MANAV RACHNA
vidyanatariksha

MANAV RACHNA UNIVERSITY
FORMERLY MANAV RACHNA COLLEGE OF ENGINEERING
NAAC ACCREDITED 'A' GRADE INSTITUTION
Declared as State Private University under section 2f of the UGC act, 1956

Manav Rachna University

Faculty of Applied Sciences
Department of Mathematics

Scheme & Syllabus

M.Sc. Mathematics (2019)
Scheme - B

MAP01- Semester-I

SUBJECT CODES	SUBJECT NAME	**OFFERING DEPARTMENT	*COURSE NATURE (Hard/Soft/ Workshop/ NTCC)	COURSE TYPE (Core/Elective / University Compulsory)	L	P	O	NO. OF CONTACT HOURS PER WEEK	NO. OF CREDITS
MAH501B	ABSTRACT ALGEBRA	MA	HARD	CORE	4	0	0	4	4
MAH502B	TOPOLOGY-I	MA	HARD	CORE	4	0	0	4	4
MAH503B	DIFFERENTIAL EQUATIONS	MA	HARD	CORE	4	0	0	4	4
MAH504B	MEASURE THEORY	MA	HARD	CORE	4	0	0	4	4
MAW505B	EXCEL WORKSHOP	MA	HARD	CORE	0	4	0	4	2
MAH506B	MATHEMATICS LAB –I	MA	HARD	ELECTIVE (ANY ONE)	0	2	0	2	1
CSH511B	PYTHON PROGRAMMING	CSE							
TOTAL (L-T-P-O/ CONTACT HOURS/ CREDITS)					16	6	0	22	19

DETAILED SYLLABUS
MAP01 – SEMESTER-I

Course Title/ Code	ABSTRACT ALGEBRA- MAH501B
Course Type	Core (Departmental)
Course Nature	Hard
L-P-O Structure	4-0-0-0
Objective	To familiarize students with the structure theory of groups and module theory.
Outcomes	The student would be able to conceptualize and apply the concepts of Modern Algebraic Structures namely groups & modules.
Prerequisites	N.A

	Sections	Weightage
Syllabus	A	25%
	B	25%
	C	25%
	D	25%
	TOTAL	100%

SECTION A

Structure Theory of Groups: Direct Products, External direct product, Internal direct product, Cauchy's theorem for Abelian groups, Sylow's P-subgroups, Double Cosets, Sylow's Theorems, Finite Abelian Groups, Fundamental Theorem of Finite Abelian Groups.

SECTION B

Solvable Groups & Jordan Holder Theorem: Generators of a subgroup and derived subgroups, Maximal Subgroups, Normal and subnormal Series, Composition Series, Zassenhaus Lemma, Jordan Holder Theorem, Solvable groups, Nilpotent groups & their properties.

SECTION C

Modules: Modules, Cyclic modules, Simple and semi-simple modules, Schur lemma, Free modules, Torsion modules, Torsion free modules, Torsion part of a module, Modules over principal ideal domain and its applications to finitely generated abelian groups.

SECTION D

Noetherian and Artinian modules: Noetherian and Artinian modules, Modules of finite length, Noetherian and Artinian rings, Hilbert basis theorem.
Hom R(R,R), Opposite rings, Wedderburn – Artin theorem, Maschk theorem, Equivalent statement for left Artinian rings having non-zero nilpotent ideals. Radicals: Jacobson radical, Radical of an Artinian ring.

Recommended Books:

1. I.S. Luther and I.B.S. Passi, Algebra, Vol. I-Groups, Vol. III-Modules, Narosa Publishing House (Vol. I – 2013, Vol. III –2013).
2. Charles Lanski, Concepts in Abstract Algebra, American Mathematical Society, First Indian Edition, 2010.
3. Vivek Sahai and Vikas Bist, Algebra, Narosa Publishing House, 1999.
4. D.S. Malik, J.N. Mordenson, and M.K. Sen, Fundamentals of Abstract Algebra, McGraw Hill, International Edition, 1997.

5. P.B. Bhattacharya, S.K. Jain and S.R. Nagpaul, Basic Abstract Algebra (2nd Edition),Cambridge University Press, Indian Edition, 1997.
6. C. Musili, Introduction to Rings and Modules, Narosa Publication House, 1994.
7. N. Jacobson, Basic Algebra, Vol. I & II, W.H Freeman, 1980 (also published by Hindustan Publishing Company).
8. M. Artin, Algebra, Prentice-Hall of India, 1991.
9. Ian D. Macdonald, The Theory of Groups, Clarendon Press, 1968.

Course Title/Code	TOPOLOGY-I- MAH502B
Course Type:	Core (Departmental)
Course Nature:	Hard
L-P-O Structure	4-0-0-0
Objective	To familiarize students with Sets, metric spaces, topological spaces, continuous mappings, connectedness, compactness.
Outcomes	The student would be able to conceptualize and apply the concepts of Topological Spaces.
Prerequisites	N.A.

	Sections	Weightage
Syllabus	A	25%
	B	25%
	C	25%
	D	25%
	TOTAL	100%

SECTION A

Metric spaces, Topological spaces, Closed set, Closure, Dense subset, Neighborhoods, Interior, Exterior and Boundary, Accumulation point and Derived sets, Bases, Sub–bases, Sub space and Relative topology.

SECTION B

Characterization of topology in terms of base and subbase axioms, Topology generated by a family of subsets, Alternate methods of defining a topology in term of Kwiatkowski closure Operator and Neighborhood System, Continuous functions and Homomorphism.

SECTION C

First and Second Countable spaces, Separable spaces, Second countability and Separability, Separation axioms T0,T1,T2,T3-1\2,T4, Their Characterizations and basic Properties, Urysohn's lemma, Teitze extension theorem.

SECTION D

Compactness, Continuous functions and Compact sets, Basic properties of Compactness, Compactness and finite intersection property, Sequentially and countably compact sets, Connected spaces, Connectedness on the real line, Components, Lindelöf's theorem, Locally connected space.

Recommended Books:

1. James R. Munkres, Topology (2nd Edition) Pearson Education Pve. Ltd., Delhi-2002
2. George F. Sinmons, Introduction to Topology and Modern Analysis, McGraw Hill Book Co., 1963
3. J. Dugundji , Topology , Prentice Hall of India, New Delhi, 1975.
4. K. D. Joshi : Introduction to General Topology (Wiley Eastern Limited).
5. S. Kumaresan: Topology of Metric Spaces, alpha science.

Course Title/ Code	DIFFERENTIAL EQUATIONS-MAH503B
Course Type:	CORE (Departmental)
Course Nature:	Hard
L-P-O Structure	4-0-0-0
Objective	Exposure to Ordinary Differential Equations (Homogeneous and Non homogeneous), Different functions and methods to solve these equations, Stability of autonomous system of differential equation and PDEs and their applications in different physical situations.
Outcomes	The course will enable to the students to understand the genesis of differential equations, various techniques of getting best solutions of the different types of differential equations. The student would be able to apply the concepts of differential equations in various physical problems (heat equations, wave equations).
Prerequisites	NA

	Sections	Weightage
Syllabus	A	25%
	B	25%
	C	25%
	D	25%
	TOTAL	100%

SECTION-A

Existence and Uniqueness of Ordinary Differential equations, Picard's method (successive approximation or iteration method), solution of simultaneous differential equations with initial conditions by Picard's method. Existence and Uniqueness theorem. Lipschitz condition and Lipschitz constant. System of first order non homogeneous equations, Homogeneous Linear system, Non-homogeneous Linear system, Linear system with constant coefficient. Eigen value and Eigen functions. Strum- Lioville Boundary – Value Problems

SECTION-B

Stability of autonomous system of differential equation, Types of critical points, Critical points and Stability of linear systems, stability by Liapunov's Direct method, Simple critical points of nonlinear systems, Nonlinear mechanics, Periodic solutions, The Poincare – Bendixson Theorem.

SECTION-C

Solution of Cauchy's problem of First order Partial Differential equations, Solution of Non-homogeneous PDE by Jacobi's method, PDE of the Second order (Homogeneous and Non-Homogeneous), Monge's Method, Method of separation of variables, Method of Integral transform.

SECTION-D

Laplace Equation in two-dimension, Green function for Laplace Equation, Dirichlet and Newman problem for Half plane, Dirichlet and Newman problem for circle, Dirichlet and Newman problem for sphere and semi-infinite space, Wave Equation, Diffusion equation.

Recommended Books:

1. G. F. Simmons: Differential equation with Application and Historical Notes, McGraw-Hill
2. Ian Sneddon: Elements of Partial Differential Equations, McGraw-Hill.
3. S. L. Ross: Differential Equations, Wily India.
4. M. D. Raisinghania, Advance Differential equation, S.Chand India.

Course Title/ Code	MEASURE THEORY- MAH504B
Course Type:	Core (Departmental)
Course Nature:	Hard
L-P-O Structure	4-0-0-0
Objective	To gain understanding of the abstract measure theory and definition and main properties of the integral. To construct Lebesgue's measure on the real line.
Outcome	The student would be able to conceptualize measure and integral with respect to a measure and apply the concepts of measure theory for further studies in Analysis, probability and dynamical systems etc.
Prerequisites	N.A

	Sections	Weightage
Syllabus	A	25%
	B	25%
	C	25%
	D	25%
	TOTAL	100%

SECTION A

Introduction of Measure Theory; Extension of Real Line, Semi algebra, Algebra, σ −algebra, Borel field, Set function, Length function and their properties, Counting measure, Extension of measure, Outer measure. Finite, Semi-finite and σ −finite measure, Measurable sets, Measurable space, Completeness of measure spaces.

SECTION B

Lebesgue measure and its properties, Cantor's Theory, non-measurable sets, characterization of Lebesgue measurable sets, Measurable functions and its properties, Convergence of measurable function, Littlewood's Three principles.

SECTION C

Lebesgue Integral of a Bounded functions over a set of Finite Measure, Fatou's Lemma, Monotone Convergence Theorem, Lebesgue Convergence Theorem and Convergence in Measure. Absolute continuity, Jensen Inequality Fundamental Theorem of Calculus for Lebesgue Integrals, Vitali's Lemma, Function of bounded variation.

SECTION D

Lebesgue Convergence Theorem and Convergence in Measure, Integration of complex valued function, Product measure, Fubini's Theorem, Signed Measures, Hahn Decomposition Theorem, Jordan decomposition, Radon-Nikodym Theorem, Lebesgue decomposition.

Recommended Books:

1. Real Analysis by H. L. Royden, PHI
2. An Introduction to Measure Theory by I. K. Rana. AMS and Narosa
3. Real Analysis by W. Rudin, TMH

Course Title/ Code	EXCEL WORKSHOP-MAW505B
Course Type:	Core (Departmental)
Course Nature:	Workshop
L-P-O Structure	0-0-4-0
Objective	The course aims to develop to analyze and present data in various formats and styles, summarize data as required by specific business problem.
Outcome	On successful completion of this course, students should be able to: 1.To get the basic understanding of MS Excel 2. Using various functions available in MS Excel and be able to implement the same in practical business problems. 3. Be able to analyze and present data in various formats and styles 4. Summarize data as required by specific business problem
Prerequisites	NA

SECTION A

Introduction to Excel: Excel Introduction, Understanding Workbooks and Worksheets, Introducing the Ribbon, Using Shortcut Menus, Working with Dialog Boxes, Using the Task Pane, Creating Excel Worksheet, Entering and Editing Worksheet Data, Essential Worksheet Operations, Autosum functions, Working with Dates and Time.

SECTION B

Advanced Excel: Working with Cells and Ranges, Introducing Tables, Worksheet Formatting, Using Custom Number Formats, Understanding Excel Files, Using and Creating Templates, Financial functions, Logical functions, Creating Formulas That Look Up Values.

SECTION C

Creating Formulas for Financial Applications: Introducing Array Formulas, Visualizing Data Using Conditional Formatting, Using Data Validation, Creating Charts and Graphics 04, Understanding How Excel Handles Charts, Understanding Chart Types, Understanding Chart Elements, Modifying the Chart Area, Modifying the Plot Area, Working with Chart Titles, Working with a Legend.

SECTION D

Working with Gridlines, Working with Data Series, Creating Chart Templates, Analyzing Data with Excel, Introducing Pivot Tables, Analyzing Data with Pivot Tables, Understanding Slicers and Slicer properties.

Recommended Books:

1. John Walkenbach, Excel 2013 Bible, Wiley, PAP/CDR edition, 2013
2. John Walkenbach, Excel 2013 Power Programming with VBA (Mr. Spreadsheet's Bookshelf) Wiley; PAP/CDR edition, 2013

Course Title/ Code	MATHEMATICS LAB-I-MAH506B
Course Type:	Elective (Departmental)
Course Nature:	Hard
L-P-O Structure	0-0-2-0
Objective	Students would be able to understand the software Octave and use commands to perform various experiments.
Outcome	The student will get the get the basic understanding of Octave and use various commands available in it and be able to implement the same in Mathematical problems.
Prerequisites	NA

LAB EXERCISE

1. Introduction to OCTAVE and use of some simple OCTAVE commands.
2. To define matrices and compute matrix operations
3. Perform advanced operation on Matrices
4. Introduction to graphics: Basic Two-Dimensional Graphs, Labels, Multiple plots on the same axes, Line styles, Markers and color, Axis limits and Subplots.
5. To transform an equation using Octave
6. Find roots of cubic and bi-quadratic equations
7. To find limit & continuity of function of single variable
8. To find differentiability of function of single variable
9. To find limit & continuity of function of several variables
10. To find differentiability of function of several variables
11. Compute differentiation of function of single and several variables.
12. To find maxima and minima of function of several variables
13. To find integral of a given function
14. Application of integrals- To compute arch length and area under a given curve.
15. Multiple Integrals

Recommended Books:

1. Jesper Schmidt Hansen, GNU Octave Beginner's Guide.
2. Jason Lachniet, Introduction to Gnu Octave

Course Title/ Code	PYTHON PROGRAMMING-CSH511B
Course Type:	Elective (Allied)
Course Nature:	HARD
L-T-P-O Structure	0-0-2-0
Objective	The course is designed to provide Basic knowledge of **Python**. **Python** programming is intended for software engineers, system analysts, program managers and user support personnel who wish to learn the **Python** programming language.
Outcome	The student will be able to get the basic understanding of Python programming using anaconda IDE environment.

	Sections	Weightage
Syllabus	A	25%
	B	25%
	C	25%
	D	25%
	TOTAL	**100%**

Section-A

Introduction : Introduction to Python, Components and Versions of Python, Difference between Python 2 and Python 3, Python Distributions, Python REPL, Python Syntax.

Basic Operators – Arithmetic, Relational, Assignment, Logical, Membership and Identity operators, Variables and Data Types

Collections – String, list, set, tuple, dictionary, Understanding Mutable and Immutable types

Conditional Constructs - Working with Loops – While & For, Effects of break, continue, pass & else statement in various construct.

Section-B

Implementing custom functions, Variable scope – Global vs. Local, Dealing with various function arguments – default, named and variable length arguments, Understanding the concept of pass by value and pass by reference, Returning multiple values from a function, Recursive function.

Section-C

Understanding File Operations, Working with the File Object for reading & writing, Object oriented programming in Python, Understanding Classes & Objects, and Exploring different components of a Class

Section-D

Class inheritance & Method overriding, Working with multiple Inheritance, Understanding the Abstraction mechanism in Python, Built-in Class attributes, Exception handling

LIST OF EXPERIMENTS: Tool Used: - Jupyter Notebook/ Spyder

1. Using Jupyter Notebook to create and execute Python Program.
2. Programming Constructs in Python – Hands- on - Practice
3. Control Structure - Hands- on - Practice
4. String & List : Hands- on - Practice
5. Operation on Tuples : Hands- on - Practice
6. Dictionary : Hands- on - Practice
7. Function – Pass by reference : Hands- on - Practice
8. Working with the File Object for reading & writing
9. Object Oriented Programming
10. Class inheritance & Method overriding : Hands- on – Practice

11. Exception handling : Hands- on - Practice

Text Books:

- Learn Python 3 the Hard Way: A Very Simple Introduction to the Terrifyingly Beautiful World of Computers and Code (Zed Shaw's Hard Way Series)
- Mark Lutz's, "Learning Python", O'Reilly, 2001

Reference Books:

- Sahana Kumaraswamy, Roy Antony Arnoid G, "Assignment for Object Oriented Programming using Python", Infosys, Dec 2015.

Online Course:

- https://swayam.gov.in/nd1_noc19_cs59/preview

MAP-01- Semester-II

SUBJECT CODES	SUBJECT NAME	**OFFERING DEPARTMENT	*COURSE NATURE (Hard/Soft/ Workshop/ NTCC)	COURSE TYPE (Core/Elective / University Compulsory)	L	P	O	NO. OF CONTACT HOURS PER WEEK	NO. OF CREDITS
MAH507B	FIELD THEORY	MA	HARD	CORE	4	0	0	4	4
MAH508B	COMPLEX ANALYSIS	MA	HARD	CORE	4	0	0	4	4
MAH509B	FUNCTIONAL ANALYSIS	MA	HARD	CORE	4	0	0	4	4
MAH510B	DIFFERENTIAL GEOMETRY	MA	HARD	CORE	4	0	0	4	4
MAH511B	MATHEMATICS LAB –II	MA	HARD	ELECTIVE (ANY ONE)	0	4	0	4	2
CSW512B	PYTHON FOR DATA ANALYSIS	CSE							
RDO503	SCIENTIFIC RESEARCH - I	MA	HARD	CORE	0	0	8	2	4
TOTAL (L-T-P-O/ CONTACT HOURS/ CREDITS)					16	4	4	22	22

MAO513B	SUMMER INTERNSHIP	2

DETAILED SYLLABUS
MAP01 – SEMESTER-II

Course Title/ Code	FIELD THEORY- MAH507B
Course Type	Core (Departmental)
Course Nature	Hard
L-P-O Structure	4-0-0-0
Objective	To familiarize students with the Field Theory & its applications.
Outcomes	The student would be able to conceptualize and apply the theory of Field extensions.
Prerequisites	N.A

	Sections	Weightage
Syllabus	A	25%
	B	25%
	C	25%
	D	25%
	TOTAL	100%

SECTION - A

Extension of fields: Elementary properties, Simple Extensions, Algebraic and transcendental Extensions. Factorization of polynomials, Splitting fields, Algebraically closed fields, Separable extensions, Perfect fields.

SECTION - B

Galios theory: Automorphism of fields, Monomorphisms and their linear independence, Fixed fields, Normal extensions, Normal closure of an extension, The fundamental theorem of Galois theory, Norms and traces.

SECTION - C

Cyclotomic extensions: Normal basis, Galios fields, Cyclotomic extensions, Cyclotomic polynomials, Cyclotomic extensions of rational number field, Cyclic extension, Wedderburn theorem.

SECTION - D

Geometrical Constructions & Radicals: Ruler and compasses construction, Solutions by radicals, Extension by radicals, Generic polynomial, Algebraically independent sets, Insolvability of the general polynomial of degree $n \geq 5$ by radicals.

Recommended Books:

1. I.S. Luther and I.B.S.Passi, Algebra, Vol. IV-Field Theory, Narosa Publishing House, 2012.
2. Ian Stewart, Galios Theory, Chapman and Hall/CRC, 2004.
3. Vivek Sahai and Vikas Bist, Algebra, Narosa Publishing House, 1999.
4. P.B. Bhattacharya, S.K. Jain and S.R. Nagpaul, Basic Abstract Algebra (2nd Edition), Cambridge University Press, Indian Edition, 1997.
5. S. Lang, Algebra, 3rd editioin, Addison-Wesley, 1993.
6. Ian T. Adamson, Introduction to Field Theory, Cambridge University Press, 1982.
7. I.N. Herstein, Topics in Algebra, Wiley Eastern Ltd., New Delhi, 1975.

Course Title/ Code	COMPLEX ANALYSIS-MAH508B
Course Type:	Core (Departmental)
Course Nature:	Hard
L-P-O Structure	4-0-0-0
Objective	The objective of this course is to introduce the fundamental ideas for developing and understanding the concepts of Complex Analysis.
Outcomes	This course will enable the students to (i) Uderstand the significance of differentiability and analyticity of complex functions (ii) Apply Cauchy integral formula in evaluation of contour integrals. (iii) Apply Taylor and Laurent series expansions of analytic functions; (iv) classify the nature of singularities, poles and residues and application of Cauchy Residue theorem. (v) Apply the consequences of analytic continuation, Schwarz reflection principle, Monodromy theorem and conformal mapping.
Prerequisites	NA

	Sections	Weightage
Syllabus	A	25%
	B	25%
	C	25%
	D	25%
	TOTAL	100%

SECTION A

Analytic Functions (C R equations in Cartesian and Polar Coordinates), Complex Integration, Cauchy-Goursat Theorem, Cauchy's Integral Theorem, Cauchy's Integral Formula, Cauchy's Integral Formula for Higher order derivatives, Maximum modulus principle , Cauchy's Inequality and Liouville's theorem, The Fundamental theorem of algebra.

SECTION B

Taylor & Laurent's Series Expansion, Isolated Singularities, Casorati-Weierstress theorem, Meromorphic functions, the argument principle, Rouche's theorem, Inverse function theorem. Residues, Cauchy's residue theorem, Evaluation of integrals, Branches of many valued functions with special reference to arg Z, Log Z, and Z^a.

SECTION C

Analytic continuation, Uniqueness of direct analytic continuation, Uniqueness of analytic continuation along a curve, Power series method of analytic continuation, Schwarz reflection principle, Monodromy theorem and its consequences.

SECTION D

Introduction to mapping (transformations), Jacobian of transformation, Complex Mapping functions. Some elementary Transformation (translation, rotation, magnification and inversion). Linear transformation, Bilinear or Fractional transformation, Trigonometric transformation. The Schwarz-Christoffel Transformation. Transformation of Boundaries in Parametric Form.

Recommended Books:

1. S. Ponnusamy, Complex Analysis, Springer.
2. E. T. Copson, Complex Variables, Oxford University Press.
3. J. B. Conway, Functions of one complex variable, Narosa Publication House.
4. H.S. Kasana, Complex- Variable Theory and Applications, PHI Learning Pvt.
5. J. N. Sharma, Functions of a Complex- Variable, Krishna Prakashan Media (P) Ltd.

Course Title/ Code	FUNCTIONAL ANALYSIS- MAH509B
Course Type:	Core (Departmental)
Course Nature:	Hard
L-P-O Structure	4-0-0-0
Objective	To provide the student with the concept and the understanding in Banach spaces, Hilbert space and Banach Algebras.
Outcome	The student would be able to conceptualize basics of Functional Analysis and apply these concepts in harmonic analysis and stochastic calculus.
Prerequisites	N.A.

	Sections	Weightage
Syllabus	A	25%
	B	25%
	C	25%
	D	25%
	TOTAL	100%

SECTION A

Normed linear spaces, Banach spaces, their examples including $R^n, \mathbb{C}^n, l_p(n), c_0, c, l_p, C[a,b]$. Subspaces, Quotient spaces of normed linear space and its completeness. Joint continuity of addition and scalar multiplication. Summable sequences and completeness, Continuous and bounded linear operators and their basic properties.

SECTION B

Normed linear space of bounded linear operators and its completeness. Isometric isomorphism, Topological isomorphism. Equivalent norms. Finite dimensional normed spaces and compactness. Riesz Theorem, Open mapping theorem and its simple consequences. Closed graph theorem. Uniform boundedness, Banach-Steinhaus theorem.

SECTION C

Bounded linear functionals Dual spaces. Form of dual spaces$R^{n^*}, \mathbb{C}^{n^*}, l_p(n), c_0^*, c^*, l_p^*, C^*[a,b]$., Hahn-Banach Theorem and its consequences, Embedding and Reflexivity of Normed spaces.

SECTION D

Adjoint of Bounded linear operators, Weak convergence and strong convergence. Hilbert spaces, orthogonal complements and direct sums, Bessel inequality, total orthonormal sets and sequences.

Recommended Books:

1. P. K. Jain and O P Ahuja, Functional Analysis, New age international publishers
2. S. Ponnusamy, Foundation of Functional Analysis, Springer
3. Walter Rudin, Functional Analysis, TMH Edition
4. V.S. Sunder, Functional Analysis spectral theory, Hindustan Book Agency, 1997

Course Title/ Code	DIFFERENTIAL GEOMETRY- MAH510B
Course Type:	Core (Departmental)
Course Nature:	Hard
L-P-O Structure	4-0-0-0
Objective	To familiarize students with space curves, geodesics, intrinsic and non-intrinsic properties of a surface.
Outcome	The student would be able to apply the concepts of space curves, geodesics, intrinsic and non-intrinsic properties of a surface.
Prerequisites	NA

	Sections	Weightage
Syllabus	A	25%
	B	25%
	C	25%
	D	25%
	TOTAL	100%

SECTION A

Co-ordinate transformation, Covariant, Contravariant and Mixed tensors, Tensors of higher rank, Symmetric and Skew-symmetric tensors, Tensor algebra, Contraction, Inner product, Riemannian metric tensor, Christoffel symbols, Covariant derivatives of tensors.

SECTION B

Differentiable curves in R^3 and their parametric representations, Vector fields, Tangent vector, Principal normal, Binormal, Curvature and torsion, Serret-Frenet formula, Frame fields, Covariant differentiation, Connection forms, The structural equations.

SECTION C

Surfaces, Differentiable functions on surfaces, Differential of a differentiable map, Differential forms, Normal vector fields, First fundamental form, Shape operator, Normal curvature, Principal curvatures, Gaussian curvature, Mean curvature, Second fundamental form.

SECTION D

Gauss equations, Weingarten equation, Codazzi-Mainardi equations, Totally umbilical surfaces, Minimal surfaces, Variations, First and second variations of arc length, Geodesic, Exponential map, Jacobi vector field, Index form of a geodesic.

Recommended Books:

1. Barett O' Neill, Elementary Differential Geometry, Academic Press, 2006.
2. Manfredo P. Do' Carmo, Differential Geometry of Curves and Surfaces, , Prentice Hall Inc.
3. S. Montiel and A. Ros, Curves and Surfaces , American Mathematical Society, 2005.
5. Somasundaram, Differential Geometry, A first course, Narosa Publication.
6. Zafar Ahsan, Tensor Calculus, Anamaya Publications, New Delhi. 19 / 27
7. U. C. De, Tensor Calculus, Narosa Publications, New Delhi.

Course Title/ Code	MATHEMATICS LAB-II-MAH511B
Course Type:	Elective (Departmental)
Course Nature:	Hard
L-P-O Structure	0-0-4-0
Objective	To familiarize students with script file and m files to perform various experiments using mathematical software.
Outcome	The student would be able to apply the concept of script files and m- file to solve Mathematical problems using mathematical software
Prerequisites	Maths Lab-I(MAH506B)

LAB EXERCISE: Software Octave/ SciLab/MATLAB/ Altair

1. Introduction to m file - basic programming.
2. Introduction to conditional Statements
3. Introduction to iteration-based programming
4. Introduction to function files
5. Functions calling through main program (script file)
6. Find the rank of a matrix & solution of simultaneous Linear equations
7. Eigen values and Eigen vector of a matrix
8. Orthogonalization of a Matrix
9. Diagonalization of a matrix
10. linear dependence and independence of vectors, basis and dimension
11. Matrix of Linear Transformation

Latex Lab Exercise

1. Introduction and basics of LaTeX.
2. Document structure and text formatting in LaTeX.
3. Mechanics of error and warning, lengths, Counters and Boxes.
4. Fundamentals for creating Technical Texts.
5. To Create Special Pages: Indexing, Glossary, Bibliography
6. To Create Special Documents: Letters, Presentations, Curriculum Vitae.
7. Creating Graphics in LaTeX.
8. Programming: Macros, Plain text, Creating Packages, Themes.
9. Miscellaneous: Modular Documents, Collaborative Writing of LaTeX Documents, Export to other Formats.
10. Math – Type in Microsoft Word.

Recommended Books:

1. Jesper Schmidt Hansen, GNU Octave Beginner's Guide.
2. Jason Lachniet, Introduction to Gnu Octave

Course Title/ Code	PYTHON FOR DATA ANALYSIS-CSW512B
Course Type:	Elective (Allied)
Course Nature:	HARD
L-T-P-O Structure	0-0-4-0
Objective	To familiarize students with the advance features of python programming using various libraries and packages for exploratory data analysis and visualization.
Outcome	Students would be able to understand and implement python programming concepts to solve real life problems using Exploratory Data Analysis.
Prerequisites	Python Programming(CSH511B)

	Sections	Weightage
Syllabus	A	25%
	B	25%
	C	25%
	D	25%
	TOTAL	100%

Section-A

Jupyter and Numpy: The NumPy ndarray: A Multidimensional Array Object, Creating ndarrays, Data Types for ndarrays, Arithmetic with NumPy Arrays, Basic Indexing and Slicing, Boolean Indexing, Fancy Indexing, Transposing Arrays and Swapping Axes, **Universal Functions**: Fast Element-Wise Array Functions, **Array-Oriented Programming with Arrays :** Expressing Conditional Logic as Array Operations, Mathematical and Statistical Methods, Methods for Boolean Arrays, Sorting,Unique and Other Set Logic **File Input and Output with Arrays**

Section-B

Importing Dataset: Understanding the Data, Python Packages for Data Science, Importing and Exporting Data in Python

Pandas: Introduction to pandas Data Structures, Series, DataFrame, Index Objects, Reindexing
Dropping Entries from an Axis, Indexing, Selection, and Filtering, Integer Indexes, Arithmetic and Data Alignment, Function Application and Mapping, Sorting and Ranking,Axis Indexes with Duplicate Labels

Section-C

Summarizing and Computing Descriptive Statistics: Correlation and Covariance, Unique Values, Value Counts, and Membership

Data Cleaning and Preparation : Handling Missing Data, Filtering Out Missing Data, Filling In Missing Data **Data Transformation :** Removing Duplicates, Transforming Data Using a Function or Mapping, Replacing Values, Renaming Axis Indexes, Discretization and Binning, Detecting and Filtering Outliers, Permutation and Random Sampling, Computing Indicator/Dummy Variables

Section-D

Plotting and Visualization : Figures and Subplots, Colors, Markers, and Line Styles, Ticks, Labels, and Legends, Annotations and Drawing on a Subplot, Saving Plots to File, Line Plots, Bar Plots, Histograms and Density Plots, Scatter or Point Plots, Facet Grids and Categorical Data

MiniProject

Text Books:

1. McKinney, Wes. Python for data analysis: Data wrangling with Pandas, NumPy, and IPython. " O'Reilly Media, Inc.", 2012.
2. Mark Lutz's, "Learning Python", O'Reilly, 2001

Reference Books:

1. Lott, Steven. Functional Python Programming. Packt Publishing Ltd, 2015.
2. Matthes, Eric. Python crash course: a hands-on, project-based introduction to programming. No Starch Press, 2015.
3. https://pandas.pydata.org/

On line Course:

1. Python for Data Science: https://swayam.gov.in/nd1_noc19_cs59/preview
2. Data Analysis with Python: https://www.coursera.org/learn/data-analysis-with-python

Course Title/ Code	SCIENTIFIC RESEARCH-I-RDO503
Course Type	Core
Course Nature	NTCC
L--P-O Structure	0-0-8-0
Objectives	To acquaint the researcher with the tools of research by exposing them to the mechanics of writing a research report/ research paper/ thesis/ dissertation.
Outcomes	1. The student shall be able to describe research and its impact. 2. The student shall be able to identify broad area of research, analyze, the processes and procedures to carryout research. 3. The student shall be able to use different tools for literature survey 4. The student is able choose specific area of research and supervisor/mentor is finalized 5. To understand and adopt the ethical practice that are to be followed in the research activities 6. To work in groups with guidance

Unit 1: What is Research and its impact?

1.1 Capturing the current research trends
1.2 Insight about scientific research performed by renowned experts in the related field (case studies)
1.3 Do's and Don'ts pertaining to research

Unit 2: Identification of Broad Area of research

2.1 Identification of thrust area of research for deciding broad area
2.2 Framing the research questions and hypothesis
2.3 Identification of the research gap based on feasibility of problem
2.4 Exploration of in-house and commercially available facilities related to broad area

Unit 3: Understanding the tools for Literature Survey

3.1 Finding research papers related to a topic
3.2 Understanding the different aspects of Literature search
3.3 Usage of different sources like Google scholar, WoS, SCI/ SCIE, PubMed, Scopus, ABDC, EBSCO etc.
3.4 Search for online journals relevant to research area
3.5 Indexing of Journals
3.5 Usage of scholarly networking sites like Research Gate, Mendeley, and Academia.edu etc.
3.6 Demo sessions on the usage of above mentioned sources

Unit 4: Review of research papers pertaining to broad area and specific area of research

4.1 Selection of relevant papers
4.2 Finding specific research problem from broad area of research
4.3 Literature survey and justification of specific research problem
4.4 Experimentation and data cleaning and verification
4.5 Understanding and selection of the research domain
4.6 Seeking information through published work w.r.t the problem
4.7 Reading & categorizing the downloaded/referred papers and structuring of the idea
4.8 Model design about framing the research questions

Unit 5: Report Writing and Presentation skill Development

5.1 Report making on the surveyed literature to cater the basic idea of the research papers

5.2 Compiling and analyzing the published results to justify and understand the proposed ideas
5.3 Usage of MS-PowerPoint and other technical resources for the presentation
5.4 Development of presentation skills and group addressing
5.5 Scientific/technical writing and ethical practice, project report

MAP01 -Semester-III

SUBJECT CODES	SUBJECT NAME	**OFFERING DEPARTMENT	*COURSE NATURE (Hard/ Soft/ Workshop/ NTCC)	COURSE TYPE (Core/Elective / University Compulsory)	L	P	O	NO. OF CONTACT HOURS PER WEEK	NO. OF CREDITS
MAH601B	INTEGRAL EQUATIONS & CALCULUS OF VARIATION	MA	HARD	CORE	4	0	0	4	4
MAH602B	FLUID MECHANICS	MA	HARD	CORE	4	0	0	4	4
MAH603B	FUZZY SETS & FUZZY LOGIC	MA	HARD	ELECTIVE (ANY TWO)	4	0	0	8	8
MAH604B	OPERATIONS RESEARCH								
MAH605B	GRAPH THEORY								
MAH606B	DESIGN OF EXPERIMENTS								
MAH607B	FOURIER ANALYSIS								
MAH608B	DIFFERENTIABLE MANIFOLDS								
MAH609B	WAVELETS								
MAH610B	TOPOLOGY-II								
RDO603	SCIENTIFIC RESEARCH-II	MA	NTCC	CORE	0	8	0	2	4
EDS234	PEDAGOGICAL SKILLS	ED	SOFT	CORE	1	2	0	3	2
TOTAL (L-T-P-O/ CONTACT HOURS/ CREDITS)					17	10	0	21	22

DETAILED SYLLABUS
MAP01 - SEMESTER III

Course Title/ Code	INTEGRAL EQUATIONS & CALCULUS OF VARIATION- MAH601B
Course Type:	Core (Departmental)
Course Nature:	Hard
L-P-O Structure	4-0-0-0
Objective	The objective of this course is to introduce the fundamental ideas for developing and understanding the concepts of Integral Equations and Calculus of variation.
Outcomes	This course will enable the students to understand the concepts of integral equations, various methods and would be able to evaluate the problems on Integral equation of first and second kind of Fredholm and Volterra type of differential equations. The students also would be able to understand the problems, methods and techniques of calculation of variations.
Prerequisites	NA

	Sections	Weightage
Syllabus	A	25%
	B	25%
	C	25%
	D	25%
	TOTAL	100%

SECTION A

Introduction to Integral equation, Linear Integral equations, Some basic identities, Differentiation of function under an integral sign, Initial value problems reduced to Volterra integral equations, Methods of successive substitution and successive approximation to solve Volterra integral equations of second kind, Iterated kernels and Neumann series for Volterra equations. Resolvent kernel as a series. Solution of a Volterra integral equation of the first kind.

SECTION B

Boundary value problems reduced to Fredholm integral equations, Methods of successive approximation and successive substitution to solve Fredholm equations of second kind, Iterated kernels and Neumann series for Fredholm equations. Resolvent kernel as a sum of series. Fredholm resolvent kernel as a ratio of two series. Fredholm equations with separable kernels. Approximation of a kernel by a separable kernel, Fredholm Alternative, Non-homogeneous Fredholm equations with degenerate Kernels.

SECTION C

Green function, Use of method of variation of parameters to construct the Green function for a non homogeneous linear second order boundary value problem, Basic four properties of the Green function, Alternate procedure for construction of the Green function by using its basic four properties. Reduction of a boundary value problem to a Fredholm integral equation with kernel as Green function, Hilbert-Schmidt theory for symmetric kernels.

SECTION D

Introduction to calculus of Variation, Variation of Functionals, Euler's equation, Euler – Lagrange equation, Solutions of Euler's Equation, Necessary and sufficient condition for Extrema. Several dependent variables, Functional involving higher order derivatives, Variational methods for boundary value problems in ordinary and partial differential equations.

Recommended Books:

1. William Vernon Lovitt, Linear Integral equations, Dover Publications, INC Mineola, New York.
2. Rainer Kress, Linear Integral equations, Springer
3. Ram P. Kanwal, Linear Integral equations, Academic Press, New York and London.
4. Shanti Swarup, Shiv Raj Singh, Linear Integral equations , Krishna Prakashan Media (P) Ltd.
5. D.C Sharma, M.C Goyal, Linear Integral equations, PHI Learning PVT Delhi.
6. A.S.Gupta, Calculus of Variations with Applications, PHI Learning PVT Delhi.
7. I.M Gelfand, S. V Fomin, Calculus of Variations with Applications, Prentice Hall

Course Title/ Code	FLUID MECHANICS-MAH602B
Course Type	Core (Departmental)
Course Nature	Hard
L-P-O Structure	4-0-0-0
Objective	To familiarize students with basic concepts of fluid dynamics.
Outcome	The student would be able to apply the concepts of fluid mechanics for solving problems related to fluids.
Prerequisites	NA

	Sections	Weightage
Syllabus	A	25%
	B	25%
	C	25%
	D	25%
	TOTAL	100%

SECTION A

Concept of fluids, Physical Properties of fluids, Continuum Hypothesis, density, specific weight, specific volume, Kinematics of Fluids: Eulerian and Lagrangian methods of description of flows, Equivalence of Eulerian and Lagrangian method, General motion of fluid element, integrability and compatibility conditions, strain rate tensor, streamline, path line, streak lines, stream function¸ vortex lines, circulation.

SECTION B

Stresses in Fluids: Stress tensor, symmetry of stress tensor, transformation of stress components from one co-ordinate system to another, principle axes and principle values of stress tensor Conservation Laws: Equation of conservation of mass (continuity equation), equation of conservation of momentum, Navier Stokes equation, Euler's equation of motion, equation of moments of momentum, Equation of energy.

SECTION C

Irrotational and Rotational Flows: Bernoulli's equation, Bernoulli's equation for irrotational flows, Two dimensional irrotational incompressible flows, Circle theorem, sources and sinks, sources sinks and doublets in two dimensional flows, methods of images.

SECTION D

Approximate (analytical) solutions of Navier Stoke Equation, Order of magnitude analysis, Use of similarity variables in analytical solution techniques, Solutions of some benchmark problems like; Couette Flow, Axi-symmetric Flows, Creeping flows.

Recommended Books:

1. O'Neil, M. E., and Chorlton, F. Ideal and Incompressible Fluid Dynamics.John Wiley & Sons, 1986.
2. Kundu, P.K., Cohen, I.M. and Dowling, R. David. Fluid Mechanics, 6th edition, Academic Press, 2015.
3. Yuan, S.W. Foundations of Fluid Mechanics. Prentice Hall of India Private Limited, New Delhi, 1976.
4. Besaint, W.H. and Ramsey, A.S. A Treatise on Hydromechanics, Part II.CBS Publishers, Delhi, 1988.
5. Curle, N. & Davies, H. J. Modern Fluid Dynamics.Vol 1, D Van Nostrand Company Ltd, London, 1968.

Course Title/ Code	Fuzzy Sets & Fuzzy Logic - MAH603B
Course Type:	ELECTIVE (Departmental)
Course Nature:	Hard
L-T-P-O Structure	4-0-0-0
Objective	The students would be able to understand the concepts of fuzzy sets and fuzzy logics and model vague quantity of numerical and linguistic character, which cannot be described with classical mathematical models.
Outcomes	Enhancement of the ability to solve problems based on fuzzy arithmetic.
Prerequisites	Discrete Mathematics

	Sections	Weightage
Syllabus	A	25%
	B	25%
	C	25%
	D	25%
	TOTAL	**100%**

SECTION A

Crisp sets and Fuzzy sets - Introduction, crisp sets an overview, the notion of fuzzy sets basic concepts of fuzzy sets, membership functions, methods of generating membership functions, defuzzification methods- operations on fuzzy sets - fuzzy complement, fuzzy union, fuzzy intersection, combinations of operations, general aggregation operations.

SECTION B

Fuzzy arithmetic and Fuzzy relations: Fuzzy numbers- arithmetic operations on intervals- arithmetic operations on fuzzy numbers- fuzzy equations, Fuzzy relations: binary relations, binary relations on a single set, equivalence and similarity relations, compatibility or tolerance relations.

SECTION C

Fuzzy measures, belief and plausibility measures, probability measures, possibility and necessity measures, possibility distribution - relationship among classes of fuzzy measures.

SECTION D

Fuzzy Logic and Applications: Classical logic: an overview, fuzzy logic, approximate reasoning- other forms of implication operations - other forms of the composition operations, fuzzy decision making fuzzy logic in database and information systems - fuzzy pattern recognition, fuzzy control systems, fuzzy optimization.

Recommended Books:

1. G. J. Klir& T. A. Folger , Fuzzy sets, Uncertainty and Information, Prentice Hall of India, 1988.
2. H.J. Zimmerman, Fuzzy Set theory and its Applications, Kluwer Academic Publishers, 4nd Edn.,2001.
3. G. J. Klir& B. Yuan, Fuzzy sets and Fuzzy logic: Theory and Applications, Prentice Hall ofIndia, 1997.
4. H. T. Nguyen & E. A. Walker, First Course in Fuzzy Logic, Chapman & Hall, 2nd Edn., 1999.
5. J. M. Mendel, Uncertain Rule, Based Fuzzy Logic Systems; Introduction and New Directions, PH PTR, 2000.
6. T. J. Ross, Fuzzy Logic with Engineering Applications, McGraw Hill, 1997.
8. J. J. Buckley, E. Eslami, An Introduction to Fuzzy logic and Fuzzy sets, Springer, 2002.

Course Title/ Code	OPERATIONS RESEARCH- MAH604B
Course Type	ELECTIVE (Departmental)
Course Nature	Hard
L-P-O Structure	4-0-0-0
Objective	To familiarize students to use quantitative methods and techniques for effective decisions–making; model formulation and applications that are used in solving business decision problems.
Outcome	The student would be able to apply the concepts of Operations Research in various real time problems.
Prerequisites	NA

	Sections	Weightage
Syllabus	A	25%
	B	25%
	C	25%
	D	25%
	TOTAL	100%

SECTION A

Convex set theory: Linear independence and dependence of vectors, Convex sets, Convex hull, Extreme points, convex polyhedron, Hyper planes and Half-spaces, Convex cones, supporting hyperplane, Linear programming problem, feasible solution of LPP, basic feasible solution,

SECTION B

Introduction to Linear Programming: Linear Programming Problem Formulation, Graphical solution, Simplex Algorithm, Artificial variables techniques: Two–phase method & Big-M method , Duality theory, Dual-simplex method.

SECTION C

Transportation problem & Assignment problems: Formulation of Transportation problem,Optimal solution, Unbalanced transportation problem, Degeneracy, Formulation of Assignment problem, Optimal solution, Variants of Assignment Problem- Traveling Salesman problem.

SECTION D

Sequencing: Sequencing problems: Introduction, assumptions, processing of n - jobs through 2 machines, Processing of n - jobs through 3 machines. Processing of n - jobs through m- machines. Game Theory: Introduction, Two person zero sum game, Pure strategies, Maximin & minimax principle, Game with saddle points, Mixed strategies, Game without saddle points, Dominance rule.

Recommended Books:

1. H. A. Taha, Operations Research an introduction, Pearson India
2. J. K. Sharma, Operations Research theory & applications, 5th edition, Macmillian India Ltd-new Delhi
3. P.K. Gupta & D. S. Hira, Operations Research, S. Chand.

Course Title/ Code	GRAPH THEORY- MAH605B
Course Type	ELECTIVE (Departmental)
Course Nature	Hard
L-P-O Structure	4-0-0-0
Objective	To familiarize students with the main concepts of graph theory, graph representations and the basic classes of graphs.
Outcomes	The objective of the course is to introduce students with the fundamental concepts in Graph Theory, with a sense of some its modern applications.
Prerequisites	NA

	Sections	Weightage
Syllabus	A	25%
	B	25%
	C	25%
	D	25%
	TOTAL	100%

SECTION A

Graphs: Basic concepts in graph theory, walks, paths and circuits in a graph, connected graphs and components, degrees, operations on graphs, special graphs, isomorphic graphs, blocks, cut-points, bridges and blocks, block graph sand cut-point graphs.

SECTION B

Trees: Elementary properties of trees, minimally connected graph, distance, centers and centroids in a tree, radius and diameter, spanning trees, rank and nullity, block-cut point trees, independent cycles and co-cycles.

SECTION C

Connectivity and Traversability: Connectivity and line connectivity, Menger's theorems, Eulerian graph, Hamiltonian graphs, travelling salesman problem, shortest path.

SECTION D

Planarity and Coloring: Planar graphs, outer planar graphs, Euler's formula, Kuratowski's theorem, dual graphs, self dua graphs, chromatic number, five color theorem, chromatic polynomial.

Recommended Books:

1. R. Balakrishnan and K. Ranganathan, A Text Book of Graph Theory, Springer, 2000.
2. B. Bollobas, Modem Graph Theory, Springer,2002.
4. G. Chartrand and L. Lesniak, GraphsandDigraphs,4th Edit., Chapman &Hall (CRC),2005.
5. F. Iarary, GraphTheory, Narosa Publishing House, NewDelhi,200I.
6. *R.I.* Wilson, IntroductiontoGraphTheory,4thEdit. , Addison Wesley,1996.

Course Title/ Code	DESIGN OF EXPERIMENTS- MAH606B
Course Type	Core (Departmental)
Course Nature	Hard
L-P-O Structure	4-0-0-0
Objective	To equip students with the tool of designing experiments in a valid, efficient and economical way.
Outcomes	The student would be able to (i) understand the issues and principles of Design of Experiments (DOE) (ii) understand experimentation is a process (iii) list the guidelines for designing experiments (iv) construct BIBD
Prerequisites	N.A

Syllabus	Sections	Weightage
	A	25%
	B	25%
	C	25%
	D	25%
	TOTAL	100%

SECTION – A

Review of linear estimation and basic designs: ANOVA: Fixed effect models (2-way classification with unequal and proportional number of observations per cell), Random and Mixed effect models (2-way classification with m (>1) observations per cell).

SECTION – B

Incomplete Block Designs: Incomplete Block Designs, Concepts of Connectedness, Orthogonality and Balance. Intrablock analysis of General Incomplete Block design. B.I.B designs with and without recovery of interblock information. Elimination of heterogeneity in two directions.

SECTION – C

Factorial Experiments: Symmetrical factorial experiments (sm, where s is a prime or a prime power), Confounding in sm factorial experiments, sk-p fractional factorial where s is a prime or a prime power. Split-plot experiments.

SECTION – D

Construction of B.I.B.D: Finite fields, Finite Geometries- Projective geometry and Euclidean geometry. Construction of complete set of mutually orthogonal latin squares.
Construction of B.I.B.D. using finite Abelian groups, MOLS, finite geometry and method of differences.

Recommended Books:

1. Chakrabarti, M.C. (1962). Mathematics of Design and Analysis of Experiments, Asia Publishing House, Bombay.
2. Das, M.N. and Giri, N.C. (1986). Design and Analysis of Experiments, Wiley Eastern Limited.
3. Dean, A. and Voss, D. (1999). Design and Analysis of Experiments, Springer. First Indian Reprint 2006. 4. Dey, A. (1986). Theory of Block Designs, John Wiley & Sons.
4. Hinkelmann, K. and Kempthorne, O. (2005). Design and Analysis of Experiments, Vol. 2: Advanced Experimental Design, John Wiley & Sons.
7. John, P.W.M. (1971). Statistical Design and Analysis of Experiments, Macmillan Co., New York.
8. Kshirsagar, A.M. (1983). A Course in Linear Models, Marcel Dekker, Inc., N.Y.
9. Montgomery, D.C. (2005). Design and Analysis of Experiments, Sixth Edition, John Wiley & Sons.

Course Title/ Code	FOURIER ANALYSIS- MAH607B
Course Type	Elective (Departmental)
Course Nature	Hard
L-P-O Structure	4-0-0-0
Objective	To familiarize students with Fourier series, orthogonality, completeness, Fourier Transform, tempered distributions.
Outcome	The student would be able to apply the concepts of discrete Fourier series, integral Fourier and Inverse - Fourier transforms for solving mathematical problems.
Prerequisites	Functional Analysis (MAH509B)

	Sections	Weightage
Syllabus	A	25%
	B	25%
	C	25%
	D	25%
	TOTAL	100%

SECTION A

Basic Properties of Fourier series: Uniqueness of Fourier Series, Convolutions, Cesaro and Abel Summability, Fejer's theorem, Poisson Kernel and Dirichlet problem in the unit disc, Mean square Convergence, Example of Continuous functions with divergent Fourier series.

SECTION B

L2-theory: Orthogonality, Completeness, ON systems, Applications to partial differential equations, Separation of variables, Something about Sturm-Liouville theory and Eigen function expansions.

SECTION C

Distributions and Fourier Transforms: Calculus of Distributions, Schwartz class of rapidly decreasing functions, Fourier transforms of rapidly decreasing functions, Riemann Lebesgue lemma, Fourier Inversion Theorem, Fourier transforms of Gaussians.

SECTION D

Tempered Distributions: Fourier transforms of tempered distributions, Convolutions, Applications to PDEs (Laplace, Heat and Wave Equations), Schrodinger-Equation and Uncertainty principle. Paley-Wienner Theorems, Poisson Summation Formula: Radial Fourier transforms and Bessel's functions, Hermite functions.

Recommended Books:

1. R. Strichartz, A Guide to Distributions and Fourier Transforms, CRC Press.
2. E.M. Stein and R. Shakarchi, Fourier Analysis: An Introduction, Princeton University Press, Princeton 2003.
3. Fourier Analysis by Javier Duoandicoetxea. AMS Graduate Studies in Mathematics Volume 29, 2001
4. Classical and Modern Fourier Analysis by Loukas Grafakos. Prentice Hall 2003

Course Title/ Code	DIFFERENTIABLE MANIFOLDS – MAH608B
Course Type:	Core (Departmental)
Course Nature:	Hard
L-P-O Structure	4-0-0-0
Objective	To familiarize students with tangent vectors, cotangent vectors, immersion, submersions, connections, geodesicness
Outcome	The student would be able to apply the concepts of smooth map, tangent, cotangents, geodesicness to solve the mathematical problems
Prerequisites	Differential Geometry(MAH510B)

	Sections	Weightage
Syllabus	A	25%
	B	25%
	C	25%
	D	25%
	TOTAL	100%

SECTION A

Differentiable manifolds, Definition and examples, Smooth maps between two smooth manifolds, Tangent vector and tangent space at a point on a manifold, Tangent bundle of manifold.

SECTION B

Vector fields, Lie bracket, Jacobian of a smooth map, One parameter group of transformation, Integral curves on manifolds, Involutive distribution, Lie derivative

SECTION C

Cotangent space, Differential forms, Pullback of 1-form, Tensor fields, Exterior derivatives, Immersions, Submersions and submanifolds examples.

SECTION D

Connections, Geodesics, Covariant differentiations, Torsion, curvature, Structure equations of Cartan, Bianchi identities, Riemannian metric, Riemannian manifold, Riemannian connection, Riemannian curvature, Sectional curvature, Ricci curvature and Scalar curvature.

Recommended Books:

1. B.O. Neill, Elementary Differential Geometry, Academic Publishers, 2006.
2. U.C. De and A. Shahikh, Differentiable Manifolds, Narosa Publications, 2007.
3. S. Kumaresan, A Course in Differential Geometry and Lie Groups, Hindustan Book Agency, 2002.
4. Boothby, An Introduction to Differentiable Manifolds and Riemannian Geometry, Academic Press, 2002.
5. Gerardo F. Torres del Castillo, Differentiable Manifolds, Birkhauser, 2012.
6. M. P. DoCarmo, Riemannian Geometry, Brikhauser, 2013.

Course Title/ Code	WAVELETS- MAH609B
Course Type	Elective (Departmental)
Course Nature	Hard
L-P-O Structure	4-0-0-0
Objective	The student would be able to apply the concepts of theory of wavelets for solving problems in mathematics and image & signal processing.
Outcome	The student would be able to understand the fundamental concepts which has applications in the development of tools and techniques which may be used in image & signal processing, communication techniques, graphical algorithms and numerical analysis.
Prerequisites	Measure Theory (MAH504B) and Functional Analysis(MAH509B)

	Sections	Weightage
Syllabus	A	25%
	B	25%
	C	25%
	D	25%
	TOTAL	100%

SECTION A

Fourier Transform in $L^1(R)$, $L^2(R)$ **and Discrete Fourier Transform**

Stationary and non-stationary signals, Signal representation using basis and frames, Brief introduction to Fourier transform in $L^1(R)$ and $L^2(R)$, Inverse Fourier Transform on R, Properties of Fourier transform, parseval's relation, plancherel formula, convolution, Discrete Fourier Transform in $l^2(Z_N)$ and its properties, Fast Fourier transform, sampling theorem, Uncertainty Principle.

SECTION B

Time Frequency Analysis and Wavelet Transforms:
Localization/Isolation in time and frequency Time-frequency analysis, Short Time Fourier Transform (STFT) and windowed Fourier Transform, Wavelets, Wavelet transform-A first level introduction, Continuous Wavelet Transform, Properties of wavelets used in continuous wavelet transform, Continuous versus discrete wavelet transform, Discrete Wavelet Transform

SECTION C

Wavelets & MRA:
Wavelets on R: $\boldsymbol{L^1(R)}$&$\boldsymbol{L^2(R)}$, Orthonormal Wavelets, Characterization of Orthonormal Wavelets, Some standard Wavelets (Haar Wavelets, Shannon Wavelets, Journe's Wavelets, Meyer Wavelets, Daubechies' family of wavelets in detail), Multiresolution Analysis, Father Wavelets & Mother Wavelets, Construction of Wavelets through MRA, Scaling function.

SECTION D

Characterization of Wavelets:
Characterization of Scaling function, Low-pass filter & High Pass filter, Characterizations of Low & High pass filter, Band limited Wavelets, Compactly Supported Wavelets, Minimally-Supported Frequency (MSF) Wavelets, Wavelet Sets, Characterization of MSF wavelets & Wavelet Sets, Dimension Functions, Characterization of MRA Wavelets.

Recommended Books:

1. Michael W. Frazier, An Introduction to Wavelets through Linear Algebra, Springer
2. Hernandez & Weiss, A First Course of Wavelets, CRC Press
3. Charles K. Chui, An Introduction to Wavelets.
4. George Bachman, Lawrence Narici, Edward Beckenstein, Fourier and Wavelet Analysis, springer.
5. C. S. Burrus, Ramose and A. Gopinath, Introduction to Wavelets and Wavelet Transform, Prentice Hall Inc.

Wavelet links:

1. http://users.rowan.edu/~polikar/WAVELETS/WTtutorial.html
2. http://www.wavelet.org/
3. http://www.math.hawaii.edu/~dave/Web/Amara's%20Wavelet%20Page.htm

Course Title/ Code	TOPOLOGY-II-MAH610B
Course Type:	Elective (Departmental)
Course Nature:	Hard
L-P-O Structure	4-0-0-0
Objective	To familiarize students with concepts of topological spaces, separation Axioms, nets and filters

Outcome	The student would be able to conceptualize and apply the concepts of Topological Spaces in research.
Pre-requisites	Topology-I (MAH502B)

	Sections	Weightage
Syllabus	A	25%
	B	25%
	C	25%
	D	25%
	TOTAL	100%

SECTION A

Tychonoff product topology in term of standard sub-base and its characterizations, Projection maps, Separation axioms and product spaces, Connectedness, Compactness, Countability of product spaces.

SECTION B

Nets and filters, Topology and convergence of nets, Housdorffness and nets , Compactness, Nets Filter and their Convergence.

SECTION C

Canonical way of converting nets to filters and vice-versa, ultra filters and compactness. Stone-Cech compactification. Application of Urysohn's Lemma, The Stone–Cech Compactification, The Stone–Weierstrass Theorems.

SECTION D

Homotopy of paths, Fundamental group, Covering spaces, The fundamental group of the circle and fundamental theorem of algebra. Covering of a space, local finiteness, paracompact spaces, Mchaell theorem on characterisation of paracompactness in regular space, Paracompactness as normal, Nagata-Smirnov Metrization theorem.

Recommended Books:

1. James R. Munkres, Topology (2ndEdition) Pearson Education Pve. Ltd., Delhi-2002
2. J. Dugundji , Topology , Prentice Hall of India, New Delhi, 1975.
3. George F.Sinmons, Introduction to Topology and Modern Analysis, McGraw Hill Book Co., 1963
4. K. D. Joshi: Introduction to General Topology (Wiley Eastern Limited).

Course Title/Code	PEDAGOGICAL SKILLS-EDS234
Course Type	Core (Alied)
Course Nature	Soft
L-T-P-O Structure	(1-0-2-0)

Course Outcomes	Students will be able to: 1. Compare and contrast between objectives and outcomes based on revised Blooms Taxonomy. 2. Illustrate a concept based on innovative pedagogies. 3. Exhibit Growth mindset in group activities. 4. Evaluate projects based on Six Thinking hats. 5. Design sessions based on collaborative learning, cooperative learning and experiential learning.

SECTION A

AIMS AND OBJECTIVES OF TEACHING-LEARNING PROCESS

Concept of pedagogy, need of pedagogical skills for a professional, Meaning of learning objectives and learning outcomes, domains of learning, Developing learning objectives; Anderson and Krathwohl's Taxonomy. Writing learning objectives: Remembering, understanding, Applying, Analyzing, Evaluating, Creating. Learning objectives in Constructivist perspective. Blended learning, Flipped Classroom, Technology Enabled Learning, TPACK model.

SECTION B

ROLE OF RESEARCH IN INNOVATIVE PEDAGOGIES

Concept of STEM AND STEAM

Innovative Pedagogies (Constructivism, Collaborative learning, cooperative learning, experiential learning, project based learning), Action Research, concept mapping and its types. Growth Vs Fixed Mindset, Six Thinking Hats-an approach to problem solving, 4C's of 21st century skills. Concept of measurement, assessment and evaluation. Types of assessment. Designing evaluation rubrics.

Reference Books and Readings:

1. Bono, D. (1999). Six Thinking Hats. England: Penguin Books.
2. Krathwohl, D.R., Bloom B.S. and Maria B.B. (1964). *Taxonomy of Educational Objectives, Handbook II, Affective Domain,* New York: David McKay.
3. Lindfors, J. (1984). *How children learn or how teachers teach?* A Profound confusion: Language Arts, 61 (6), 600-606.

Pedagogy Skills Practical (EDS 234)

1. Designing Instructional Objectives.
2. Critical Analysis of Bloom's and Krathwohl Taxonomy.
3. Demonstration of a concept using low or no cost resources.
4. Design rubrics for Evaluation.
5. To conduct Action Research and submit a project report.

Course Title/Code	SCIENTIFIC RESEARCH -II-RDO603
Course Type	Core (Departmental)
Course Nature	Soft
L-T-P-O Structure	(0-0-8-0)

Course Outcomes	The students will be able to critically evaluate the work done by various researchers relevant to The research topic 2. To integrate the relevant theory and practices followed in a logical way and draw appropriate conclusions 3. To understand the research methodologies/approaches/techniques used in the literature 4. To structure and organize the collected information or findings through an appropriate abstract, headings, reference citations and smooth transitions between sections

Section-A

Literature Survey (LS)/Design of Experiment

1.1 Collection of research papers related to previously identified gap/problem (15 papers or more)
1.2 Comprehend and arrange the literature based on the idea framed
1.3 Presenting the collected data and inferring it with the further scope of expansion and Designing the experiment wherever applicable.

Section-B

Structuring of Review Paper and setting up of experimental facility

2.1 Analysis of different approach/methodology adopted by various researchers
2.2 Listing out the components of the paper/ setting up experimental facility w.r.t the problem
2.3 Identification of suitable Journal or Conference
2.4 Formatting/Styling the paper according to the respective template

Section-C

Planning of experiments

3.1 Formulate experimental procedures with Modification of the experimental set-up, if required
3.2 Procurement of materials

Execution of experiments/simulations

4.1 Conduct experiments/ build prototype
4.2 Tabulating and recording data
4.3 Analysis and interpretation of the data
4.4 Comparison of the results with other reported experiments
4.5 Interpretation of observations
4.6 Integration of relevant theory, findings in a structured way and draw appropriate conclusions

Section-D

Departmental Presentation

5.1 Structuring and preparation of PPT
5.2 Mock presentation
5.3 Review on presentation skills and content delivered both
5.4 Incorporating the review comments in the slides

MAP01- Semester-IV

SUBJECT CODES	SUBJECT NAME	**OFFERING DEPARTMENT	*COURSE NATURE (Hard/ Soft/ Workshop/ NTCC)	COURSE TYPE (Core/Elective / University Compulsory)	L	P	O	NO. OF CONTACT HOURS PER WEEK	NO. OF CREDITS
MAH612B	COMPUTATIONAL FLUID DYNAMICS	MA	HARD	ELECTIVE (ANY TWO)	4	0	0	4	8
MAH613B	GENERALISED FUZZY SET THEORY								
MAH614B	ADVANCED OPERATIONS RESEARCH								
MAH615B	CODING THEORY								
MAH616B	STOCHASTIC PROCESSES								
MAH617B	HARMONIC ANALYSIS								
MAH618B	LIGHTLIKE MANIFOLDS								
MAH619B	WAVELETS AND ITS APPLICATIONS								
MAH620B	ALGEBRAIC TOPOLGY								
MAH621B	DYNAMICS OF RIGID BODY								
MAN622B	PROJECT	MA	NTCC	CORE	0	0	10	2	10
TOTAL (L-T-P-O/ CONTACT HOURS/ CREDITS)					8	0	10	10	18

Course Title/ Code	COMPUTATIONAL FLUID DYNAMICS- MAH612B
Course Type	Elective(Departmental)
Course Nature	Hard
L-P-O Structure	4-0-0-0
Objective	To familiarize students with basic concepts of fluid dynamics,
Outcome	The student would be able to apply the concepts of fluid mechanics for solving problems related to fluids.
Prerequisites	NA

	Sections	Weightage
Syllabus	A	25%
	B	25%
	C	25%
	D	25%
	TOTAL	100%

SECTION A

Governing Equations and Boundary Conditions: Basics of computational fluid dynamics – Governing equations of fluid dynamics – Continuity, Momentum and Energy equations – Chemical species transport – Physical boundary conditions – Time-averaged equations for Turbulent Flow – Turbulent–Kinetic Energy Equations – Mathematical behaviour of PDEs on CFD – Elliptic, Parabolic and Hyperbolic equations.

SECTION B

Finite Difference and Finite Volume Methods for Diffusion: Derivation of finite difference equations – Simple Methods – General Methods for first and second order accuracy – Finite volume formulation for steady state One, Two and Three - dimensional diffusion problems –Parabolic equations – Explicit and Implicit schemes – Example problems on elliptic and parabolic equations – Use of Finite Difference and Finite Volume methods.

SECTION C

Finite Volume Method for Convection Diffusion: Steady one-dimensional convection and diffusion – Central, upwind differencing schemes properties of discretization schemes – Conservativeness, Boundedness, Transportiveness, Hybrid, Power-law, QUICK Schemes.

SECTION D

Flow Field Analysis: Finite volume methods -Representation of the pressure gradient term and continuity equation – Staggered grid – Momentum equations – Pressure and Velocity corrections – Pressure Correction equation, SIMPLE algorithm and its variants – PISO Algorithms.
Turbulence Models and Mesh Generation: Turbulence models, mixing length model, Two equation (k-Є) models – High and low Reynolds number models – Structured Grid generation – Unstructured Grid generation – Mesh refinement – Adaptive mesh – Software tools.

Recommended Books:

1. Versteeg, H.K., and Malalasekera, W., “An Introduction to Computational Fluid Dynamics: The finite volume Method”, Pearson Education Ltd.Second Edition, 2007.
2. Ghoshdastidar, P.S., “Computer Simulation of flow and heat transfer”, Tata McGraw Hill Publishing Company Ltd., 1998.
3. Patankar, S.V. “Numerical Heat Transfer and Fluid Flow”, Hemisphere Publishing Corporation, 2004.
4. Chung, T.J. “Computational Fluid Dynamics”, Cambridge University, Press, 2002.
5. Ghoshdastidar P.S., “Heat Transfer”, Oxford University Press, 2005
6. Muralidhar, K., and Sundararajan, T., “Computational Fluid Flow and Heat Transfer”,Narosa Publishing House, New Delhi, 1995.
7. Prodip Niyogi, Chakrabarty, S.K., Laha, M.K. “Introduction to Computational Fluid Dynamics”, Pearson Education, 2005.
8. Anil W. Date “Introduction to Computational Fluid Dynamics” Cambridge University Press, 2005.

Course Title/ Code	GENERALISED FUZZY SET THEORY-MAH613B
Course Type:	Elective(Departmental)

Course Nature:	Hard
L-T-P-O Structure	4-0-0-0
Objective	The students would be able to understand the concepts of Generalizedset structures such as Fuzzy sets, Multisets, Rough sets,Soft sets, Rough multisets, Genuine sets Information systems
Outcomes	Students get an advanced level understanding of Generalized set structures such as Fuzzy sets, Multisets, Rough sets, Soft sets, Rough multisets, Genuine sets Information systems.
Pre-requisites	Fuzzy Sets & Fuzzy Logic (MAH603B)

	Sections	Weightage
Syllabus	A	25%
	B	25%
	C	25%
	D	25%
	TOTAL	100%

SECTION A

An overview of basic operations on Fuzzy sets and Multisets, Multiset relations, Compositions, equivalence multiset relations and partitions of multisets, Multiset functions, Fuzzy Multisets.

SECTION B

Rough sets, Approximations of a set, Properties of Approximations, Rough membership function, Rough sets and Reasoning from data: Information systems, Decision tables, Dependency of attributes, Reduction of attributes, Indiscernibility matrices and functions.

SECTION C

Soft sets, Tabular representation of a soft set, Operations with Soft sets: soft subset, complement of a soft set, null and absolute soft sets, AND and OR operations, Union and intersection of soft sets, De-Morgan laws, Applications and soft analysis.

SECTION -D

Fuzzy soft sets, Operations on fuzzy soft sets, Soft fuzzy sets and its properties, Fuzzy rough sets and rough fuzzy sets, Rough multisets, Genuine sets, Applications.

Recommended Books:

1. Bing-Yuan Cao, Fuzzy Information and Engineering, Springer, 2007.
2. K. P. Girish & J. J.Sunil, Relations and Functions in Multiset context, Information Sciences' 179 (2009) 758 - 768.
3. J. F. Peters & A. Skowron, Transactions on Rough Sets I, Springer, 2004.
5. L. Polkowski, Rough Sets: Mathematical Foundations, Springer, 2002.
6. M. Demirci, Genuine Sets, Fuzzy Sets and Systems, 105 (1999) 377-384.
7. H.J. Zimmerman, Fuzzy set Theory and its Applications, Allied Publishers Ltd., 2000.

Course Title/ Code	ADVANCED OPERATIONS RESEARCH- MAH614B

Course Type	Elective (Departmental)
Course Nature	Hard
L-P-O Structure	4-0-0-0
Objective	The student would be able to apply the concepts of Operations Research in various real time problems.
Outcome	Applications of the different methods and techniques of Operations Research in practice. A collection of real-life cases will be discussed during the course, and a range of solution approaches will be highlighted.
Prerequisites	Operations Research (MAH604B)

Syllabus	Sections	Weightage
	A	25%
	B	25%
	C	25%
	D	25%
	TOTAL	100%

SECTION A

Project management- PERT & CPM: Significance, Phases of project management, PERT /CPM networkcomponents and precedence relationship, Critical path analysis, Forward and backward pass methods, Slack of an activity and event, Project scheduling with uncertain activity times, Estimation of project completion time, Project time –cost trade off, Updating of the project progress.

SECTION B

Replacement: Introduction, Replacement of items that deteriorate with time – when money value is not counted andcounted–Replacement of items that fail completely, Group replacement, Staffing problem, Equipment renewal problem.

SECTION C

Queuing Theory: Introduction, Single Channel, Poisson arrivals, Exponential service times – with infinite population and finite population models, Multichannel, Poisson arrivals, exponential service times with infinite population single channel Poisson arrivals.

SECTION D

Quadratic Programming: Wolfe's method, Complementary pivot algorithm, Duality in quadratic programming.

Recommended Books:

1. H. A. Taha, Operations Research an introduction, Pearson India
2. J. K. Sharma, Operations Research theory & applications, 5th edition, Macmillian India Ltd-new Delhi
3. P.K. Gupta &D. S. Hira, Operations Research, S. Chand.

COURSE TITLE/ CODE	CODING THEORY - MAH615B

Course Type	Elective
Course Nature	Hard
L-T-P-O Structure	4-0-0-0
Objective	Students would be able to: • To equip students with the basic understanding of the fundamental concept of entropy and information as they are used in communications. • To enhance knowledge of probabilities, entropy, measures of information. • To guide the student through the implications and consequences of fundamental theories and laws of information theory and coding theory with reference to the application in modern communication and computer systems
Outcomes	This course will enable the students to: Study simple ideal statistical communication models. Understand the development of codes for transmission and detection of information. Learn about the input and output of a signal via transmission channel. Study detection and correction of errors during transmission. Represent a linear code by matrices - encoding and decoding
Pre-requisites	Group Theory

	Sections	Weightage
SYLLABUS	A	25%
	B	25%
	C	25%
	D	25%
	Total	100%

SECTION A

Concepts of Information Theory: Communication processes, A model of communication system, A quantitative measure of information, Binary unit of information, A measure of uncertainty, *H* function as a measure of uncertainty, Sources and binary sources, Measure of information for two-dimensional discrete finite probability schemes.

SECTION B

Entropy Function : A sketch of communication network, Entropy, Basic relationship among different entropies, A measure of mutual information, Interpretation of Shannon's fundamental inequalities; Redundancy, efficiency, and channel capacity; Binary symmetric channel, Binary erasure channel, Uniqueness of the entropy function, Joint entropy and conditional entropy, Relative entropy and mutual information, Chain rules for entropy, Conditional relative entropy and conditional mutual information, Jensen's inequality and its characterizations, The log sum inequality and its applications.

SECTION C

Concepts of Coding: Block codes, hamming distance, Maximum likelihood decoding, Levels of error handling, Error correction, Error detection, Erasure correction, Construction of finite fields, Linear codes, Matrix representation of linear codes, Hamming codes.

SECTION D

Bounds of Codes: Orthogonality relation, Encoding and decoding of linear codes, the singleton bound and maximum distance separable codes, The sphere-packing bound and perfect codes, The Gilbert-Varshamov bound, MacWilliams' identities.

Cyclic Codes :Definition and examples of cyclic codes, Generator polynomial and check polynomial, Generator matrix and check matrix, Bose-Chaudhuri-Hocquenghem (BCH) code as a cyclic code.

Recommended Books:

1. Robert B. Ash, (2014). Information Theory. Dover Publications.
2. Thomas M. Cover & Joy A. Thomas (2013). Elements of Information Theory (2nd edition). Wiley India Pvt. Ltd.
4. Joseph A. Gallian (2017). Contemporary Abstract Algebra (9th edition), Cengage.
5. Fazlollah M. Reza, (2003). An Introduction to Information Theory. Dover Publications.
6. Ron M. Roth (2007). Introduction to Coding Theory. Cambridge University Press.
7. Claude E. Shannon & Warren Weaver (1969). The Mathematical Theory of Communication. The University of Illinios Press.

Course Title/ Code	

	STOCHASTIC PROCESSES- MAH616B
Course Type	Core (Departmental)
Course Nature	Hard
L-P-O Structure	4-0-0-0
Objective	To familiarize students with mathematical theory of random variables and random processes and applications.
Outcomes	The student would be able to (i) Illustrate and formulate fundamental probability distribution and density functions, as well as functions of random variables (ii) Analyze continuous and discrete-time random processes (iii) Apply the theory of stochastic processes to analyze linear systems (iv) Apply the above knowledge to solve basic problems in filtering, prediction and smoothing
Prerequisites	N.A

	Sections	Weightage
Syllabus	A	25%
	B	25%
	C	25%
	D	25%
	TOTAL	100%

SECTION A

Poisson process, Brownian motion process, Thermal noise, Markov-shot noise, Two-valued processes. Model for system reliability.

SECTION B

Mean value function and covariance kernel of the Wiener and Poisson processes. Increment process of a Poisson process, Stationary and evolutionary processes. Compound distributions, Total progeny in branching processes.

SECTION C

Time series as discrete parameter stochastic process. Auto covariance and auto correlation functions and their properties. Detailed study of the stationary processes: Moving average (MA), Auto regressive (AR), ARMA and ARIMA models. Box-Jenkins models. Discussion (without proof) of estimation of mean, auto covariance and auto correlation functions under large sample theory.

SECTION D

Choice of AR and MA periods. Estimation of ARIMA model parameters. Smoothing spectral analysis of weakly stationary process. Periodo gram and correlogram analysis. Filter and transfer functions. Problems associated with estimation of spectral densities. Forecasting: Exponential and adaptive Smoothing methods.

Recommended Books:

1. Bhat, B.R. (2000). Stochastic Models- Analysis and Applications, New Age International Publishers.
2. Judge, G.C., Hill, R,C. Griffiths, W.E., Lutkepohl, H. and Lee, T-C. (1988). Introduction to the Theory and Practice of Econometrics, Second Edition, John Wiley & Sons.
3. Kendall, M.G. and Stuart, A. (1968). The Advanced Theory of Statistics (Vol. III), Second Edition, Charles Griffin.
4. Kmenta, J. (1986). Elements of Econometrics, Second Edition, Mac millan.
5. Medhi, J. (1994). Stochastic Processes, Second Edition, Wiley Eastern, New Delhi
6. Montgomery, D.C. and Johnson, L.A. (1976). Forecasting and Time Series Analysis, Mc Graw Hill, New York .

Course Title/ Code	Harmonic Analysis-MAH617B
Course Type:	Elective (Departmental)
Course Nature:	Hard
L-P-O Structure	4-0-0-0
Objective	This module brings together methods learned in algebra, group theory and analysis courses to introduce the students to harmonic analysis. Harmonic analysis extends key ideas of Fourier analysis from Euclidean spaces to general topological groups.
Outcome	Having successfully completed this module you will be able to: • Explain the concept of Haar measure and identify Haar measures for the group of the integers, the reals under addition and multiplication, the torus, and the ax+b group. • Define Banach algebra and list main examples. • State the Gelfand-Naimark theorem and use it to identify the C* algebra of the groups Rn and Zn. • Explain the concept of Pontryagin duality and the connection with the Fourier series and Fourier transform. • Use the Pontryagin duality to identify duals of examples of locally compact abelian groups.q
Prerequisites	Functional Analysis (MAH509B), Fourier Analysis(MAH607B)

SECTION A

Groups and Homogenous spaces, linear Lie groups, Computation of Haar measures on some known examples, Convolution Various function spaces.

SECTION B

Harmonic Analysis over Torus and Euclidean spaces. Generalities about locally compact abelian groups, which includes Fourier Inversion Formula, Bochner's theorem.

SECTION C

Basic Representation Theory, Induced representations, Positive Definite functions, Schur's lemma, Naimark Theorem. Peter-Weyl Theory of compact groups- Examples: Unitary groups, Orthogonal groups.

SECTION D

Abstract Theory of Gelfand Paris, Spherical Fourier Transforms, Plancherel-Godement Theorem, Inverse Sperical Fourier Transforms, Compact Gelfand Pair. Representation Theory of Heisenberg group, Gelfand pair consisting of Heisenberg group and Unitary group. Associated Plancherel-Godment Theorem, Special functions.

Recommended Books:

1. J. Faraut. Analysis on Lie Groups: An Introduction. Cambridge Studies in Advanced Mathematics. Cambridge University Press, 2008.
2. G. Folland, A course in abstarct harmonic analysis, CRC Press, 1994.
3. Y. Katznelson: Introduction to Harmonic Analysis J. Wiley and Sons, 1968
4. Fourier Analysis by Javier Duoandicoetxea. AMS Graduate Studies in Mathematics Volume 29, 2001
5. Classical and Modern Fourier Analysis by Loukas Grafakos. Prentice Hall 2003
6. Harmonic Analysis. Real-variable methods, orthogonality, and oscillatory integrals by E. Stein. Princeton University Series 43, 1993.

Course Title/ Code	LIGHTLIKE MANIFOLDS – MAH618B
Course Type	Core (Departmental)
Course Nature	Hard
L-P-O Structure	4-0-0-0
Objective	To familiarize students with the concept of indefinite metric, semi-Riemannian manifolds, lightlike manifolds.
Outcome	The student would be able to apply the concepts of semi-Riemannian manifolds and lightlike submanifolds manifolds to prove and solve different types mathematical theorems and problems.
Prerequisites	Differentiable manifolds(MAH608B)

	Sections	Weightage
Syllabus	A	25%
	B	25%
	C	25%
	D	25%
	TOTAL	100%

SECTION A

Semi- Riemannian manifolds: Metric tensors and isometries, Parallel transport, connections, and derivative operators · **Curvature**: Riemannian, Ricci, sectional, scalar, Geodesics, Cartan's Structure Equations.

SECTION B

Semi-Riemannian Manifolds: Tangent and normals**,** induced connections, geodesic, totally geodesic.
Hypersurfaces: Hyperquadrics, codazzi equations, totally umbilical hypersurfaces, Normal connection, congruence theorem, isometric immersion.

SECTION C

Lightlike Hypersurfaces: Basic general results, Screen conformal hyper surfaces, Unique existence of screen distributions, Induced scalar curvature, Lightlike Einstein hypersurfaces, Semi-symmetric hypersurfaces.

SECTION D

Lightlike Submanifolds: Half lightlike submanifolds- Unique existence of screen distributions, Totally umbilical submanifolds, Screen conformal submanifolds, lightlike Submanifolds of indefinite Kaehler manifolds, lightlike submanifolds of Sasakian manifolds.

Recommended Books:

1. K. L. Duggal and A. Bejancu, Lightlike Submanifolds of Semi-Riemannian Manifolds and Applications, vol. 364 of Mathematics and Its Applications, Kluwer Academic Publishers, Dordrecht, The Netherlands, 1996.
2. D. N. Kupeli, Singular Semi-Riemannian Geometry, vol. 366 of Mathematics and Its Applications, Kluwer Academic Publishers, Dordrecht, The Netherlands, 1996.
3. K. L. Duggal and A. Bejancu, Lightlike submanifolds of semi-Riemannian manifolds and applications, vol. 364 of Mathematics and its Applications, Kluwer Academic Publishers Group, Dordrecht, 1996.

Course Title/ Code	WAVELETS AND ITS APPLICATIONS-MAH619B
Course Type:	Elective (Departmental)
Course Nature:	Hard
L-P-O Structure	4-0-0-0
Objective	The student would be able to apply the concepts of theory of wavelets for solving problems in mathematics signal& image processing.
Outcome	The student would be able to understand the fundamental concepts which has applications in the development of tools and techniques which may be used in signal theory, communication techniques, graphical algorithms and numerical analysis.
Prerequisites	Wavelets(MAH609B)

	Sections	Weightage
Syllabus	A	25%
	B	25%
	C	25%
	D	25%
	TOTAL	100%

SECTION A

Discrete Wavelet Transform and Relation to Filter Banks:
Signal decomposition (Analysis), Relation with filter banks, Frequency response, Signal reconstruction: Synthesis from coarse scale to fine scale, Upsampling and filtering, Perfect reconstruction filters, QMF conditions, Computing initial s_{j+1} coefficients, Concepts of Multi-Resolution Analysis (MRA) and Multi-rate signal processing.

SECTION B

Alternative Wavelet Representations:
Introduction, Bi-orthogonal wavelet bases, Filtering relationship for bi-orthogonal filters, Examples of bi-orthogonal scaling functions and wavelets. 2-D wavelets.

SECTION C

Non-separable multidimensional wavelets:
Non-separable multidimensional wavelets, wavelet packets. Wavelets Transform and Data Compression: Introduction, transform coding, DTWT for image compression (i) Image compression using DTWT and run-length encoding

SECTION D

Applications of Wavelets:
Signal and Image compression, Detection of signal changes, analysis and classification of audio signals using CWT, Wavelet based signal de-noising and energy compaction, Wavelets in adaptive filtering, Adaptive wavelet techniques in signal acquisition, coding and lossy transmission, Digital Communication and Multicarrier Modulation, Trans multiplexers, Image fusion, Edge Detection and object isolation.

Recommended Books:

1. A Wavelet Tour of Signal Processing, 2nd edition, S. Mallat, Academic Press, 1999.
2. Wavelets and Sub band Coding, M. Vetterli and J. Kovacevic, Prentice Hall, 1995.
3. Wavelet transforms: Introduction, Theory and applications, Raghuveer rao and Ajit S.Bopardikar, Pearson Education Asia, 2000.
4. Fundamentals of Wavelets: Theory, Algorithms, and Applications, J.C. Goswami and A.K. Chan, 2nd ed., Wiley, 2011.
5. Wavelets and their Applications, Michel Misiti, Yves Misiti, Georges Oppenheim, Jean-Michel Poggi, John Wiley & Sons, 2010 .
6. A premier on Wavelets and their scientific applications, J S Walker, CRC press, 2002.
7. Wavelets and signal processing: An application-based introduction, Stark, Springer, 2005.
8. A friendly guide to Wavelets, Gerald keiser, Springer, 2011.
9. Multirate Systems and Filter Banks, P. P. Vaidyanathan, Pearson Education, 2004.
10. Wavelets: from math too practice, Desanka.P.Radunovik, springer, 2009.
11. Insight into wavelets from theory to practice, K P Soman and KL Ramachandran, PHI, 2008.

Course Title/ Code	ALGEBRAIC TOPOLOGY- MAH620B
Course Type:	Elective (Departmental)
Course Nature:	Hard
L-P-O Structure	4-0-0-0
Objective	To familiarize students with topological groups, Homotopies, Deck transform etc.
Outcome	The student would be able to conceptualize and apply the concepts of Algebraic topology in research.
Prerequisites	Topology I (MAH502B) & Topology II (MAH610B)

	Sections	Weightage
Syllabus	A	25%
	B	25%
	C	25%
	D	25%
	TOTAL	100%

SECTION A

Introduction, Topological groups, Paths, Homotopies and the fundamental group, Categories and functors, Functorial properties of the fundamental group, Brouwer's theorem and its applications.

SECTION B

Homotopies of maps, Deformation retracts, Fundamental group of the circle, covering projections, Lifting of paths and Homotopies, Action of $\Pi 1(X, x0)$ on the fibers $p^{-1}(x0)$, The lifting criterion.

SECTION C

Deck transformations, Orbit spaces, Fundamental groups of SO(3, R) and SO(4, R), Coproducts and push-outs, Adjunction spaces, The Seifert Van Kampen theorem.

SECTION D

Homology theory, Singular complex of a topological space, The homology groups and there functoriality, Homotopy invariance of homology, Small simplicies, The Mayer Vietoris sequence, Abelianization of the fundamental group, The Mayer Vietoris sequence, Maps of spheres, Relative homology, Excision theorem, Inductive limits, Jordan Brouwer separation theorem.

Recommended Books:

1. Allen Hatcher, Algebraic Topology. Cambridge, UK: Cambridge University Press
2. William S. Massey, A Basic Course in Algebraic Topology. New York, NY: Springer-Verlag
8. Glen Bredon, Topology and Geometry
8. James R. Munkres, Topology (2ndEdition) Pearson Education Pve. Ltd., Delhi-2002.

Course Title/ Code	DYNAMICS OF RIGID BODY- MAH621B
Course Type:	Elective (Departmental)
Course Nature:	Hard
L-P-O Structure	4-0-0-0
Objective	The course aims to develop an understanding of Lagrangian and Hamiltonian which allow simplified treatments of many problems in classical mechanics. The course aims to provide the foundation for the modern understating of dynamics.
Outcome	On successful completion of this course, students should be able to understand the Lagrangian and Hamiltonian formalisms so that they can apply these methods to solve real world problems. Understand the theory of small oscillations and concepts of Motion of rigid body in two & three dimensions.
Prerequisites	NA

SECTION A

Moments and products of inertia, The momental ellipsoid, Equimomental systems Principal axes, D'Alembert's principle, The general equation of motion of a rigid body, Motion of Centre of inertia and motion relative to the centre of inertia.

SECTION B

Motion about the fixed axis, The compound pendulum, Centre of Percussion, Motion of rigid body in two dimensions under finite and impulsive forces.

SECTION C

Conservation of Momentum and Energy for finite as well as impulsive forces, Initial motions, Motion in three dimensions with reference to Euler's dynamics and geometrical equations .

SECTION D

Lagrange's equation, of motion, Energy equation for conservative field, Small oscillations, Hamiltons's principle, Hamilton's equation of motion, Variational principle of least action.

Recommended Books:

1. P. P. Gupta & G.S. Malik, Rigid Dynamics, Krishna's Publishers
2. S.L. Loney, An elementary Treatise on the dynamics of particle and rigid bodies, Cambridge University Press.
3. D. Greenwood, Classical Dynamics, Prentice Hall of India, New Delhi, 1985.
4. H. Goldstein, Classical Mechanics, (2ndEdition) Narosa Publishing House, New Delhi.
9. A.S Gupta, Calculus of variations with –Applications, Prentice Hall of india,1997
10. Synge, J.L., and Griffith, B.A., Principles of Mechanics, Tata McGraw Hill (1971).