stampacchia theory, Physical phenomenon represented by variational inequalities, points and external sets-Krein Miliman theorem.

BOOKS RECOMMENDED:

1. Munkres J. R., *Topology – A First Course*, Prentice-Hall of India, 1978.
2. Kelley, J.L., *Linear topological spaces*, Van Nostrand East West Press, New Delhi.
3. Wilansky A., *Modern Methods in Topological Vector Spaces,* McGraw Hill, 1978.
4. Simmons G. F., *Introduction to Topology and Modern Analysis*, McGraw-Hill, 1963.
5. Rudin W., *Functional Analysis*, 2nd Edition, McGraw Hill, 1973.

UC-MSM-512-18	**Fractional Calculus**	**L-4, T-1, P-0**	**4 Credits**
Pre-requisite: Differential Equations (Ordinary and Partial), Mathematical Methods			
Course Objectives: The objective of this course to cover the basics of the fractional calculus, or more aptly called the calculus of derivatives and integrals to an arbitrary order. Then introduce the concept of fractional differential equations and consider some of their applications. Also, study the numerical solution of fractional differential equations			
Course Outcomes: At the end of the course, the studenst will be able to			

CO1	understand the Riemann-Liouville fractional integral and evaluate fractional integrals of some common functions
CO2	define the Riemann-Liouville and Caputo fractional derivatives and find the fractional derivatives of some common functions
CO3	state sufficient conditions under which the fractional integrals and derivatives exist
CO4	investigate some applications of the fractional calculus to the real world.
CO5	solve linear fractional differential equations using the Laplace transform and Fourier Transforms

Mapping of course outcomes with the program outcomes

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10
CO1	✓	-	✓		✓	-	-	-	-	✓
CO2	✓	-	✓		✓	-	-	-	-	✓
CO3	✓	-	✓		✓	-	-	-	-	✓
CO4	✓	-	✓	✓	✓	-	-	-	-	✓
CO5	✓	-	✓		✓	-	-	-	-	✓

Course Title: Fractional Calculus

Course Code: UC-MSM-512-18

Unit-I

Special Functions of the Fractional Calculus. Gamma Function. Mittag-Leffler function, Fractional Derivatives and Integrals. Grunwald-Letnikov Fractional Derivatives. Riemann Liouville Fractional Derivatives. Some Other Approaches.

Unit-II

Geometric and Physical Interpretation of Fractional Integration and Fractional Differentiation. Sequential Fractional Derivatives. Left and Right Fractional Derivatives. Properties of Fractional Derivatives. Laplace Transforms of Fractional Derivatives. Fourier Transforms of Fractional Derivatives. Mellin Transforms of Fractional Derivatives.

Unit-III

Linear Fractional Differential Equations. Fractional Differential Equation of a General Form. Existence and Uniqueness Theorem as a Method of Solution. Dependence of a Solution on Initial Conditions. The Laplace Transform Method. Standard Fractional Differential Equations. Sequential Fractional Differential Equations. Fractional Green's Function. Definition and Some Properties. One-Term Equation. Two Term Equation. Three-Term Equation. Four-Term Equation. General Case: n-term Equation.

Unit-IV

Other Methods for the Solution of Fractional-order Equations. The Mellin Transform Method. Power Series Method. Babenko's Symbolic Calculus Method. Method of Orthogonal Polynomials. Numerical Evaluation of Fractional Derivatives. Approximation of Fractional Derivatives. Order of Approximation. Computation of Coefficients. Higher-order Approximations.

Books Recommended

1. Podlubny, I., *Matrix approach to discrete fractional calculus vol. 3,* Fractional Calculus and Applied Analysis, 2000.
2. Carpinteri A, Mainardi F, editors. *Fractals and fractional calculus in continuum mechanics,* New York, Springer-Verlag Wien, 1997.
3. Mandelbrot B.B., *The fractal geometry of nature,* New York, W. H. Freeman, 2000.
4. Miller K.S., Ross B., *An introduction to the fractional calculus*. New York, John Wiley, 1993.
5. Oldham KB, Spanier J., *The fractional calculus,* New York, Academic Press; 1974.