ORDINANCE Cum COURSE STRUCTURE

for

POSTGRADUATE DEGREE PROGRAMME: M.A./M.SC.

in

MATHEMATICS

for the

DEPARTMENT OF MATHEMATICS
PROF. RAJENDRA SINGH (RAJJU BHAIYA) INSTITUTE OF PHYSICAL SCIENCES FOR STUDY AND RESEARCH

VEER BAHADUR SINGH PURVANCHAL UNIVERSITY
JAUNPUR, 222003, (U.P.)

Proposed by

BoS COMMITTEE

Dated: Sep 23, 2022

[As per CBCS pattern recommended by UGC]
Effective from Academic Session: 2022-2023

Sr. No.	Paper	Course Code	Paper Title	Nature of Paper	Credit	Marks		
			Semester VII					
						CIA	End Sem.	Total
01.	I	B030701T	Algebra	Theory	4	25	75	100
02.	II	B030702T	Point-Set Topology	Theory	4	25	75	100
03.	III	B030703T	Advanced Complex Analysis	Theory	4	25	75	100
04.	IV	B030704T	Classical Mechanics	Theory	4	25	75	100
05.	V	B030705P	Programming for Mathematics	Practical	4	25	75	100
06.	VI	B030706R	Topic and Supervisor Allocation for Research Project		4	-----		
07.	VII	Any Minor Elective Course to be chosen from a faculty other than the Faculty of Science						

Sr. No.	Paper	Course Code	Paper Title	Nature of Paper	Credit	Marks		
			Semester VIII					
						CIA	End Sem.	Total
01.	I	B030801T	Module Theory	Theory	5	25	75	100
02.	II	B030802T	Linear Integral Equations and Boundary Value Problems	Theory	5	25	75	100
03.	III	B030803T	Advanced Real Analysis	Theory	5	25	75	100
04.	IV	B030804T	Elective Courses	Theory	5	25	75	100
05.	V	B030805R	[Topic and Supervisor Allocation for Research Project] / [Joint Evaluation of Research Project of Semester VII and Semester VIII]		4	The research project will be assessed at the end of Semester VIII out of a maximum of 100 marks.		
06	VI	Any Minor Elective Course to be chosen from a faculty other than the Faculty of Science, if students do not opt for Elective Course in Semester VII.						

Sr. No.	Paper	Course Code	Title of Paper	Nature of Paper	Credit	Marks		
			Semester IX					
						CIA	End Sem.	Total
01.	I	B030901T	Functional Analysis – I	Theory	4	25	75	100
02.	II	B030902T	Measure and Integration	Theory	4	25	75	100
03.	III	B030903T	Elective Courses	Theory	4	25	75	100
04.	IV	B030904T	Elective Courses	Theory	4	25	75	100
05.	V	B030905P	Mathematics Using Mathematica	Practical	4	25	75	100
06.	VI	B030906R	Topic and Supervisor Allocation for Research Project		4	-----		

Sr. No.	Paper	Course Code	Title of Paper	Nature of Paper	Credit	Marks		
			Semester X					
						CIA	End Sem.	Total
01.	I	B031001T	Wavelets	Theory	5	25	75	100
02.	II	B031002T	Elective Courses	Theory	5	25	75	100
03.	III	B031003T	Elective Courses	Theory	5	25	75	100
04.	IV	B031004T	Elective Courses	Theory	5	25	75	100
05.	V	B031005R	[Topic and Supervisor Allocation for Research Project] / [Joint Evaluation of Research Project of Semester IX and Semester X]		4	The research project will be assessed at the end of Semester X out of a maximum of 100 marks.		

Semester wise details of elective courses

Elective Courses [IV Paper/Course Code: B030804T] for Semester VIII :-

Elective 01 - Differentiable Manifold
Elective 02 - Mechanics of Solids - I
Elective 03 - Number Theory

Elective Courses [III Paper/Course Code: B030903T] for Semester IX :-

Elective 01 - Theory of Ordinary Differential Equations
Elective 02 - Galois Theory
Elective 03 - Fuzzy Set Theory and its Applications

Elective Courses [IV Paper/Course Code: B030904T] for Semester IX :-

Elective 01 - Fluid Mechanics
Elective 02 - Commutative Algebra
Elective 03 - Mathematical Modelling

Elective Courses [II Paper/Course Code: B031002T] for Semester X :-

Elective 01 - Advanced Fluid Mechanics
Elective 02 - Representation Theory of Finite Groups
Elective 03 - Measure and Integration – II
Elective 04 - Algebraic Coding Theory

Elective Courses [III Paper/Course Code: B031003T] for Semester X :-

Elective 01 - Special Functions and Lie Theory
Elective 02 - Algebraic Number Theory
Elective 03 - Magnetohydrodynamics
Elective 04 - Mechanics of Solids - II

Elective Courses [IV Paper/Course Code: B031004T] for Semester X :-

Elective 01 - Algebraic Topology
Elective 02 - Functional Analysis - II
Elective 03 - Complex Manifold
Elective 04 - Non-Linear Analysis

SEMESTER VII

Sr. No.	Course/ Paper No.	Course/ Paper Code	Course/Paper Title	Credits	Teaching /Periods (Hours per week)	Maximum Marks		
						Continuous Internal Assessment*	End-Semester Examination	Total
1.	First	B030701T	Algebra	4	4	25	75	100
2.	Second	B030702T	Point-Set Topology	4	4	25	75	100
3.	Third	B030703T	Advanced Complex Analysis	4	4	25	75	100
4.	Fourth	B030704T	Classical Mechanics	4	4	25	75	100
5.	Fifth	B030705P	Basic Programming For Mathematics	4	8	25	75	100
6.	Sixth	B030706R	Research Project	4	4	According to NEP-2020**		
7.	Seventh	--	Minor Elective Course*	--	--	--	--	

Remark:

(a) ***If the student opts for a Minor Elective Paper in this semester(Semester VII), all the information(like Course/Paper Number, Course/Paper Code, Course/Paper Title, Credits, etc.) regarding the Minor Elective Paper will be as per the NEP-2020.**

(b) ****Students in the fourth year of higher education shall submit a joint dissertation (project report/dissertation) of the research project undertaken in both semesters(Semester VII and Semester VIII) at the end of the year, which will be assessed jointly out of 100 marks by the supervisor and the external examiner at the end of the year.**

First Paper, Seventh Semester/Fourth Year, M.A./M.Sc.(Mathematics)

Program: Graduation With Research Degree Program / PG Degree Program	Class: M.A./M.Sc.	
	Year: Fourth	Semester: Seventh
Subject: Mathematics		
Course Code: B030701T	Course Title: Algebra	

Course Outcomes

After the completion of the course, students are expected to have the ability to :

1. Understand the concepts of group action, stabilizer (Isotropy) subgroups and orbit decomposition, translation and conjugation actions, transitive and effective actions.
2. Know about the *p*-groups, Sylow's theorems, normal series, composition series, Commutator or derived subgroups, Commutator series, solvable groups, nilpotent groups.
3. Learn about class equation, Burnside theorem, Sylow's theorems and its applications, Schreier's refinement theorem, Zassenhaus' lemma.
4. Know about the Jordan-Hölder's theorem, Internal and External direct products and their relationship, Indecomposability.

Credits: 4	Maximum Marks: 25+75 (CIA+UE)
Nature of Course: Theory(Compulsory)	Minimum Passing Marks: 36 (CIA+UE)
Total Number of Lectures-Tutorials-Practicals (In Hours per week): L-T-P: 4-0-0	

Course Contents

Unit	Topics	L-T-P
I	Action of a group G on a set S, Examples, Stabilizer (Isotropy) subgroups and Orbit decomposition, Class equation, Translation and conjugation actions, Transitive and effective actions, Burnside theorem, Core of a subgroup.	15
II	p-groups, Sylow subgroups, Sylow's theorems, Examples and applications, Structure of groups of order pq, Characterization of finite Abelian groups and finite cyclic groups of specific orders in terms of Sylow subgroups.	15
III	Normal series and composition series, Schreier's refinement theorem, Zassenhaus' lemma, Jordan-Hölder's theorem, Descending chain conditions (D.C.C.), Ascending chain conditions (A.C.C.), Examples, Internal and External direct products and their relationship, In decomposability.	15
IV	Commutator or derived subgroup, Commutator series, Solvable groups, Solvability of subgroups and factor groups and of finite p-groups, Examples.	8
V	Lower and upper central series, Nilpotent groups and their equivalent characterizations.	7

Books Recommended:

1. I. N. Herstein, Topics in Algebra, Wiley Eastern, 1975.
2. P. B. Bhattacharya, S. K. Jain and S. R. Nagpal, Basic Abstract Algebra (2nd Edition), Cambridge University Press, Indian Edition 1977.
3. Ramji Lal, Algebra 1 and Algebra 2, Infosys Science foundation Series in Mathematical Sciences,

Springer, Singapore, 2017.

4. D. S. Dummit and R.M. Foote, Abstract Algebra, John Wiley, N.Y., 2003.
5. T. W. Hungerford, Algebra, Springer (India) Pvt. Ltd., New Delhi, 2004.
6. J. B. Fraleigh, A first course in Abstract Algebra, Pearson Education, inc. 2002.

Second Paper, Seventh Semester/Fourth Year, M.A./M.Sc.(Mathematics)

Program: Graduation With Research Degree Program / PG Degree Program	Class: M.A./M.Sc.	
	Year: Fourth	Semester: Seventh
Subject: Mathematics		
Course Code: B030702T	Course Title: Point-Set Topology	

Course Outcomes

After the completion of the course, students are expected to have the ability to:

1. Know about countable and uncountable sets, cardinal numbers and it's arithmetic, Schroeder-Bernstein theorem, topological spaces, neighbourhood of a point in a topological space; open sets, closed sets, interior of sets, closure of sets, boundary of sets, limit points of sets in topological spaces; apply the knowledge to solve relevant exercises.
2. Learn about bases, subbases for a topology, subspaces of topological spaces, first countable spaces, second countable spaces, separable spaces, continuous functions and it's characterizations.
3. Understand the concepts of homeomorphism, product of two spaces, quotient topology, compact spaces, connected spaces, path connected spaces, components, separation axioms and their properties; demonstrate understanding of the statements and proofs of specified theorems.

Credits: 4	Maximum Marks: 25+75 (CIA+UE)
Nature of Course: Theory(Compulsory)	Minimum Passing Marks: 36 (CIA+UE)
Total Number of Lectures-Tutorials-Practicals (In Hours per week): L-T-P: 4-0-0	

Course Contents

Unit	Topics	L-T-P
I	Countable and uncountable sets, Infinite sets and the axiom of choice, Cardinal numbers and its arithmetic, Schroeder-Bernstein theorem, Zorn's Lemma, Well ordering principle.	10
II	Topological spaces, Closed sets, Open sets, Closure, Dense subsets, Neighbourhoods, exterior of a set, interior of a set, closure of a set, boundary of a set, Accumulation points and derived sets, Bases and subbases, Subspaces and relative topology.	15
III	Separable space, Neighbourhood systems, first countable space, second countable space, Continuous functions and its characterizations via the closure and interior, open map, closed map, Homeomorphism, product of two spaces, quotient of a space.	15
IV	Compact space, Connected space, path connected space, components.	10
V	Separation axioms: *T1*-space, *T2* -space, regular space, *T3* -space, completely regular space, normal space, *T4* – space, their characterizations and basic properties, Embedding lemma, Embedding theorem, the Urysohn Metrization Theorem, the Urysohn's Lemma and the	10

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	Tietze Extension Theorem.	

Books Recommended:

1. G. F. Simmons, Introduction to Topology and Modern Analysis, McGraw Hill, 1963.
2. J. R. Munkres, Topology, Narosa Publishing House, New Delhi, 2005.
3. K. D. Joshi, Introduction to General Topology, Wiley Eastern, 1983
4. S.W. Davis Topology, Tata McGraw Hill, 2006
5. Sze-Tsen Hu, Elements of General Topology, Holden-Day Inc., 1964.

Third Paper, Seventh Semester/Fourth Year, M.A./M.Sc.(Mathematics)

Program: Graduation With Research Degree Program / PG Degree Program	Class: M.A./M.Sc.	
	Year: Fourth	Semester: Seventh
Subject: Mathematics		
Course Code: B030703T	Course Title: Advanced Complex Analysis	

Course Outcomes

After the completion of the course, students are expected to have the ability to:

1. Understand advanced topics in Complex Analysis as well as the fundamental topics required for students to pursue research in pure Mathematics.
2. Develop manipulation skills in the use of Rouche's theorem and Argument Principle.
3. Understand the general theory of conformal mappings, Möbius transformations and their applications.
4. Show knowledge of Gamma and Zeta functions with their properties and relationships.
5. Understand the Harmonic functions defined on a disc and concerned results.
6. Make factorization of entire functions having infinite number of zeros.

Credits: 4	Maximum Marks: 25+75 (CIA+UE)
Nature of Course: Theory(Compulsory)	Minimum Passing Marks: 36 (CIA+UE)
Total Number of Lectures-Tutorials-Practicals (In Hours per week): L-T-P: 4-0-0	

Course Contents

Unit	Topics	L-T-P
I	Uniform convergence of sequence and series of functions, Cauchy's criterion, Weierstrass's M-test, analytic convergence theorem, absolute and uniform convergence of power series, integration and differentiation of power series, radius of convergence.	10
II	Schwarz's Lemma, Minimum Modulus Theorem, Zeroes of holomorphic functions, Open Mapping Theorem, Inverse Function Theorem, Index of a closed path, meromorphic functions, argument principle, Rouche's theorem, Hadamard's three circle theorem.	10
III	Conformal mappings, Special types of transformations, Basic properties of Möbius maps, Images of circles and lines under Mobius maps, Fixed points, Characterizations of Möbius maps in terms of their fixed points, Triples to triples under Möbius maps, Cross-ratio and its invariance property, Mappings of half-planes onto disks, Inverse function theorem and related results.	15

IV	Function spaces, Hurwitz theorem, Infinite products, Weierstrass factorization theorem, Mittag-Leffler's theorem, Gamma functions and its properties, Riemann's Zeta function	10
V	Uniqueness of direct analytic continuation, Power series method of analytic continuation, Harmonic Functions, Mean value property for harmonic functions, Harnack's inequality, Poisson formula, Jensen's formula, Poisson-Jensen's formula, Convex functions, Hadamard's three circle theorem as a convexity theorem, Canonical products, Hadamard's factorization theorem, order of entire functions.	15

Books Recommended:

1. S. Ponnusamy and H. Silverman, Complex Variables, Birkhäuser, Inc., Boston, MA, 2006.
2. J. B. Conway, Functions of One Complex Variable, Narosa Publishing House, New Delhi, 2002.
3. V. Ahlfors, Complex Analysis (Third Edition), McGraw-Hill, 1979.
4. S. Ponnusamy, Foundation of complex analysis, Narosa publication, 2003.

Fourth Paper, Seventh Semester/Fourth Year, M.A./M.Sc.(Mathematics)

Program: Graduation With Research Degree Program / PG Degree Program	Class: M.A./M.Sc.	
	Year: Fourth	Semester: Seventh
Subject: Mathematics		
Course Code: B030704T	Course Title: Classical Mechanics	

Course Outcomes

After the completion of the course, students are expected to have the ability to:

1. Explain the basic concepts of classical Mechanics, apply Newton's laws and write the kinetic energy and potential energy of a system of particles, distinguish the concept of linear and angular momentum for rigid body, rigid body dynamics, Euler's dynamical equation of motion, Lagrangian and Hamiltonian approaches to solve the equations of motion.
2. Know the applicability of degree of freedom, derivation of Lagrange's equations, generalized coordinates, use of Poisson brackets to determine whether a given transformation is canonical or not, Hamilton's equations, Poisson bracket and Poisson-Jacobi identity.

Credits: 4	Maximum Marks: 25+75 (CIA+UE)
Nature of Course: Theory(Compulsory)	Minimum Passing Marks: 36 (CIA+UE)
Total Number of Lectures-Tutorials-Practicals (In Hours per week): L-T-P: 4-0-0	

Course Contents

Unit	Topics	L-T-P
I	The momentum of a system of particles, the linear and the angular momentum, rate of change of momentum and the equations of motion for a system of particles, principles of linear and angular momentum, motion of the center of mass of a system, theorems on the rate of change of angular momentum about different points, with special reference to the center of mass, the kinetic energy of a system of particles in terms of the motion relative to the center of mass of the system.	15

	Rigid bodies as systems of particles, general displacement of a rigid body, the displacement of a rigid body about one of its points and the concept of angular velocity, computation of the angular velocity of a rigid body in terms of the velocities of two particles of the system chosen appropriately.	
II	The angular momentum and kinetic energy of a rigid body in terms of inertia constants, Equations of motion. Euler's dynamical equations of motion, Euler's geometrical equations of motion. Motion under no forces, the invariable line and the invariable cone, Instantaneous axis of rotation, Eulerian angles	**10**
III	Generalized co-ordinates, geometrical equations, holonomic and non-holonomic systems, configuration Space, Lagrange's equations using D' Alembert's Principle for a holonomic conservative system, Lagrangian function, deduction of equation of energy when the geometrical equations do not contain time t explicitly, Lagrange's multipliers case, deduction of Euler's dynamical equations from Lagrange's equations, Lagrange equations for impulsive motion.	**15**
IV	Generalized momentum and the Hamiltonian for a dynamical system, Hamilton's canonical equations of motion, Hamiltonian as a sum of kinetic and potential energies, phase space and Hamilton's Variational principle, Hamilton's principle function, the principle of least action, canonical transformations, conditions of canonicality, Hamilton-Jacobi (H-J) equation of motion (outline only), Poisson-Brackets, Poisson-Jacobi identity, Poisson's first theorem.	**10**
V	Theory of small oscillations, Lagrange's method, normal (principal) co-ordinates and the normal modes of oscillation, small oscillations under holonomic constraints, stationary property of normal modes, orthogonality of normal modes.	**10**

Books Recommended:

1. S.L. Loney, Dynamics of Rigid Bodies, CBS Publishers, New Delhi, 1913.
2. H. Goldstein, Classical Mechanics, Addison-Wesley Publishing Company, London, 1969.
3. N.C. Rana and P.S. Joag, "Classical Mechanics", Tata McGraw Hill, 1991.
4. E. A. Milne, Vectorial Mechanics, Methuen & Co. Ltd., London, 1965.
5. L. A. Pars, A Treatise on Analytical Dynamics, Heinemann, London, 1968.
6. N. Kumar, Generalized Motion of Rigid Body, Narosa Publishing House, New Delhi, 2004.
7. A. S. Ramsey, Dynamics, Part II, CBS Publishers & Distributors, Delhi, 1985.

Fifth Paper, Seventh Semester/Fourth Year, M.A./M.Sc.(Mathematics)

Program: Graduation With Research Degree Program / PG Degree Program	Class: M.A./M.Sc.	
	Year: Fourth	Semester: Seventh
Subject: Mathematics		
Course Code: B030705P	Course Title: Programming For Mathematics	

Course Outcomes

After the completion of the course, students have capability to:

1. Know the about WORD, Power Point Presentation (PPT), Excel and related phenomenon.
2. Create the personnel/official logo, typing of Mathematical equations and their representation.
3. Understand about the fundamental approach on Latex and presentation through Beamer.

Credits: 4	Maximum Marks: 25+75 (CIA+UE)
Nature of Course: Practical(Compulsory)	Minimum Passing Marks: 36 (CIA+UE)
Total Number of Lectures-Tutorials-Practicals (In Hours per week): L-T-P: 2-0-4	

Course Contents

Unit	Topics	L-T-P
I	Basics on MS-office including WORD, Power Point Presentation (PPT), Excel and related phenomenon.	12
II	Sketching/Designing of images, Plotting of curves in mathematical flow chart view.	12
III	Simulation and typing of mathematical equations in WORD and PPT, Designing of official/personnel logo.	15
IV	Fundamentals assumption of Latex typing, Strategy for typing in Latex and related phenomenon.	11
V	Command for clickable hyperlinks, Introduction of Beamer Presentation and related phenomenon.	10

Books Recommended:

1. James J. Marshall, Beginning Microsoft Word Business Documents, Apress, 2006.
2. George Gratzer, More Math Into LATEX, *Springer*, 2007.
3. Leslie Lamport, LaTeX, *Addison-Wesley Longman*, 1994.

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SEMESTER VIII

Sr. No.	Course/ Paper No.	Course/ Paper Code	Course/Paper Title	Credits	Teaching /Periods (Hours per week)	Maximum Marks		
						Continuous Internal Assessment*	End-Semester Examination	Total
1.	First	B030801T	Module Theory	5	5	25	75	100
2.	Second	B030802T	Linear Integral Equations and Boundary Value Problems	5	5	25	75	100
3.	Third	B030803T	Advanced Real Analysis	5	5	25	75	100
4.	Fourth	B030804T	Students are required to choose any one of the following elective courses/Papers: ⇓					
			Elective 01	5	5	25	75	100
			Elective 02	5	5	25	75	100
			Elective 03	5	5	25	75	100
5.	Fifth	B030805R	Research Project	4	4	According to NEP-2020**		
6.	Sixth	--	Minor Elective*	--	--	--		

Remark:

(b) *If the student opts for a Minor Elective Paper in this semester(Semester VIII), all the information(like Course/Paper Number, Course/Paper Code, Course/Paper Title, Credits, etc.) regarding the Minor Elective Paper will be as per the NEP-2020.

(c) **Students in the fourth year of higher education shall submit a joint dissertation (project report/dissertation) of the research project undertaken in both semesters(Semester VII and Semester VIII) at the end of the year, which will be assessed jointly out of 100 marks by the supervisor and the external examiner at the end of the year.

First Paper, Eighth Semester/Fourth Year, M.A./M.Sc.(Mathematics)

Program: Graduation With Research Degree Program / PG Degree Program	Class: M.A./M.Sc.	
	Year: Fourth	Semester: Eighth
Subject: Mathematics		
Course Code: B030801T	Course Title: Module Theory	

Course Outcomes

After the completion of the course, students are expected to have the ability to :

1. Understand concepts of modules, submodules, direct sum, exact sequences, , quotient modules, free modules, Five lemma, products, co-products and their universal propert, homomorphism extension property, equivalent characterization as a direct sum of copies of the underlying ring, Split exact sequences and their characterizations.
2. Know about projective modules, injective modules, divisible groups, Noetherian modules and rings, Baer's characterization, Hilbert basis theorem.
3. Learn about torsion and torsion-free modules, p-primary components, decomposition of p-primary finitely generated torsion modules, elementary divisors and their uniqueness, rational canonical form of matrices, and elementary Jordan matrices, structure of finite abelian groups, and Jordan-Chevalley Theorem.

Credits: 5	Maximum Marks: 25+75 (CIA+UE)
Nature of Course: Theory(Compulsory)	Minimum Passing Marks: 36 (CIA+UE)
Total Number of Lectures-Tutorials-Practicals (In Hours per week): L-T-P: 4-1-0	

Course Contents

Unit	Topics	L-T-P
I	Modules, Submodules, Faithful modules, Factor modules, Exact sequences, Five lemma, Products, co-products and their universal property, Direct summands, Annihilators, Free modules, External and internal direct sums.	12
II	Homomorphism extension property, Equivalent characterization as a direct sum of copies of the underlying ring, Split exact sequences and their characterizations, Left exactness of Hom sequences and counter-examples for non-right exactness.	12
III	Projective modules, Injective modules, Baer's characterization, Divisible groups, Noetherian modules and rings, Equivalent characterizations, Submodules and factors of noetherian modules, Hilbert basis theorem (statement only).	15
IV	Submodules of finitely generated free modules over a PID, Torsion submodule, Torsion and torsion-free modules, Direct decomposition into torsion and a torsion free submodule, p-primary components, Decomposition of p-primary finitely generated torsion modules, Elementary divisors and their uniqueness, Decomposition into invariant factors and uniqueness, Structure of finite abelian groups.	11
V	Similarity of matrices and $F[x]$-module structure, Rational canonical form of matrices, Elementary Jordan matrices, Reduction to Jordan canonical form, Diagonalizable and nilpotent parts of a linear transformation, Jordan-Chevalley Theorem.	10

Books Recommended:

1. P. Ribenboim, Rings and Modules, Wiley Interscience, New York, 1969.
2. J. Lambek, Lectures on Rings and Modules, Blaisedell, Waltham, 1966.
3. Ramji Lal, Algebra 2, Infosys Science foundation Series in Mathematical Sciences, Springer, Singapore, 2017.
4. D. S. Dummit and R. M. Foote, Abstract Algebra, John Wiley, N.Y., 2003.
5. N. S. Gopalkrishnan, University Algebra, Wiley Eastern Ltd., New Delhi, 1986.

Second Paper, Eighth Semester/Fourth Year, M.A./M.Sc.(Mathematics)

Program: Graduation With Research Degree Program / PG Degree Program	Class: M.A./M.Sc.	
	Year: Fourth	Semester: Eighth
Subject: Mathematics		
Course Code: B030802T	Course Title: Linear Integral Equations and Boundary Value Problems	

Course Outcomes

After the completion of the course, students are expected to have the ability to:

1. Classify the integral equations having separate and symmetric kernels.
2. Reduce an integral equation into an algebraic equation.
3. Find solution of integral equations through method of successive approximations and iterated kernels.
4. Study of Sturm-Liouville problems, Eigen functions and Legendre function BVP.
5. Construct the Green function for ODEs and Green formula for Second order equation.

Credits: 5	Maximum Marks: 25+75 (CIA+UE)
Nature of Course: Theory(Compulsory)	Minimum Passing Marks: 36 (CIA+UE)
Total Number of Lectures-Tutorials-Practicals (In Hours per week): L-T-P: 4-1-0	

Course Contents

Unit	Topics	L-T-P
I	Linear Integral Equations: Definition and Classification of conditions, Special kinds of Kernels, Eigen values and Eigen functions, Convolution integral, Inner product, Integral equations with separable Kernels.	12
II	Reduction to a system of algebraic equations, Fredholm alternative, Fredholm Theorem,Fredholm alternative theorem, Approximate method, Method of successive approximations, Iterative scheme.	12
III	Solution of Fredholm and Volterra integral equation, Results about resolvent Kernel, Singular integral equation, Abel integral equation, General forms of Abel Singular integral equation,Weakly singular kernel, Cauchy principal value of integrals.	15
IV	Sturm-Liouville System, Eigen functions, Bessel functions, Singular Sturm Liouville systems, Legendre functions boundary value problem for ordinary differential equation, Solution by Eigenfunction Expansion.	11

V	Green's functions, Construction of Green's function for Ordinary differential equation, Lagrange's identity and Green's formula for second-order equation.	10

Books Recommended:

1. R.P. Kanwal, Linear Integral Equations, Birkhäuser, 1997.
2. R. Kress, Linear Integral Equations, Springer, 2014.
3. D.L. Powers, Boundary Value Problems, Academic Press, 1979.
4. M.D. Raisinghania, Integral Equations and Boundary Value Problems, S. Chand, 2016.

Third Paper, Eighth Semester/Fourth Year, M.A./M.Sc.(Mathematics)

Program: Graduation With Research Degree Program / PG Degree Program	Class: M.A./M.Sc.	
	Year: Fourth	Semester: Eighth
Subject: Mathematics		
Course Code: B030803T	Course Title: Advanced Real Analysis	

Course Outcomes

After the completion of the course, students are expected to have the ability to:

1. Understand the concept of Riemann-Stieltjes integral along its properties; integration of vector-valued functions with application to rectifiable curves.
2. Understand and handle convergence of sequences and series of functions; construct a continuous nowhere-differentiable function; demonstrate understanding of the statement and proof of Weierstrass approximation theorem.
3. Know about differentiability and continuity of functions of several variables and their relation to partial derivatives; apply the knowledge to prove inverse function theorem and implicit function theorem.
4. Learn about the concepts of power Series, exponential & logarithmic functions, trigonometric functions, Fourier series and Gamma function; apply the knowledge to prove specified theorems.

Credits: 5	Maximum Marks: 25+75 (CIA+UE)
Nature of Course: Theory(Compulsory)	Minimum Passing Marks: 36 (CIA+UE)
Total Number of Lectures-Tutorials-Practicals (In Hours per week): L-T-P: 4-1-0	

Course Contents

Unit	Topics	L-T-P
I	Functions of Bounded Variation and some properties of functions of bounded variation, Lipschitz condition and Lipschitz function. Variation function, Positive Variation function, Negative Variation function and The Jordan Decomposition theorem.	12
II	Definition and existence of the Riemann-Stieltjes integral, properties of the Riemann-Stieltjes integral, the first and second mean value theorem, the fundamental theorem of calculus, change of variable and Integration by parts for Riemann- Stieltjes, relation between Riemann and Riemann-Stieltjes integral.	12
III	Sequences and series of functions: Pointwise and uniform convergence of sequences of	15

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	functions, Cauchy criterion for uniform convergence, Dini's theorem, uniform convergence and continuity, uniform convergence and Riemann integration, uniform convergence and differentiation. Convergence and uniform convergence of series of functions, Weierstrass M-test, integration and differentiation of series of functions, existence of a continuous nowhere-differentiable function, the Weierstrass approximation theorem.	
IV	Power Series: Uniqueness theorem for power series, Abel's and Tauber's theorem, Taylor's theorem, Exponential & Logarithmic functions, trigonometric functions, Fourier series, Gamma function.	11
V	Functions of several variables: Partial derivatives, continuity and differentiability of functions of several variables and their relation to partial derivatives, linear transformations, the space of linear transformations from open sets of R^n to open sets of R^m and it's properties, chain rule, continuously differentiable mappings, Jacobian, the contraction principle, the inverse function theorem, the implicit function theorem.	10

Books Recommended:

1. Walter Rudin, Principles of Mathematical Analysis (3rd Edition) McGraw-Hill, 2013.
2. R.R. Goldberg, Methods of Real Analysis, Oxford and IBH Publishing, 2020
3. T.M. Apostol, Mathematical Analysis, Narosa Publishing House, New Delhi, 1985.
4. Gabriel Klambauer, Mathematical Analysis, Marcel Dekkar, Inc. New York, 1975.
5. A.J. White, Real Analysis; an introduction. Addison-Wesley Publishing Co., Inc., 1968.
6. E. Hewitt and K. Stromberg. Real and Abstract Analysis, Berlin, Springer, 1969.
7. Serge Lang, Analysis I & II, Addison-Wesley Publishing Company Inc., 1969.
8. S.C. Malik and Savita Arora, Mathematical Analysis, New Age International Limited, New Delhi,4th Edition 2010.
9. D. Somasundaram and B. Choudhary, A First Course in Mathematical Analysis, Narosa Publishing House, New Delhi, 1997.

Fourth Paper, Eighth Semester/Fourth Year, M.A./M.Sc.(Mathematics)

Program: Graduation With Research Degree Program / PG Degree Program	Class: M.A./M.Sc.	
	Year: Fourth	Semester: Eighth
Subject: Mathematics		
Course Code: B030804T	Course Title: Differentiable Manifolds	

Course Outcomes

After the completion of the course, students are expected to have the ability to :

1. Elaborate the concept of differentiable manifolds and their examples.
2. Clarify the concepts of vector fields, tangent vectors & tangent spaces in a manifold.
3. Apply various concepts of differential calculus to the settings of abstract set called manifold.
4. Use Riemannian metric on a given manifold to find the various types of curvatures with emphasis on the surface/ type of manifold.
5. Bring out different connections on Riemannian manifold and it's properties.
6. Calculate curvature tensor & tensors of respective connections.

Credits: 5	Maximum Marks: 25+75 (CIA+UE)
Nature of Course: Theory(Elective 01)	Minimum Passing Marks: 36 (CIA+UE)
Total Number of Lectures-Tutorials-Practicals (In Hours per week): L-T-P: 4-1-0	

Course Contents

Unit	Topics	L-T-P
I	Definition and examples of differentiable manifolds, Tangent vectors, Tangent Spaces, Vector fields and their examples, Jacobian map.	12
II	Immersions and submersions, Diffeomorphism and their examples, Curve in a manifold, Integral curves and their examples, Distributions, Hypersurface of R^n , Submanifolds.	12
III	Standard connection on R^n , Covariant derivative, Sphere map, Weerigarten map, Gauss equation, the Gauss curvature equation and Coddazi-Mainardi equations.	15
IV	Invariant view point,cortan view point, coordinate view point, Difference Tensor of two connections, Torsion and curvature tensors.	11
V	Riemannian Manifolds, Length and distance in Riemannian manifolds, Riemanian connection and curvature, Curves in Riemannian manifolds, Submanifolds of Riemannian manifolds.	10

Books Recommended:

1. N.J. Hicks: Notes on Differential Geometry, D. Van Nostrand, 1965.
2. Y. Matsushima: Differentiable Manifolds, Marcel Dekker, INC. New York, 1972.
3. U. C. De., A. A. Shaikh: Differential Geometry of Manifolds, Narosa Publishing House.

Ashish Verma

Fourth Paper, Eighth Semester/Fourth Year, M.A./M.Sc.(Mathematics)

Program: Graduation With Research Degree Program / PG Degree Program	Class: M.A./M.Sc.	
	Year: Fourth	Semester: Eighth
Subject: Mathematics		
Course Code: B030804T	Course Title: Mechanics of Solids – I	

Course Outcomes

After the completion of the course, students are expected to have the ability to :

1. Learn about the suffix notations, Tensor Algebra, Calculus of Tensors, analysis of strain, analysis of stress, equations of elasticity.
2. Introduce the basics of continuum mechanics and Mathematical theory of elasticity.
3. Understand basics and applied problems in the area of waves and vibrations in elastic solids.

Credits: 5	Maximum Marks: 25+75 (CIA+UE)
Nature of Course: Theory(Elective 02)	Minimum Passing Marks: 36 (CIA+UE)
Total Number of Lectures-Tutorials-Practicals (In Hours per week): L-T-P: 4-1-0	

Course Contents

Unit	Topics	L-T-P
I	**Suffix notation:** Range and Summation conventions, free and dummy suffixes, results in vector algebra and matrix algebra, The symbols δij and ϵijk. **Tensor Algebra:** Coordinate-transformations, Cartesian Tensors of second and higher order,Properties of tensors, equality of tensors, scalar multiple of a tensor, Sum and difference of tensors, contraction, quotient laws, Isotropic tensor of different orders and relation between them, transpose and inverse of a tensor, symmetric, skew, orthogonal tensor, dual vector of a skew tensor, tensor invariants, Deviatoric tensors, Eigen space of a tensor.	12
II	**Calculus of Tensors:** Comma notation, Gradient, divergence and curl of tensor, Laplacian of a tensor. **Analysis of Strain:** Homogeneous Strain and its properties, Affine transformation, Infinitesimal affine deformation,	12
III	**Analysis of Strain:** Geometrical Interpretation of the components of strain. Components of strain in polar coordinates, dilatation, Strain quadric of Cauchy. Principal strains and Strain invariance, General infinitesimal deformation. Types of strain, Examples of strain, Saint-Venant's equations of Compatibility.	15
IV	**Analysis of Stress:** Body and surface forces, Stress at a point, Stress tensor, Equations of equilibrium, Transformation of coordinates. Stress quadric of Cauchy, Principal stress and invariants. Maximum normal and shear stresses. Mohr's circles. Nature of stress, Examples of stress. Stress function	11
V	**Equations of Elasticity:** Hooke's law and Generalized Hooke's Law, Strain energy function and its connection with Hooke's Law, Homogeneous isotropic medium. Elasticity	10

	moduli for Isotropic media. Simple tension, Pure shear, Hydrostatic pressure, Dynamical equations for an isotropic elastic solid. Beltrami-Michell compatibility equations. Uniqueness of solution.	

Books Recommended:

1. I. S. Sokolnikoff, Mathematical Theory of Elasticity, Tata-McGraw Hill Publishing Company Ltd., New Delhi, 1977.
2. D. S. Chandrasekharaiah and L. Debnath, Continuum Mechanics, Academic Press, 1994.
3. A.E.H. Love, A Treatise on the Mathematical Theory of Elasticity Dover Publications, New York.
4. Y. C. Fung, Foundations of Solid Mechanics, Prentice Hall, New Delhi, 1965.
5. Shanti Narayan, Text Book of Cartesian Tensor, S. Chand & Co., 1950.

Fourth Paper, Eighth Semester/Fourth Year, M.A./M.Sc.(Mathematics)

Program: Graduation With Research Degree Program/PG Degree Program	Class: M.A./M.Sc.	
	Year: Fourth	Semester: Eighth
Subject: Mathematics		
Course Code: B030804T	Course Title: Number Theory	

Course Outcomes

After the completion of the course, students are expected to have the ability to:

1. Know about the basics of Elementary Number Theory starting with primes, divisibility, congruences, quadratic residues, primitive roots, arithmetic functions to Legendre symbol.
2. Find the solutions of Diophantine equations.
3. Learn about the fundamentals of different branches of Number Theory, namely, Geometry of Numbers, Partition Theory and Analytic Number Theory.
4. Understand simple continued fractions, approximation of reals by rational numbers, Pell's equations.
5. Understand concept of Ferrers graphs and Generating function.
6. Know about the Rogers-Ramanujan identities, Minkowski's theorem in geometry of numbers and its applications to Diophantine inequalities, Abel's identity, equivalent forms of Prime Number Theorem, inequalities for (n) and pn, Shapiro's Tauberian Theorem, the partial sums of Mobius functions.

Credits: 5	Maximum Marks: 25+75 (CIA+UE)
Nature of Course: Theory(Elective 03)	Minimum Passing Marks: 36 (CIA+UE)
Total Number of Lectures-Tutorials-Practicals (In Hours per week): L-T-P: 4-1-0	

Course Contents

Unit	Topics	L-T-P
I	**Basic review of Number theory:** Divisibility, Congruences, Residue classes and reduced residue classes, Arithmetic functions: Euler's Phi function, Divisor function, Sum of divisors function, Mobius function, Primitive roots and indices. Quadratic residues, Legendre symbol, Euler's criterion, Gauss's lemma, Quadratic reciprocity law, Jacobi symbol, Diophantine equations	12

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II	Continued fractions, Approximation of reals by rationals, Best possible approximation, Pell's equations, Partitions, Ferrers graphs, Generating function, Jacobi's triple product identity, Euler's formula.	12
III	Congruence properties of p(n) , Rogers-Ramanujan identities, Minkowski's theorem in geometry of numbers and its applications to Diophantine inequalities.	15
IV	Order of magnitude and average order of arithmetic functions, Euler's summation formula, Elementary results on distribution of primes. Abel's identity. Equivalent forms of Prime Number Theorem, Inequalities for (n) and pn .	11
V	Shapiro's Tauberian Theorem, The partial sums of Mobius functions, Characters of finite Abelian groups, Dirichlet's theorem on primes in arithmetical progression.	10

Books Recommended:

1. David M. Burton – Elementary Number Theory, Tata McGraw Hill, 6th Edition, 2007.
2. G. H. Hardy and E. M. Wright – An Introduction to Theory of Numbers, Oxford University Press, 6th Ed , 2008.
3. I. Niven, H. S. Zuckerman and H. L. Montgomery – An Introduction to the Theory of Numbers, John Wiley and Sons, (Asia) 5th Ed., 2004.
4. H. Davenport - The Higher Arithmetic, Camb. Univ. Press, 7th edition, 1999.
5. T. M. Apostol – Introduction to Analytic Number Theory, Narosa Publishing House, New Delhi, 1990.

SEMESTER IX

Sr. No.	Course/ Paper No.	Course/ Paper Code	Course/Paper Title	Credits	Teaching /Periods (Hours per week)	Maximum Marks		
						Continuous Internal Assessment*	End-Semester Examination	Total
1.	First	B030901T	Functional Analysis – 1	4	4	25	75	100
2.	Second	B030902T	Measure and Integration – 1	4	4	25	75	100
3.	Third	B030903T	Students are required to choose any one of the following elective courses/Papers: ⇓					
			Elective 01	4	4	25	75	100
			Elective 02	4	4	25	75	100
			Elective 03	4	4	25	75	100
4.	Fourth	B030904T	Students are required to choose any one of the following elective courses/Papers: ⇓					
			Elective 01	4	4	25	75	100
			Elective 02	4	4	25	75	100
			Elective 03	4	4	25	75	100
5.	Fifth	B030905P	Mathematics Using Mathematica	4	4	25	75	100
6.	Sixth	B030906R	Research Project	4	4	According to NEP-2020**		

Remark:

(a) ****Students in the fifth year of higher education shall submit a joint dissertation (project report/dissertation) of the research project undertaken in both semesters(Semester IX and Semester X) at the end of the year, which will be assessed jointly out of 100 marks by the supervisor and the external examiner at the end of the year.**

First Paper, Ninth Semester/Fifth Year, M.A./M.Sc.(Mathematics)

Program: PG Degree Program	Class: M.A./M.Sc.	
	Year: Fifth	Semester: Ninth
Subject: Mathematics		
Course Code: B030901T	Course Title: Functional Analysis – I	

Course Outcomes

After the completion of the course, students are expected to have the ability to :

1. Know about the requirements of a norm; learn about the concept of completeness with respect to a norm; check boundedness of a linear operator and relate it to continuity; understand convergence of operators by using a suitable norm; apply the knowledge to compute the dual spaces.
2. Extend a linear functional under suitable conditions; apply the knowledge to prove Hahn Banach Theorem for further application to bounded linear functionals on C[a,b]; know about adjoint of operators; understand reflexivity of a space and demonstrate understanding of the statement and proof of uniform boundedness theorem.
3. Know about strong and weak convergence; understand open mapping theorem, bounded inverse theorem and closed graph theorem; distinguish between Banach spaces and Hilbert spaces; decompose a Hilbert space in terms of orthogonal complements.
4. Understand totality of orthonormal sets and sequences; represent a bounded linear functional in terms of inner product; classify operators into self-adjoint, unitary and normal operators.

Credits: 4	Maximum Marks: 25+75 (CIA+UE)
Nature of Course: Theory(Compulsory)	Minimum Passing Marks: 36 (CIA+UE)
Total Number of Lectures-Tutorials-Practicals (In Hours per week): L-T-P: 4-0-0	

Course Contents

Unit	Topics	L-T-P
I	Norm and its properties, Normed linear spaces, Banach spaces, the sequence spaces and the function spaces as Banach spaces, Characterization of Continuous linear transformations between two normed spaces, Bounded linear operators, B(X,Y) as a normed linear space.	12
II	Hahn-Banach Theorem, Open mapping theorem, Closed graph theorem, Banach-Steinhaus theorem (only statement), Uniform boundedness principle (only statement).	12
III	Conjugate spaces, Weak and Weak*-topology on a conjugate space, Simple Application to reflexive separable spaces and to the Calculus of Variation.	15
IV	Hilbert Spaces, Schwarz's inequality, orthogonal complement of a subspace, orthonormal bases, Continuous linear functionals on Hilbert spaces, Riesz Representation Theorem, Reflexivity of Hilbert Spaces, Applications of polarization identity.	11
V	The adjoint of an operator, Self adjoint operators, Normal and unitary operators, Projections. Finite dimensional spectral theory – Spectrum of an operator, the Spectral theorem.	10

Books Recommended:

1. G. F. Simmons, Introduction to Topology and Modern Analysis, McGraw Hill, 1963.
2. S. Ponnusamy, Foundations of Functional Analysis, Narosa Publishing House, New Delhi, 2002.
3. G. Bachman and L. Narici, Functional Analysis, Academic Press, 1966.
4. A. E. Taylor, Introduction to Functional Analysis, John Wiley, 1958.
5. N. Dunford and J. T. Schwartz, Linear Operators, Part-I, Interscience, 1958.
6. R. E. Edwards, Functional Analysis, Holt Rinehart and Winston, 1965.
7. C. Goffman and G. Pedrick, First Course in Functional Analysis, Prentice- Hall of India, 1987.

Second Paper, Ninth Semester/Fifth Year, M.A./M.Sc.(Mathematics)

Program: PG Degree Program	Class: M.A./M.Sc.	
	Year: Fifth	Semester: Ninth
Subject: Mathematics		
Course Code: B030902T	Course Title: Measure and Integration – I	

Course Outcomes

After the completion of the course, students are expected to have the ability to:

1. Learn about Cardinality of a set, the Cantor's ternary set and its properties, the Cantor-Lebesgue function, semi-algebras, algebras, σ-algebras, measure and outer measures.
2. Understand the concepts of measurable sets and Lebesgue measure; construct a non-measurable set; apply the knowledge to solve relevant exercises. Know about Lebesgue measurable functions and their properties; and apply the knowledge to prove Egoroff's theorem and Lusin's theorem.
3. Understand the requirement and the concept of the Lebesgue integral (as a generalization of the Riemann integration) along its properties and demonstrate understanding of the statement and proofs of the fundamental integral convergence theorems: Bounded convergence theorem, Lebesgue monotone convergence theorem, Fatou's lemma, Lebesgue dominated convergence theorem; apply the knowledge to prove specified theorems.

Credits: 4	Maximum Marks: 25+75 (CIA+UE)
Nature of Course: Theory(Compulsory)	Minimum Passing Marks: 36 (CIA+UE)
Total Number of Lectures-Tutorials-Practicals (In Hours per week): L-T-P: 4-0-0	

Course Contents

Unit	Topics	L-T-P
I	Cardinality of a set, Arithmatic of cardinal numbers, Schröder-Bernstein theorem, The Cantor's ternary set and its properties, The Cantor-Lebesgue function.	12
II	Semi-algebras, algebras, monotone class, σ-algebras, measure and outer measures, Caratheödory extension process of extending a measure on semi-algebra to generated σ - algebra, completion of a measure space	12
III	Borel sets, Lebesgue outer measure and Lebesgue measure on *R*, translation invariance of Lebesgue measure, Lebesgue measurable sets, existence of a non-measurable set, characterizations of Lebesgue measurable sets.	15

IV	Measurable functions, Characterization of measurable functions, Linearity and products of measurable functions, Borel and Lebesgue measurable functions, Characteristic functions, simple functions and their integrals, Lebesgue integral on R and its properties, Characterizations of Riemann and Lebesgue integrability.	11
V	Littlewood's three principles (statement only), Bounded convergence theorem, Lebesgue monotone convergence theorem, Fatou's lemma, Lebesgue dominated convergence theorem.	10

Books Recommended:

1. I K. Rana, An Introduction to Measure and Integration, Second Edition, Narosa Publishing House, New Delhi, 2005.
2. P. R. Halmos, Measure Theory, Grand Text Mathematics, 14, Springer, 1994.
3. E. Hewit and K. Stromberg, Real and Abstract Analysis, Springer, 1975.
4. K. R. Parthasarathy, Introduction to Probability and Measure, TRIM 33, Hindustan Book Agency, New Delhi, 2005.
5. H. L. Royden and P. M. Fitzpatrick, Real Analysis, Fourth edition, Prentice Hall of India, 2010.

Third Paper, Ninth Semester/Fifth Year, M.A./M.Sc.(Mathematics)

Program: PG Degree Program	Class: M.A./M.Sc.	
	Year: Fifth	Semester: Ninth
Subject: Mathematics		
Course Code: B030903T	Course Title: Theory of Ordinary Differential Equations	

Course Outcomes

After the completion of the course, students are expected to have the ability to:

1. Understand the geometrical approach of differential equation, isoclines, role of Lipschitzian and non-Lipschitzian functions.
2. Know the Importance of p- discriminant and c-discriminant of a differential equation, concept of envelopes.
3. Know the Existence of singular solution through uniqueness of solutions with a given slope and norm of Euclidean spaces.
4. Learn about Wronskian and general solution of linear non-homogeneous differential equations.
5. Find out the ordinary, regular and irregular singular points of a differential equation.

Credits: 4	Maximum Marks: 25+75 (CIA+UE)
Nature of Course: Theory(Elective 01)	Minimum Passing Marks: 36 (CIA+UE)
Total Number of Lectures-Tutorials-Practicals (In Hours per week): L-T-P: 4-0-0	

Course Contents

Unit	Topics	L-T-P

I	Picard's method of successive approximations, Geometrical meaning of a differential equation of first order and first degree, Isoclines, Lipschitz conditions, Sufficient conditions for being Lipschitzian in terms of partial derivatives, Examples of Lipschitzian and non-Lipschitzian functions.	12
II	Existence and uniqueness theorem for first order initial value problem (statements only), p-discriminant of a differential equation and c-discriminant of family of solutions, respectively, Envelopes of one parameter family of curves.	12
III	Uniqueness of solutions with a given slope, Singular solutions as envelopes of families of solution curves, Sufficient conditions for existence and non-existence of singular solutions. Systems of I order equations arising out of equations of higher order, Norm of Euclidean spaces convenient for analysis of systems of equations, Lipschitz condition for functionsfrom R^{n+1} to R^n.	15
IV	Gronwall's inequality, Conditions for transformability of a system of I order equations into an equation of higher order, Linear dependence and linear independence, Wronskians, General solutions covering all solutions for homogeneous and non-homogeneous linear systems, Abel's formula, Method of variation of parameters for particular solutions, Linear systems with constant coefficients.	11
V	Matrix methods, Different cases involving diagonalizable and non-diagonalizable coefficient matrices, Real solutions of systems with complex eigenvalues, Ordinary and singular points.	10

Books Recommended:

1. B. Rai, D.P. Choudhury and H. I. Freedman, *A Course in Ordinary Differential Equations*, Narosa Publishing House, New Delhi, 2002.
2. L. Collatz, *The Numerical Treatment of Differential Equations*, Springer-Verlag, 1960.
3. E. A. Coddington, *An Introduction to Ordinary Differential Equations*, Prentice Hall, 1968.
4. S. L. Ross, *Differential Equations*, Wiley, 2004.

Third Paper, Ninth Semester/Fifth Year, M.A./M.Sc.(Mathematics)

Program: PG Degree Program	Class: M.A./M.Sc.	
	Year: Fifth	Semester: Ninth
Subject: Mathematics		
Course Code: B030903T	Course Title: Galois Theory	

Course Outcomes

After the completion of the course, students are expected to have the ability to:

1. Understand concepts of irreducible polynomials, field extensions, algebraic and transcendental extensions, and algebraically closed fields.
2. Know about splitting fields, normal extensions, separable extensions, and normal closures .
3. Learn about automorphism groups, fixed fields, Galois groups of the extension fields, Abelian extensions, cyclic extensions, Galois extensions, Dedekind's theorem., fundamental theorem of Galois theory, roots of unity, Cyclotomic extensions, and Cyclotomic polynomials.
4. Know about polynomials solvable by radicals, Abel-Ruffini theorem, symmetric functions, and ruler and compass construction.
5. Observe the applications in areas of applied mathematics, science and engineering.

Credits: 4	Maximum Marks: 25+75 (CIA+UE)
Nature of Course: Theory(Elective 02)	Minimum Passing Marks: 36 (CIA+UE)
Total Number of Lectures-Tutorials-Practicals (In Hours per week): L-T-P: 4-0-0	

Course Contents

Unit	Topics	L-T-P
I	Field extensions, Degree of extension, Finite extensions, Algebraic and transcendental elements, Algebraic and transcendental extensions, Simple extensions, Primitive element of the extension.	12
II	Splitting fields and their uniqueness, Normal extensions, Separable extensions, Perfect fields, Transitivity of separability, Algebraically closed field and Algebraic Closure, Normal closures, Dedekind's theorem.	12
III	Automorphisms of fields, K-automorphisms, Fixed fields, Galois group of the extension field, Abelian extension, Cyclic extension, Galois extensions, Fundamental theorem of Galois theory, Computation of Galois groups of polynomials.	15
IV	Finite fields, Existence and uniqueness, Subfields of finite fields, Characterization of cyclic Galois groups of finite extensions of finite fields, Solvability by radicals, Galois' characterization of such solvability, Generic polynomials, Abel-Ruffini theorem, Geometrical constructions.	11
V	Cyclotomic extensions, Cyclotomic polynomials and its computations, Cyclotomic extensions of Q, Galois groups of splitting fields of $x^n - 1$ over Q.	10

Books Recommended:

1. T. W. Hungerford, Algebra, Springer (India) Pvt. Ltd., New Delhi, 2004.

2. I. A. Adamson, An Introduction to Field Theory. Oliver & Boyd, Edinburgh, 1964.
3. D. S. Dummit and R. M. Foote, Abstract Algebra, John Wiley, N.Y., 2003.
4. N. S. Gopalakrishnan, University Algebra, Wiley Eastern Ltd., New Delhi, 1986.
5. F. W. Anderson and K. R. Fuller, Rings and Categories of Modules, Springer, New York, 1974.

Third Paper, Ninth Semester/Fourth Year, M.A./M.Sc.(Mathematics)

Program: Graduation With Research Degree Program / PG Degree Program	Class: M.A./M.Sc.	
	Year: Fourth	Semester: Eighth
Subject: Mathematics		
Course Code: B030804T	Course Title: Fuzzy Set Theory and its Applications	

Course Outcomes

After the completion of the course, students are expected to have the ability to :

1. Be familiar with fuzzy sets; understand fuzzy-set-related notions such as α level sets, convexity, normality, support, etc., their properties and various operations on fuzzy sets.
2. Understand the concepts of t-norms, t-conforms, fuzzy numbers; extend standard arithmetic operations on real numbers to fuzzy numbers, various types of Fuzzy relations.
3. Apply Fuzzy set theory to possibility theory and Fuzzy logic.
4. Learn about few powerful mathematical tools for modelling; facilitators for common-sense reasoning in decision making in the absence of complete and precise information.

Credits: 5	Maximum Marks: 25+75 (CIA+UE)
Nature of Course: Theory(Elective 03)	Minimum Passing Marks: 36 (CIA+UE)
Total Number of Lectures-Tutorials-Practicals (In Hours per week): L-T-P: 4-1-0	

Course Contents

Unit	Topics	L-T-P
I	**Fuzzy Sets:** Basic definitions, α -cuts, strong α -cuts, level set of a fuzzy set, support of a fuzzy set, the core and height of a fuzzy set, normal and subnormal fuzzy sets, convex fuzzy sets, cutworthy property, strong cutworthy property, standard fuzzy set operations, standard complement, equilibrium points, standard intersection, standard union, fuzzy set inclusion, scalar cardinality of a fuzzy set, the degree of subsethood. Additional properties of α cuts involving the standard fuzzy set operators and the standard fuzzy set inclusion, representation of fuzzy sets, three basic decomposition theorems of fuzzy sets; Extension principle for fuzzy sets: the Zedah's extension principle, Images and inverse images of fuzzy sets, proof of the fact that the extension principle is strong cutworthy but not cutworthy. Operations on fuzzy sets: types of operations, fuzzy complements, equilibrium of a fuzzy complement, equilibrium of a continuous fuzzy complement, first and second characterization theorems of fuzzy complements	12
II	Fuzzy intersections (t-norms), standard fuzzy intersection as the only idempotent t-norm,	12

	standard intersection, algebraic product, bounded difference and drastic intersection as examples of t-norms, decreasing generator, the Pseudo-inverse of a decreasing generator, increasing generators and their Pseudo-inverses, convertion of decreasing generators and increasing generators to each other, characterization theorem of t-norms(statement only). Fuzzy unions (t-conorms), standard union, algebraic sum, bounded sum and drastic union as examples of t-conorms, characterization theorem of t-conorms (Statement only), combination of operations, aggregation operations.	
III	Fuzzy numbers, relation between fuzzy number and a convex fuzzy set, characterization of fuzzy numbers in terms of its membership functions as piecewise defined functions, fuzzy cardinality of a fuzzy set using fuzzy numbers, arithmetic operations on fuzzy numbers, extension of standard arithmetic operations on real numbers to fuzzy numbers, lattice of fuzzy numbers, (R, MIN, MAX) as a distributive lattice, fuzzy equations, equation $A+X = B$, equation $A.X = B$. **Fuzzy Relations:** Crisp and fuzzy relations, projections and cylindrical extensions, binary fuzzy relations, domain, range and height of a fuzzy relation, membership matrices, sagittal diagram, inverse of a fuzzy relation.	15
IV	Composition of fuzzy relations, standard composition, max-min composition, relational join, binary relations on a single set, directed graphs, reflexive, irreflexive, antireflexive, symmetric, asymmetric, antisymmetric, transitive (max-min transitive), non transitive, antitransitive fuzzy relations. Fuzzy equivalence relations, fuzzy compatibility relations, α -compatibility class, maximal α -compatibles, complete α -cover, reflexive undirected graphs, fuzzy ordering relations, fuzzy upper bound, fuzzy pre ordering, fuzzy weak ordering, fuzzy strict ordering, fuzzy morphisms. Sup-i compositions of Fuzzy relations, Inf-i compositions of Fuzzy relations.	11
V	Possibility Theory : Fuzzy measures, continuity from below and above, semicontinuous fuzzy measures, examples and simple properties; Evidence Theory, belief measure, superadditivity, monotonicity, plausibility measure, subadditivity, basic assignment, its relation with belief measure and plausibility measure, focal element of basic assignment, body of evidence, total ignorance, Dempster's rule of combination, examples; Possibility Theory, necessity measure, possibility measure, implications, possibility distribution function, lattice of possibility distributions, joint possibility distribution. Fuzzy sets and possibility theory, Possibility theory versus probability theory. Fuzzy Logic: An overview of classical logic, about logic functions of two variables, Multivalued logics, Fuzzy propositions,Fuzzy Quantifiers,Linguistic Hedges, Inference from conditional fuzzy propositions, inference from conditional and qualified propositions, inference from unqualified propositions. Applications: Fuzzy theory and weather classifications,Water demand forecasting Soil	10

	water movement and applications in environmental science, Medical diagnosis, Financial markets, Uncertainty in Business management, Psychology, Foods and nutrition with case studies.	

Books Recommended:

1. Fuzzy sets and fuzzy logic, theory and applications – George J. Klir, Yuan Prentice Hall 2006.
2. Analysis and management of uncertainty: Theory and applications: Ayyub, B. M., L.N. Kanal, North Holland, New york 1992.
3. Fuzzy data Analysis : Bandler, W. and W. Nather, Kluwer 1996.
4. Kwang H. Lee, First Course on Fuzzy Theory and Applications, Springer International Edition, 2005.
5. H. J. Zimmerman, Fuzzy Set Theory and its Applications, Allied Publishers Ltd., New Delhi, 1991.
6. John Yen, Reza Langari, Fuzzy Logic - Intelligence, Control and Information, Pearson Education, 1999.
7. A. K. Bhargava, Fuzzy Set Theory, Fuzzy Logic & their Applications, S. Chand & Company Pvt. Ltd., 2013.

Fourth Paper, Ninth Semester/Fifth Year, M.A./M.Sc.(Mathematics)

Program: PG Degree Program	Class: M.A./M.Sc.	
	Year: Fifth	Semester: Eighth
Subject: Mathematics		
Course Code: B030904T	Course Title: Fluid Mechanics	

Course Outcomes

After the completion of the course, students are expected to have the ability to:

1. Understand the concept of fluid and types of fluid flows and certain approaches to study the fluid motion.
2. Reduce the orthogonal curvilinear coordinates in various coordinates systems.
3. Know the influence of singularities arising in two-dimensional fluid motion.
4. Understand the application of circle theorem and circulation theorem.
5. Explain the nature of forces, concept of stress and rate of deformation tensors.

Credits: 4	Maximum Marks: 25+75 (CIA+UE)
Nature of Course: Theory(Elective 01)	Minimum Passing Marks: 36 (CIA+UE)
Total Number of Lectures-Tutorials-Practicals (In Hours per week): L-T-P: 4-0-0	

Course Contents

Unit	Topics	L-T-P
I	Concept of fluid, Types of fluids, certain types of fluid flow, Continuum hypothesis, Lagrangian and Eulerian method of describing fluid motion, Equation of continuity in Lagrangian and Eulerian approaches, General displacement of a fluid element: Translation, Rotation and Deformation.	12
II	Material and convective derivatives, Reynolds transport theorem (statement only), Orthogonal curvilinear coordinates,Reduction of orthogonal curvilinear coordinates	12

	in Cartesian, cylindrical polar and spherical polar coordinates. Euler's equations of motion in the Cartesian, cylindrical polar and spherical polar coordinates.	
III	Bernoulli's equation, Stream function, Velocity potential,Complex potential,Basic singularities: Source, Sink and doublet, Complex potential due to these basic singularities,Image system of a simple source and a simple doublet with regard to a line and a circle.	15
IV	Milne-Thomson circle theorem and its applications,Complex potential for a uniform flow past a circular cylinder, Streaming and circulation about a fixed circular cylinder, Kelvin's circulation theorem.	11
V	Kelvin's minimum kinetic energy theorem, Axisymmetric motion, Stokes stream function, Body forces and surface forces, Concept of stress, Rate of deformation components.	10

Books Recommended:

1. F. Chorlton: Textbook of Fluid Dynamics, CBS Publishers and Distributers, New Delhi, India.
2. N. Curle and H. J. Davies:Modern Fluid Dynamics, D. Van Nostrand Company Ltd., London.
3. S. K. Som, G. Biswas and S. Chakraborty: Introduction to Fluid Mechanics and Fluid Machines, Tata McGraw- Hill Education, India.

Fourth Paper, Ninth Semester/Fifth Year, M.A./M.Sc.(Mathematics)

Program: PG Degree Program	Class: M.A./M.Sc.	
	Year: Fifth	Semester: Eighth
Subject: Mathematics		
Course Code: B030804T	Course Title: Commutative Algebra	

Course Outcomes

After the completion of the course, students are expected to have the ability to:

1. Know about commutative rings, their modules and ideals that are important tools in the study of two enormously important branches of Mathematics: Algebraic Geometry and Algebraic Number Theory.
2. Learn about free nilradical and Jacobson radical, operation on ideals, modules and module homomorphisms, tensor product of modules, tensor product of Algebras.
3. Understand rings and modules of fractions, extended and contracted ideals in ring of fractions.
4. Know about integrally closed domains, Hilbert's Nullstellensatz theorem, chain conditions on rings and modules, primary decomposition of an ideal in Notherian rings, structure theorem of Artinian rings.

Credits: 4	Maximum Marks: 25+75 (CIA+UE)
Nature of Course: Theory(Elective 02)	Minimum Passing Marks: 36 (CIA+UE)
Total Number of Lectures-Tutorials-Practicals (In Hours per week): L-T-P: 4-0-0	

Course Contents

Unit	Topics	L-T-P
I	Basic review of Rings and ring homomorphism, ideals, quotient rings, zero divisors,	12

	nilpotent elements, units, prime ideals and maximal ideals, Nilradical and Jacobson radical, operation on ideals, extension and contraction of ideals, Modules and module homomorphisms, tensor product of modules, Algebras, tensor product of algebras.	
II	Rings and Modules of fractions, local properties, extended and contracted ideals in ring of fractions, Primary Decomposition.	12
III	Integral dependence, the going up theorem, Integrally closed domains, The going down theorem, valuations rings, Hilbert's Nullstellensatz theorem.	15
IV	Chain conditions, Noetherian rings, Primary decomposition in Noetherian rings.	11
V	Artinian rings, structure theorem for Artin rings, Discrete valuation rings, Dedekind domains, fractional ideals.	10

Books Recommended:

1. M. F. Atiyah and I.G. MacDonald: Introduction to Commutative Algebra, Levant Books, Indian Edition, 2007.
2. M. Artin: Algebra, Prentice Hall of India, New Delhi 1994.
3. Nathan Jacobson: Basic Algebra-II, Hindustan Publishing Corporation 1994.
4. R. Y. Sharp: Steps in Commutative Algebra, London Math. Soc. Student Text 19, Cambridge University Press, 1990.
5. Zariski & Samuel, Commutative Algebra,Vol. 1 & 2.
6. David S. Dummit and Richard M Foote: Abstract Algebra, John Wiley & Sons, 2004.

Fourth Paper, Ninth Semester/Fifth Year, M.A./M.Sc.(Mathematics)

Program: PG Degree Program	Class: M.A./M.Sc.	
	Year: Fifth	Semester: Eighth
Subject: Mathematics		
Course Code: B030904T	Course Title: Mathematical Modelling	

Course Outcomes

After the completion of the course, students are expected to have the ability to:

1. Understand the need/techniques/classification of Mathematical modelling through the use of ODEs and their qualitative solutions through sketching.
2. Learn to develop Mathematical models using systems of ODEs to analyse/predict population growth, epidemic spreading for their significance in Economics, Medicine, arm-race or battle/war.
3. Attain the skill to develop Mathematical models involving linear ODEs of order two or more and difference equations, for their relevance in Probability theory, Economics, finance, population dynamics and genetics.
4. Learn about non age and age structured models, simple logistic models, physical basis of logistic model, Smith's model, generalized logistic model.

Credits: 4	Maximum Marks: 25+75 (CIA+UE)

Nature of Course: Theory(Elective 03)	Minimum Passing Marks: 36 (CIA+UE)	
Total Number of Lectures-Tutorials-Practicals (In Hours per week): L-T-P: 4-0-0		
Course Contents		
Unit	**Topics**	**L-T-P**
I	Mathematical modelling, simple situations requiring Mathematical modelling, tools, techniques and classification of Mathematical models, characteristics of Mathematical models, limitations of Mathematical modelling, Mathematical modelling using various Mathematical disciplines.	12
II	Mathematical modelling through differential equations, Mathematical modelling in population dynamics: human population and biological growth, growth and decay models, microbes and microbial kinetics, microbial growth in chemostat, stability of steady states for chemostat, growth of microbial populations.	12
III	Introduction to difference equations, Stability theory for difference equations, applications of difference equations in population dynamics, Mathematical modelling through difference equations.	15
IV	Mathematical modelling in probability theory, Economics, Finance, medicine, arm-race, battle.	11
V	Single species: non age and age structured models, simple logistic models, physical basis of logistic model, Smith's model, generalized logistic model, difference equation for logistic model, logistic model for a non-isolated population, BLL model, some Leslie matrix and its eigen values and eigen vectors.	10

Books Recommended:

1. J. N. Kapur: *Mathematical Modelling*, New Age International Ltd., 1988.
2. M. Adler, *An Introduction to Mathematical Modelling*, Heaven For Books.Com, 2001.
3. S. M. Moghadas, M.J.-Douraki, *Mathematical Modelling: A Graduate Text Book*, Wiley, 2018.
4. E. A. Bender, *An Introduction to Mathematical Modeling*, Dover Publication, 2000.
5. J. N. Kapur: Mathematical Models in Biology and Medicine, Affiliated East-West Press Pvt. Ltd., New Delhi. 1985.
6. J. Mazumdar: An Introduction to Mathematical Physiology and Biology, Cambridge University Press, 1999.

Fifth Paper, Ninth Semester/Fifth Year, M.A./M.Sc.(Mathematics)

Program: PG Degree Program	Class: M.A./M.Sc.	
	Year: Fifth	Semester: Ninth
Subject: Mathematics		
Course Code: B030905P	Course Title: Mathematics using Mathematica	

Course Outcomes

After the completion of the course, students have capability to:

1. Know the origin of Mathematica and fundamentals about this software.
2. Find out the graphs in 2D, 3D and manipulation on plots.
3. Verify solution of certain special types of differential equations with Isoclines techniques.
4. Solve the various problems on Matrices, Mathematical analysis, etc.

Credits: 4	Maximum Marks: 25+75 (CIA+UE)
Nature of Course: Practical(Compulsory)	Minimum Passing Marks: 36 (CIA+UE)
Total Number of Lectures-Tutorials-Practicals (In Hours per week): L-T-P: 2-0-4	

Course Contents

Unit	Topics	L-T-P
I	About the origin of Mathematica, Basic concepts on Mathematica, Historical reviews on Mathematica.	12
II	Plotting of curves, Plotting of surfaces in three-dimensional view, Curve fitting, Manipulation of plots.	12
III	Representation of orthogonal curvilinear coordinates such as cylindrical polar, spherical polar and parabolic cylindrical coordinates.	15
IV	General solution of certain types of differential equations and their verification using sketching of solution curves.	11
V	Analytical and numerical problems of Mathematical analysis, matrices and algebraic equations.	10

Books Recommended:

1. Hartmut F. W. Höft and Margret Höft, Computing with Mathematica, *Academic Press*, 2003.
2. Roman E. Maeder, Computer Science with Mathematica, Cambridge University Press, 2000.
3. Daniel Dubin, Numerical and Analytical Methods for Scientists and Engineers Using Mathematica, *Wiley*, 2003.

SEMESTER X

Sr. No.	Course/ Paper No.	Course/ Paper Code	Course/Paper Title	Credits	Teaching /Periods (Hours per week)	Maximum Marks		
						Continuous Internal Assessment*	End-Semester Examination	Total
1.	First	B031001T	Wavelets	5	5	25	75	100
2.	Second	B031002T	Students are required to choose any one of the following elective courses/Papers: ⇓					
			Elective 01	5	5	25	75	100
			Elective 02	5	5	25	75	100
			Elective 03	5	5	25	75	100
			Elective 04	5	5	25	75	100
3.	Third	B031003T	Students are required to choose any one of the following elective courses/Papers: ⇓					
			Elective 01	5	5	25	75	100
			Elective 02	5	5	25	75	100
			Elective 03	5	5	25	75	100
			Elective 04	5	5	25	75	100
4.	Fourth	B031004T	Students are required to choose any one of the following elective courses/Papers: ⇓					
			Elective 01	5	5	25	75	100
			Elective 02	5	5	25	75	100
			Elective 03	5	5	25	75	100
			Elective 04	5	5	25	75	100
5.	Fifth	B031005R	Research Project	4	4	According to NEP-2020**		

Remark:

(a) **Students in the fifth year of higher education shall submit a joint dissertation (project report/dissertation) of the research project undertaken in both semesters(Semester IX and Semester X) at the end of the year, which will be assessed jointly out of 100 marks by the supervisor and the external examiner at the end of the year.

First Paper, Tenth Semester/Fifth Year, M.A./M.Sc.(Mathematics)

Program: PG Degree Program	Class: M.A./M.Sc.	
	Year: Fifth	Semester: Tenth
Subject: Mathematics		
Course Code: B031001T	Course Title: Wavelets	

Course Outcomes

After the completion of the course, students are expected to have the ability to:

1. Know more recent developments such as the discrete, inverse discrete and fast Fourier transforms.
2. Understand the Shannon wavelets, Daubechies' D6 wavelets on Z_N, wavelets on Z, Haar wavelets on Z, Daubechies' D6 wavelets for $l^2(Z)$, orthonormal bases generated by a single function in $L^2(R)$, orthonormal wavelets in $L^2(R)$, and Balian-Low theorem.
3. Learn about the idea of multiresolution analysis and the journey from MRA to wavelet bases.
4. Understand the construction of scaling function with compact support, Shannon wavelet, Franklin wavelet, Minimally Supported Wavelets, Wavelet Sets, Journe's wavelet, and Decomposition and reconstruction algorithms of Wavelets.

Credits: 5	Maximum Marks: 25+75 (CIA+UE)
Nature of Course: Theory(Compulsory)	Minimum Passing Marks: 36 (CIA+UE)
Total Number of Lectures-Tutorials-Practicals (In Hours per week): L-T-P: 4-1-0	

Course Contents

Unit	Topics	L-T-P
I	The discrete Fourier transform and the inverse discrete Fourier transform, their basic properties and computations, the fast Fourier transform, The translation invariant linear transformation.	12
II	Construction of first stage wavelets on Z_N, Shannon wavelets, Daubechies' D6 wavelets on Z_N. Description of $l^2(Z)$, $L^2[-\pi, \pi)$, $L^2(R)$, their orthonormal bases, Fourier transform and convolution on $l^2(Z)$, wavelets on Z, Haar wavelets on Z, Daubechies' D6 wavelets for $l^2(Z)$.	12
III	Orthonormal bases generated by a single function in $L^2(R)$, Fourier transform and inverse Fourier transform of a function f in $L^1(R) \cap L^2(R)$, Parseval's relation, Plancherel's formula, Orthonormal wavelets in $L^2(R)$, Balian-Low theorem.	15
IV	Multi-resolution analysis and MRA wavelets, Low pass filter, Characterizations in multiresolution analysis, compactly supported wavelets, band-limited wavelets.	11
V	Franklin wavelets on R, Dimension function, Characterization of MRA wavelets (Sketch of the proof), Minimally Supported Wavelets, Wavelet Sets, Characterization of two-interval wavelet sets, Shannon wavelet, Journe's wavelet, Decomposition and reconstruction algorithms of Wavelets.	10

Books Recommended:

1. Eugenio Hernández and Guido Weiss, A First Course on Wavelets, CRC Press, 1996.
2. Ingrid Daubechies, Ten Lectures on Wavelets, CBS-NFS Regional Conferences in Applied Mathematics, 61, SIAM, 1992.
3. Michael W. Frazier, An Introduction to Wavelets through Linear Algebra, Springer-Verlag, 1999.
4. C. K. Chui, An Introduction to Wavelets, Academic Press, 1992.

Second Paper, Tenth Semester/Fifth Year, M.A./M.Sc.(Mathematics)

Program: PG Degree Program	Class: M.A./M.Sc.	
	Year: Fifth	Semester: Tenth
Subject: Mathematics		
Course Code: B031002T	Course Title: Advanced Fluid Mechanics	

Course Outcomes

After the completion of the course, students are expected to have the ability to:

1. Obtain the Navier-Stokes equations to study the fluid motion in various coordinates.
2. Derive the vorticity theorem, distinguish the fluid flow and concept of similarities.
3. Obtain the Stokes equations and origin of Stokes flow.
4. Understand the phenomenon of fluid flow through porous medium.
5. Explain the phenomenon of boundary layer and some types of thicknesses.

Credits: 5	Maximum Marks: 25+75 (CIA+UE)
Nature of Course: Theory(Elective 01)	Minimum Passing Marks: 36 (CIA+UE)
Total Number of Lectures-Tutorials-Practicals (In Hours per week): L-T-P: 4-1-0	

Course Contents

Unit	Topics	L-T-P
I	Two-dimensional stress invariants, Principal stresses, Principal directions, Newton's law of viscosity, Constitutive equations for Newtonian fluids, Navier-Stokes equations in tensor and vector forms, Navier-Stokes equations in Cartesian, cylindrical and spherical coordinate systems.	12
II	Helmholtz vorticity theorem, Vorticity equations, Energy dissipation due to viscosity, Dynamical similarity and dimensionless numbers and their significance, Fully developed,Plane Poiseuille and Couette flows between parallel plates, Hagen Poiseuille flow, Steady flow between pipes of uniform cross- section.	12
III	Couette flow between coaxial rotating cylinders, Flow between steadily rotating spheres, Small Reynolds number flow, Stokes equations, Relation between pressure andstream function, solution of Stokes equations in spherical polar coordinates, Steady flow past a sphere.	15
IV	Flow past a circular cylinder, Stokes paradox, Oseen's equations, Elementary ideas about perturbation and cell methods,Fluid flow through porous medium, Brinkman equation.	11

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V	Two-dimensional boundary layer equations, Separation phenomena, method, Boundary layer on a semi-infinite plane, Blasius equation and solution, Displacement thickness, Momentum thickness and Energy thickness.	10

Books Recommended:

1. J. Happel and H. Brenner, Low Reynolds Number Hydrodynamics, Kluwer Academic Publishers Group, Dordrecht, The Netherlands, 1983.
2. Z. U. A. Warsi, Fluid Dynamics, CRC Press, 2005.
3. N. Curle and H. J. Davies, Modern Fluid Dynamics, Vol. I, D. Van Nostrand Comp. Ltd. London, 1964.
4. D.A. Nield and A. Bejan, Convection in Porous Media, Springer, 2006.

Second Paper, Tenth Semester/Fifth Year, M.A./M.Sc.(Mathematics)

Program: PG Degree Program	Class: M.A./M.Sc.	
	Year: Fifth	Semester: Tenth
Subject: Mathematics		
Course Code: B031002T	Course Title: Representation Theory of Finite Groups	

Course Outcomes

After the completion of the course, students are expected to have the ability to:

1. Learn about irreducible and completely reducible modules, Schur's Lemma, Jacobson density Theorem, Wedderburn Structure theorem for semisimple modules and rings, equivalent and non-equivalent representations, Characters, Burnside's $paqb$ – Theorem, Induced representations, The character of an induced representations, Frobenius reciprocity Theorem, Mackey's irreducibility criterion, Clifford's Theorem, Statement of Brauer and Artin's Theorems.
2. Know the link between group representations over a field F and modules using the concept of a group ring F[G].
3. Understand the story of the representation theory of a group as the theory of all F[G]-modules, viz modules over the group ring of G over F which leads to significant applications to the structure theory of finite groups.
4. Construct complex representations for popular groups as well as their character tables which serve as invariants for group rings.

Credits: 5	Maximum Marks: 25+75 (CIA+UE)
Nature of Course: Theory(Elective 02)	Minimum Passing Marks: 36 (CIA+UE)
Total Number of Lectures-Tutorials-Practicals (In Hours per week): L-T-P: 4-1-0	

Course Contents

Unit	Topics	L-T-P
I	Irreducible and completely reducible modules, Schur's Lemma, Jacobson density Theorem, Wedderburn Structure theorem for semisimple modules and rings. Group Algebra, Maschke's Theorem.	12
II	Representation of a group on a vector space, matrix representation of a group, equivalent	12

	and non-equivalent representations, Decomposition of regular representation, Number of irreducible representations.	
III	Characters, irreducible characters, Orthogonality relations, Integrality properties of characters, character ring, Burnside's *paqb* - Theorem.	15
IV	Representations of direct product of two groups, Induced representations, The character of an induced representations, Frobenius reciprocity Theorem. Construction of irreducible representations of Dihedral group D_n, Alternating group A_4, Symmetric groups S_4 and S_5.	11
V	Mackey's irreducibility criterion, Clifford's Theorem, Statement of Brauer and Artin's Theorems.	10

Books Recommended:

1. M. Burrow, Representation Theory of Finite Groups, Academic Press, 1965.
2. L. Dornhoff, Group Representation Theory, Part A, Marcel Dekker, Inc., New York, 1971.
3. N. Jacobson, Basic Algebra II, Hindustan Publishing Corporation, New Delhi, 1983.
4. S. Lang, Algebra, 3rd ed., Springer, 2004.
5. J. P. Serre, Linear Representation of Groups, Springer-Verlag, 1977.

Second Paper, Tenth Semester/Fifth Year, M.A./M.Sc.(Mathematics)

Program: PG Degree Program	Class: M.A./M.Sc.	
	Year: Fifth	Semester: Tenth
Subject: Mathematics		
Course Code: B031002T	Course Title: Measure and Integration – II	

Course Outcomes

After the completion of the course, students are expected to have the ability to:

1. Understand the concepts of abstract integration, measurability and its properties, measurable spaces, measurable and simple functions.
2. Learn about the concepts of positive Borel measures, regularity properties of Borel measures; demonstrate understanding of the statemenst and proofs of the Lusin's theorem and Vitali Caratheodory theorem.
3. Understand the concepts of Lp-spaces and it's properties, complex measures and Radon-Nikodym theorem.
4. Know about derivatives of measures, product measures and Fubini theorem.

Credits: 5	Maximum Marks: 25+75 (CIA+UE)
Nature of Course: Theory(Elective 03)	Minimum Passing Marks: 36 (CIA+UE)
Total Number of Lectures-Tutorials-Practicals (In Hours per week): L-T-P: 4-1-0	

Course Contents

Unit	Topics	L-T-P
I	Abstract integration, the concept of measurability, simple functions, elementary properties of measures, integration of positive functions, integration of complex functions, the role played by sets of measure zero.	12
II	Positive Borel measures: vector spaces, The Riesz Representation Theorem (statement	12

	only), regularity properties of Borel measures, Lusin's theorem, Vitali Caratheodory theorem.	
III	Lp-spaces: Convex functions and inequalities, The Lp- spaces, Approximations by continuous functions.	15
IV	Complex measures: Total variation, absolute continuity, Radon- Nikodym theorem, Bounded linear functional on Lp- spaces.	11
V	Differentiation: Derivatives of measures, the Fundamental theorem of Calculus. Integration on product spaces: Measurability on cartesian products, product measures, the Fubini theorem.	10

Books Recommended:

1. H. L. Royden, Real Analysis (3rd Edition) Prentice-Hall of India, 2008.
2. G. de Barra, Measure theory and integration, New Age International,2014.
3. P. R. Halmos: Measure Theory, Springer New York, 2013.
4. I.K. Rana: An Introduction to Measure and Integration, Narosa Publishing House, Delhi, 1997.
5. R. G. Bartle: The Elements of Integration, John Wiley and Sons, Inc. New York, 1966.

Second Paper, Tenth Semester/Fifth Year, M.A./M.Sc.(Mathematics)

Program: PG Degree Program	Class: M.A./M.Sc.	
	Year: Fifth	Semester: Tenth
Subject: Mathematics		
Course Code: B031002T	Course Title: Algebraic Coding Theory	

Course Outcomes

This course will enable the students to:

1. Know about the coding and communication of messages, and efficient encoding and decoding procedures using modern algebraic techniques.
2. Understand group codes, matrix encoding techniques, polynomial codes and Hamming codes, basic results of error detection and error correction of codes, and codes defined by generator.
3. Have deep understanding of finite fields, BCH codes.
4. Know about the linear codes, cyclic codes, self dual binary cyclic codes.
5. Learn about the MDS codes, Hadamard matrices and Hadamard codes.

Credits: 5	Maximum Marks: 25+75 (CIA+UE)
Nature of Course: Theory(Elective 04)	Minimum Passing Marks: 36 (CIA+UE)
Total Number of Lectures-Tutorials-Practicals (In Hours per week): L-T-P: 4-1-0	

Course Contents

Unit	Topics	L-T-P
I	Group codes, elementary properties, matrix encoding techniques. Generator and parity check matrices, polynomial codes. Vector space and polynomial ring, binary representation of numbers, Hamming codes.	12
II	Basic properties of finite fields, irreducible polynomial over finite field, roots of unity.	12

	Some examples of primitive polynomials, BCH codes.	
III	Linear codes, generator and parity check matrices, dual code of a linear code, Weight distribution of the dual code of a binary linear code, new codes obtained from given codes.	15
IV	Cyclic codes, check polynomials, BCH and Hamming codes as cyclic codes, non-binary Hamming codes, idempotent , solved examples and invariance property, cyclic codes and group algebras, self dual binary cyclic codes.	11
V	Necessary and sufficient condition for MDS codes, the weight distribution of MDS codes, an existence problem, Read Solomon codes. Hadamard matrices and Hadamard codes.	10

Books Recommended:

1. Steven Roman, Coding and Information Theory, Springer-Verlag, 1992.
2. L.R. Vermani, Elements of Algebraic Coding Theory, CRC Press, 1996.
3. San Ling and Chaoping Xing- Coding Theory, Cambridge University Press,1st Edition, 2004.
4. W. C. Huffman and Vera Pless – Fundamentals of Error Correcting Codes, Cambridge University Press, 1st South Asian Edition, 2004.
5. Raymond Hill- Introduction to Error Correcting Codes, Oxford University Press, 1986, reprint 2009.
6. F. J. MacWilliams and N.J.A.Sloane – Theory of Error Correcting Codes Part I & II, Elsevier/North-Holland, Amsterdam, 1977.
7. Vera Pless - Introduction to Theory of Error Correcting Codes, Wiley-Interscience, 3rd Edition, 1982.

Third Paper, Tenth Semester/Fifth Year, M.A./M.Sc.(Mathematics)

Program: PG Degree Program	Class: M.A./M.Sc.	
	Year: Fifth	Semester: Tenth
Subject: Mathematics		
Course Code: B031003T	Course Title: Special Functions and Lie Theory	

Course Outcomes

After successful completion of the course, students will be able to:

1. Solve, expand and interpret solutions of many types of important differential equations by making use of special functions and orthogonal polynomials.
2. Understand the basic knowledge of special matrix functions so that further use in Advanced level and research.
3. Derive the formulas and results of certain classical special functions and orthogonal polynomials by different methods.
4. Derive the generating relations involving special functions by applying the Lie algebraic techniques.
5. Gain the ability to analyse problems using special functions and orthogonal polynomials, which helps in examining the role of special functions and orthogonal polynomials in other areas of mathematics.

Credits: 5	Maximum Marks: 25+75 (CIA+UE)
Nature of Course: Theory(Elective 01)	Minimum Passing Marks: 36 (CIA+UE)

Total Number of Lectures-Tutorials-Practicals (In Hours per week): L-T-P: 4-1-0		
	Course Contents	
Unit	**Topics**	**L-T-P**
I	Gamma Function, Hypergeometric Functions: Definition and special cases, convergence, integral representation, differentiation, continuous function relations, transformations and summation theorems. The Confuent Hypergeometric function: Basic properties of 1F1, Kummers first formula. Kummers second formula.	12
II	Beta and Gamma matrix functions, Hypergeometric matrix functions, Appell matrix functions, Incomplete gamma functions, Incomplete hypergeometric matrix functions and their Properties.	12
III	Bessel Functions: Definition, connection with hypergeometric function, differential and pure recurrence relations, generating function, Integral representation; Hermite and Laguerre polynomials; Ordinary and singular points of differential equations, Regular and irregular singular points of hypergeometric, Bessel, Legendre, Hermite and Laguerre differential equations; Examples on above topics.	15
IV	Legendre polynomials: (i) Generating function (ii) Special values (iii) Pure and differential recurrence relations (iv) Differential equation (v) Series definition (vi) Rodrigues' formula (vii) Integral representation; Hermite polynomials: Results (i) to (vii) and expansion of x^n in terms of Hermite polynomials; Laguerre polynomials: Results (i) to (vii); Examples on above topics.	11
V	Lie groups; Tangent vector; Lie bracket; Lie algebra; General linear and special linear groups and their Lie algebras; Exponential of matrix and its properties; Construction of partial differential equation; Linear differential operators; Group of operators; Extended forms of the group generated by the operators; Derivation of generating functions; Examples on above topics.	10

Books Recommended:

1. E. D. Rainville: Special Functions, Chelsea Publishing Co., Bronx, New York, Reprint, 1971.
2. W. Jr. Miller: Lie Theory and Special Functions, Academic Press, New York and London, 1968.
3. E. B. McBride: Obtaining Generating Functions, Springer Verlag, Berlin Heidelberg, 1971.

Third Paper, Tenth Semester/Fifth Year, M.A./M.Sc.(Mathematics)

Program: PG Degree Program	Class: M.A./M.Sc.	
	Year: Fifth	Semester: Tenth
Subject: Mathematics		
Course Code: B031003T	Course Title: Algebraic Number Theory	

Course Outcomes

After successful completion of the course students will be able to:

1. Know about one of the recent ideas of Mathematics.
2. Introduce Number fields, the ring of algebraic integers and it's calculations, norm and trace.
3. Understand concept of integral bases and discriminants of algebraic number fields.
4. Learn about Dedekind domains, unique factorization of ideals Learn about, the ideal class group and class number computations.
5. Demonstrate the statement and proof of Dirichlet unit theorem, some Diophantine equations, and Eisenstein reciprocity law.

Credits: 5	Maximum Marks: 25+75 (CIA+UE)
Nature of Course: Theory(Elective 02)	Minimum Passing Marks: 36 (CIA+UE)
Total Number of Lectures-Tutorials-Practicals (In Hours per week): L-T-P: 4-1-0	

Course Contents

Unit	Topics	L-T-P
I	Number fields, the ring of algebraic integers, calculation for quadratic, cubic and cyclotomic case, norms and traces, integral bases and discriminants.	12
II	Dedekind domains, unique factorization of ideals, norm of ideals, factorization of prime ideals in extensions.	12
III	The ideal class group, lattices in R^n, Minkowski's theorem, finiteness of the class number and its consequences , some class number computations.	15
IV	Dirichlet unit theorem, units in real quadratic fields, some Diophantine equations.	11
V	Cubic residue symbol, Jacobi sums, Cubic reciprocity law, biquadratic reciprocity law and Eisenstein reciprocity law.	10

Books Recommended:

1. J. Esmonde and M. Ram Murty, Problems in Algebraic Number Theory, GTM-190, Springer-Verlag, 1999.
2. R.A. Mollin, Algebraic Number Theory, CRC Press, 2011.
3. D. A. Marcus, Number Fields, Springer-Verlag, New York 1977.
4. S. Alaca and K. S. Williams, Introductory Algebraic Number theory. Cambridge University Press, 2004.
5. Paulo Ribenboim, Classical Theory of Algebraic Numbers, Springer-Verlag New York 2001.
6. P. Samuel: Algebraic Theory of Numbers, Dover Publications, 1970.
7. I. Stewart and D. Tall: Algebraic Number theory, 2nd Edition, Chapman & Hall, 1907.

Third Paper, Tenth Semester/Fifth Year, M.A./M.Sc.(Mathematics)

Program: PG Degree Program	Class: M.A./M.Sc.	
	Year: Fifth	Semester: Tenth
Subject: Mathematics		
Course Code: B031003T	Course Title: Magnetohydrodynamics	

Course Outcomes

After the completion of the course, students are expected to have the ability to:

1. Know about Maxwell's equations, conservation of energy, electromagnetic momentum density, main assumptions of MHD, electromagnetic fields in a conductor at rest, mass, momentum and energy conservation laws.
2. Understand basic properties of the magnetic field and MHD terms.
3. Learn about magnetohydrodynamic flows, formulation and solution of Linear flows, Couette flow, MHD waves in a perfectly conducting fluid and magnetosonic waves.

Credits: 5	Maximum Marks: 25+75 (CIA+UE)
Nature of Course: Theory(Elective 03)	Minimum Passing Marks: 36 (CIA+UE)
Total Number of Lectures-Tutorials-Practicals (In Hours per week): L-T-P: 4-1-0	

Course Contents

Unit	Topics	L-T-P
I	Maxwell's equations, conservation of energy, poynting vector, conservation of momentum and Maxwell's stress tensor, Electromagnetic momentum density.	12
II	Nature of Magnetohydrodynamics, Main assumptions of MHD, Electromagnetic fields in a conductor at rest, a uniformly moving rigid conductor and a deformable conductor. Basic equations of non- viscous and viscous magnetohydrodynamics: mass, momentum and energy conservation laws.	12
III	Basic Properties of the magnetic field and MHD terms: Magnetic Reynolds number, magnetic viscosity, magnetic pressure, magnetic diffusion and frozen- in- effect. Magnetohydrodynamic boundary conditions.	15
IV	Magnetohydrodynamic Flows, Formulation and solution of Linear flow, Flow between parallel plates Hartmann flow, Couette flow.	11
V	Magnetohydrodynamic Waves, Linearized equations, MHD waves in a perfectly conducting fluid, Alfven waves and magnetosonic waves.	10

Books Recommended:

1. J. D .Jackson, Classical Electrodynamics, Wile Eastwern Limited, New Delhi, 1990.
2. L. D. Landau and E. M. Lifshitz, Classical Electrodynamics, Butterworth-Heinemann, 2nd Edition, 1984.
3. A. Jaffery, Magnetohydrodynamics, Oliver and Boyd, N.Y. 1966.

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Third Paper, Tenth Semester/Fifth Year, M.A./M.Sc.(Mathematics)

Program: PG Degree Program	Class: M.A./M.Sc.	
	Year: Fifth	Semester: Tenth
Subject: Mathematics		
Course Code: B031003T	Course Title: Mechanics of Solids – II	

Course Outcomes

This course is in continuation with Mechanics of Solids - I.

After the completion of the course, students are expected to have the ability to:

1. Understand the basic foundations of waves and vibrations in elastic solids.
2. Learn about the condition of existence and frequency equation of Rayleigh waves, Particle motion of Rayleigh waves, and Snell's law of reflection and refraction.
3. Know about the problems related to earthquake science and problems of waves in manufactured bodies.

Credits: 5	Maximum Marks: 25+75 (CIA+UE)
Nature of Course: Theory(Elective 04)	Minimum Passing Marks: 36 (CIA+UE)
Total Number of Lectures-Tutorials-Practicals (In Hours per week): L-T-P: 4-1-0	

Course Contents

Unit	Topics	L-T-P
I	Extension of beams by longitudinal forces, Beam stretched by its own weight, Bending of beam by terminal couples, Torsion of a circular shaft, Torsion of a cylindrical bar, Torsion of elliptic cylinder.	12
II	Waves: Definition of wave and basic terminologies, Harmonic waves, Plane waves, wave equation in 3-D, Superposition of waves, Progressive type wave solutions, Stationary type wave solution of wave equation in different coordinate systems, Equation of Telegraphy.	12
III	D'Alembert's Solution of wave equation, Dispersion of waves and group velocity, Relation between phase and group velocity. Elastic waves, Stress waves in semi-infinite beam, Reduction of equation of motion to wave equation, P and S waves, Polarization of S wave,Helmholtz Decomposition of vector.	15
IV	Condition of existence and Frequency equation of Rayleigh waves, Love waves and Torsional waves. Particle motion of Rayleigh waves. Snell's law of reflection and refraction.	11
V	Reflection of plane waves (P/SV and SH-waves) from free surface of an elastic half-space, Reflection and transmission at interface of two different elastic solids, Partition of energy at the interface. Haskell matrix method for Love waves in multilayered media.	10

Books Recommended:

1. D. S. Chandrasekharaiah and L. Debnath, Continuum Mechanics, Academic Press, 1994.
2. I. S. Sokolnikoff, Mathematical Theory of Elasticity, Tata-McGraw Hill Publishing Company Ltd., New Delhi, 1977.
3. A. E. H. Love, A Treatise on the Mathematical Theory of Elasticity, Dover Publications, New York.

4. Y. C. Fung. Foundations of Solid Mechanics, Prentice Hall, New Delhi, 1965.
5. P. K. Ghosh, The Mathematics of Waves and Vibrations, The Macmillian Company of India ltd., 1975.
6. C. A. Coulson and A. Jefferey, Waves, Longman, New York, 1977.

Fourth Paper, Tenth Semester/Fifth Year, M.A./M.Sc.(Mathematics)

Program: PG Degree Program	Class: M.A./M.Sc.	
	Year: Fifth	Semester: Tenth
Subject: Mathematics		
Course Code: B031004T	Course Title: Algebraic Topology	

Course Outcomes

After the completion of the course, students are expected to have the ability to:

1. Know about homotopy of paths, fundamental group of a topological space; apply knowledge to compute fundamental groups; understand the concepts of contractible and simply connected spaces.
2. Learn about Brouwer's fixed- point theorem for the disc and Borsuk- Ulam theorem for S^2.
3. Understand the concepts of Covering spaces, covering transformations, orbit spaces; demonstrate understanding of the statement and proof of the unique lifting theorem and path-lifting theorem.
4. Learn about Singular complex of a topological space , singular homology groups and related concepts; demonstrate understanding of the Meyer-Vietoris sequence and its Applications, Jordan-Brouwer separation theorem, invariance of domain.

Credits: 5	Maximum Marks: 25+75 (CIA+UE)
Nature of Course: Theory(Elective 01)	Minimum Passing Marks: 36 (CIA+UE)
Total Number of Lectures-Tutorials-Practicals (In Hours per week): L-T-P: 4-1-0	

Course Contents

Unit	Topics	L-T-P
I	Homotopy of paths, fundamental group of a topological space, fundamental group functor, homotopy of maps of topological spaces; homotopy equivalence; contractible and simply connected spaces.	12
II	Fundamental group of the circle, Calculation of fundamental groups of S^n $(n > 1)$, RP^2, torus and dunce cap , Brouwer's fixed- point theorem for the disc, fundamental theorem of algebra, vector fields, Borsuk- Ulam theorem for S^2.	12
III	Covering spaces, unique lifting theorem, path-lifting theorem, covering homotopy theorem, criterion of lifting of maps in terms of fundamental groups, universal covering space, covering transformations, orbit spaces.	15
IV	Singular complex of a topological space , singular homology groups and their funcoriality, homotoy invariance of homology, Eilenberg-Steenrod axioms (without proof), abelianization of the fundamental group, relative homology.	11
V	Calculations of homology of S^n, Brouwer's fixed point theorem for $f : D^n \rightarrow D^n$ $(n > 2)$ and	10

	its applications to spheres and vector fields, Meyer-Vietoris sequence and its Applications, Jordan-Brouwer separation theorem, invariance of domain.	

Books Recommended:

1. J. R. Munkres , Topology, Prentice-Hall of India, 2000.
2. M. J. Greenberg and J. R. Harper, Algebraic topology, a first course, Addison-Wesley Publishing co., 1997.
3. S. Deo, Algebraic Topology, A Primer, Hindustan Book Agency, 2006.
4. J. W. Vick, Homology Theory , An introduction to Algebraic Topology, Springer-Verlag, 1994.

Fourth Paper, Tenth Semester/Fifth Year, M.A./M.Sc.(Mathematics)

Program: PG Degree Program	Class: M.A./M.Sc.	
	Year: Fifth	Semester: Tenth
Subject: Mathematics		
Course Code: B031004T	Course Title: Functional Analysis – II	

Course Outcomes

This course will enable the students to:

1. Undersatnd the spectrum of a bounded operator, spectral properties of bounded linear operators; apply the knowledge to prove spectral mapping theorem for polynomials; be familiar with Banach algebras and its properties.
2. Learn about compact linear operators on normed spaces, their spectral properties and application to operator equations involving compact linear operators.
3. Understand the spectral properties of bounded self-adjoint linear operators; apply the knowledge to prove spectral theorem for bounded self adjoint linear operators and extend the spectral theorem to continuous functions.
4. Understand the basics of unbounded linear operators on Hilbert spaces, adjoints of unbounded linear operators, spectral properties of self-adjoint operators, multiplication and differentiation operators.

Credits: 5	Maximum Marks: 25+75 (CIA+UE)
Nature of Course: Theory(Elective 02)	Minimum Passing Marks: 36 (CIA+UE)
Total Number of Lectures-Tutorials-Practicals (In Hours per week): L-T-P: 4-1-0	

Course Contents

Unit	Topics	L-T-P
I	Spectrum of a bounded operator: point spectrum, continuous spectrum and residual spectrum, spectral properties of bounded linear operators, the closedness and compactness of the spectrum of a bounded linear operator on a complex Banach space; further properties of resolvent and spectrum, spectral mapping theorem for polynomials. Non-emptiness of the spectrum of a bounded linear operator on a complex Banach space, spectral radius, spectral radius formula, Banach algebras, resolvent set and spectrum of a Banach algebra element, further properties of Banach algebras, spectral radius of a Banach	12

	algebra element, non-emptiness of the spectrum of a Banach algebra element.	
II	Compact linear operators on normed spaces, compactness criterion, conditions under which the limit of a sequence of compact linear operators is compact, weak convergence and compact operators, separability of range, adjoint of compact operators, Spectral properties of compact linear operators on normed spaces, eigen values of compact linear operators, closedness of the range of T_{λ}, further spectral properties of compact linear operators. Operator equations involving compact linear operators, necessary and sufficient conditions for the solvability of various operator equations, further theorems of Fredholm type. Fredholm alternative.	12
III	Spectral theory of bounded self-adjoint linear operators : spectral properties of bounded self adjoint operators, positive operators, projection operators and their properties. Spectral family of a bounded self adjoint linear operator, spectral representation of bounded self-adjoint linear operators, spectral theorem for bounded self-adjoint linear operators, extension of the spectral theorem to continuous functions, properties of the spectral family of a bounded self adjoint operator.	15
IV	Unbounded linear operators and their Hilbert adjoints, Hellinger-Toeplitz theorem, Hilbert-adjoint, symmetric and self-adjoint linear operators. Closed linear operators and closures, spectral properties of self adjoint linear operators.	11
V	Spectral representation of unitary operators : Wecken's lemma, spectral theorem for unitary operators, spectral representation for self-adjoint linear operators, multiplication and differentiation operators.	10

Books Recommended:

1. E.Kreyszig: Introductory Functional Analysis with Applications, Wiley India, 2007.
2. G.F. Simmons: Introduction to Topology and Modern Analysis, McGraw Hill Book Co.,New York, 1983.
3. R. Bhatia, Notes on Functional Analysis, TRIM series, Hindustan Book Agency, India, 2009.
4. J.E. Conway, A course in Operator Theory, Graduate Studies in Mathematics, Volume 21, AMS, 1999.
5. Martin Schechter, Principles of Functional Analysis, American Mathematical Society, 2004.
6. W. Rudin, Functional Analysis, TMH Edition, 1974.

Fourth Paper, Tenth Semester/Fifth Year, M.A./M.Sc.(Mathematics)

Program: PG Degree Program	Class: M.A./M.Sc.	
	Year: Fifth	Semester: Tenth
Subject: Mathematics		
Course Code: B031004T	Course Title: Complex Manifolds	

Course Outcomes

After the completion of the course, students are expected to have the ability to:

1. Explain the concepts of complexification of a real vector space, complex structure, the tangent space and the cotangent space and their examples.
2. Understand the concepts of vectors and tensors, real tensors, vectors and one-forms of type (1,0) and type (0,1), complex tensors and complex manifolds, tensor fields.
3. Know about almost complex structure, almost complex structure on a complex manifold, the Nijenhuis tensor.
4. Understand Hermitian structures on vector spaces, Hermitian manifolds, Kaehlerian manifolds, curvature on Kaehlerian manifolds, complex space forms, Nearly Kaehler and para Kaehler Manifolds.

Credits: 5	Maximum Marks: 25+75 (CIA+UE)
Nature of Course: Theory(Elective 03)	Minimum Passing Marks: 36 (CIA+UE)

Total Number of Lectures-Tutorials-Practicals (In Hours per week): L-T-P: 4-1-0

Course Contents

Unit	Topics	L-T-P
I	Complexification of a real vector space, complex structure, relation between complexification and complex structure, conjugate complex structure, complexification of the dual space, expressions in terms of bases, orientations, complex structures, necessary conditions for a complex structure to exist, examples of complex manifolds.	12
II	The tangent space and the cotangent space, complexified tangent space, complex structure on the tangent space, complex structure on the cotangent space, relation between the canonical complex structure and the manifold complex structure, vectors and tensors, real tensors, vectors and one-forms of type (1,0) and type (0,1), complex tensors and complex manifolds, tensor fields.	12
III	Almost complex structure, conditions for existence of an almost complex structure, almost complex structure on a complex manifold, the Nijenhuis tensor, vanishing of the Nijenhuis tensor as necessary and sufficient condition for integrability.	15
IV	Hermitian structures on vector spaces, Hermitian manifolds, curvature tensor on a Hermitian manifold, holomorphic sectional curvature, Kaehlerian manifolds, curvature on Kaehlerian manifolds, complex space forms.	11
V	Nearly Kaehler and para Kaehler Manifolds, projective correspondence between two nearly Kaehler manifolds, conformal flatness of a para Kaehler manifold, curvature identities.	10

Books Recommended:

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1. S.S. Chern, W. H. Chen and K. S. Lam, Lectures on Differential Geomerty, World Scientific, 2000.
2. E.J. Flaherty, Hermitian and Kaehlerian Geometry in Relativity, LNP 46, Springer, 1976.
3. T. J. Wilmore, Riemannian Geometry, Oxford Science Publications, 1993.
4. Kobayashi and Nomizu, Foundations of Differential geometry, Vol-II, Interscience Publishers, 1963. K. Yano & M. Kon, Structures, on Manifolds, World Scientific, 1984.

Fourth Paper, Tenth Semester/Fifth Year, M.A./M.Sc.(Mathematics)

Program: PG Degree Program	Class: M.A./M.Sc.	
	Year: Fifth	Semester: Tenth
Subject: Mathematics		
Course Code: B031004T	Course Title: Non-Linear Analysis	

Course Outcomes

After the completion of the course, students are expected to have the ability to:

1. Provide the applicability in differential equations, integral equations and variational inequality problems.
2. Know the basic tools for variational analysis and optimization.
3. Understand the strong and weak convergence theorems in Banach space.

Credits: 5	Maximum Marks: 25+75 (CIA+UE)
Nature of Course: Theory(Elective 04)	Minimum Passing Marks: 36 (CIA+UE)
Total Number of Lectures-Tutorials-Practicals (In Hours per week): L-T-P: 4-1-0	

Course Contents

Unit	Topics	L-T-P
I	Compactness in Metric spaces, Measure of Noncompactness, Normed spaces, Banach spaces, Hilbert spaces, Uniformly convex, strictly convex and reflexive Banach spaces, Lipschitzian and contraction mapping, Application to Volterra and Fredholm integral equations , Banach contraction principle and its applications to system of linear equations, integral equations and differential equations; Contractive mappings and Eldestien Theorem, Boyd-Wong's fixed point theorem, Matkowski's fixed point theorem.	12
II	Nonexpansive, asymptotically nonexpansive, accretive and quasinonexpansive mappings, Fixed point theorems for nonexpansive mappings, Nonexpansive operators in Banach spaces satisfying Opial's conditions, The demiclosedness principle.	12
III	Schauder's fixed point theorem. Condensing maps. Fixed points for condensing maps, The modulus of convexity and normal structure, radial retraction, Sadovskii's fixed point theorem, Set-valued mappings.	15
IV	Fixed point iteration procedures, The Mann Iteration, Lipschitzian and Pseudocontractive operators in Hilbert spaces, Strongly pseudocontractive operators in Banach spaces, The Ishikawa iteration, Stability of fixed point iteration procedures.	11
V	Iterative solution of Nonlinear operator equations in arbitrary and smooth Banach spaces, Nonlinear *m*-accretive operator, Equations in reflexive Banach spaces.	10

Books Recommended:

1. M. A. Khamsi and W. A. Kirk, An Introduction to Metric Spaces and Fixed Point Theory, John Wiley & Sons, New York, 2001.
2. Sankatha P. Singh, B. Watson and P. Srivastava, Fixed Point Theory and Best Approximation: The KKM-map Principle, Kluwer Academic Publishers, Dordrecht, The Netherlands, 1997.
3. V. I. Istratescu, Fixed Point Theory, An Introduction, D. Reidel Publishing Co., 1981.
4. K. Goebel and W. A. Kirk, Topic in Metric Fixed Point Theory, Cambridge University Press, 1990.
5. V. Berinde, Iterative Appróximation of Fixed Points, Lecture Notes in Mathematics, No. 1912, Springer, 2007.

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Course Structure of the Course Research Project for all Semesters [VII-X Sem.]

Program: Graduation With Research Degree Program / PG Degree Program	Class: M.A./M.Sc.	
	Year: Fourth/Fifth	Semester: VII/VIII/IX/X
Subject: Mathematics		
Course Code: B030706R/ B030805R/ B030906R/ B031005R	Course Title: Research Project	

Course Outcomes

This course will enable the students to:

1. Identify an area of interest and to select a topic therefrom realizing ethical issues related to one's work and unbiased truthful actions in all aspects of work and to develop research aptitude.
2. Have deep knowledge and level of understanding of a particular topic in core or applied areas of Mathematics, imbibe research orientation and attain capacity of investigating a problem.
3. Obtain capability to read and understand mathematical texts from books/journals/e-contents, to communicate through write up/report and oral presentation.
4. Demonstrate knowledge, capacity of comprehension and precision, capability to work independently and tendency towards life-long learning.

Credits: 4	Maximum Marks: 100
Nature of Course: Theory(Compulsory)	Minimum Passing Marks: 36

Total Number of Lectures-Tutorials-Practicals (In Hours per week): L-T-P: 3-1-0

Course Contents	L-T-P
• Each student will have to undertake major research project related to the major subject (Mathematics). • This research project can also be Interdisciplinary / Multi-disciplinary. • This research project can also be in the form of Industrial Training/Internship/Survey Work, etc. • The topic of the research project will be decided by the supervisor concerned according to the area of interest of the student. • The concerned supervisor (for each student) will prepare the course contents for the research project and will also finalize the procedure for completing the research project.	

Books Recommended:

1. The books required for the research project for the students will be recommended by the concerned supervisor.

Minor Elective Courses for students of other faculties (offered by the Department of Mathematics).

Any one of the following minor elective courses may be opted for by a student of the Graduation With Research Degree Program/PG degree program of another Faculty in any one semester of the Fourth Year of Higher Education. The course code for the minor elective courses chosen by the students of other faculties will be according to minor elective course number and semester number.

Minor Elective Course-I

Course Code:	Course Title: Basic Mathematics

Course Outcomes

After the completion of the course, students are expected to have the ability to:

1. Know about the basic set theory, Number systems, relations, functions, graphs.
2. Understand convergence of sequences and series; attain the skill to handle the convergence of various infinite series.
3. Know about the limit, continuity, differentiability of real valued functions defined on real numbers, maxima and minima; attain the skill to compute maxima and minima.
4. Learn about the Riemann integration, useful methods for solving ordinary differential equations and partial differential equations (first and second order) and their applications, permutations and combinations, Probability.

Credits: 4/5	Maximum Marks: 25+75 (CIA+UE)
Nature of Course: Theory(Compulsory)	Minimum Passing Marks: 36 (CIA+UE)

Total Number of Lectures-Tutorials-Practicals (In Hours per week): L-T-P: 3-1-0/3-2-0

Course Contents

Unit	Topics	L-T-P
I	Basics of set theory, Number systems, relations, functions, graphs, and their properties.	12
II	Basics of sequences and series for real numbers, limit, continuity, differentiability of real valued functions defined on real numbers, maxima and minima.	12
III	Basics of Riemann integration, applications of Riemann integration.	15
IV	Origin of ordinary differential equations and partial differential equations (first and second order). Useful methods for solving ordinary differential equations and partial differential equations (first and second order) and their applications.	11
V	The concepts of permutation and combination, and their applications in daily life. Basics of Probability Theory and its applications.	10

Books Recommended:

1. W. Rudin: 'Principles of Mathematical Analysis'. 3rd Edition (International Student Edition) McGraw-Hill Inc. 1976.
2. N. L. Carothers, Real Analysis, (Indian Ed.) Cambridge University Press, 2000.

3. T. Apostol.. 'Mathematical Analysis – a modern approach to Advanced Calculus, Addison– Wesley Publishing Company, Inc. 1957. (Indian Edition by Narosa Publishing House New Delhi also available).
4. R. G. Bartle and D. R. Sherbert, Introduction to Real Analysis, 3rd Ed., John Wiley and Sons (Asia) Pvt. Ltd., Singapore, 2002.
5. E. C. Titchmarsh: The Theory of functions, 2nd Edition, The English Language Book Society and Oxford University Press 1961.
6. S. C. Malik and, Savita Arora: Mathematical Analysis, New Age International (P) Ltd, New Delhi, 3rd Edition, 2008.
7. R. R. Goldberg, Methods of Real Analysis, Oxford and IHB Publishing Company, New Delhi.
8. D.P. Choudhary and H. I. Freedman: A Course in Ordinary Differential Equations, Narosa Publishing House, New Delhi,2002.
9. E.A. Coddington: AN Introduction to Ordinary Differential Equations, Prentice Hall of India,New Delhi,1968.
10. T. Amaranath: An Elementary Course in Partial Differential Equations, Narosa Publishing House, New Delhi, 2005.
11. M. D. Raisinghania, Advanced Differential Equations, S. Chand, 2016.
12. K. L. Chung and F. AitSahlia, Elementary Probability Theory With Stochastic Processes and an Introduction to Mathematical Finance, Springer, 2003.
13. S. Ross, A First Course in Probability, Prentice Hall, 2010.

Minor Elective Course-II

Course Code:	Course Title:

Course Outcomes

After the completion of the course, students are expected to have the ability to:

1. Learn the use of numerical methods for solving transcendental and polynomial equations and direct methods for solving system of linear equations.
2. Solve system of linear equations through iterative methods and knowledge of using various interpolation methods for fitting polynomials to a data-set / function.
3. Understand few useful schemes/operators for numerical differentiation and attain ability to apply numerical methods for solving definite integrals.
4. Learn numerical techniques for solving linear first order IVP involving ODEs .
5. Draw the algorithm for the use of numerical methods in source programs of any programming language.

Credits: 4/5	Maximum Marks: 25+75 (CIA+UE)
Nature of Course: Theory(Compulsory)	Minimum Passing Marks: 36 (CIA+UE)
Total Number of Lectures-Tutorials-Practicals (In Hours per week): L-T-P: 3-0-2/3-1-2	

Course Contents

Unit	Topics	L-T-P
I	Solution of Polynomial and Transcendental Equations: Bisection method, secant method, Regula-Falsi method, Newton-Raphson method.	12
II	Solution of Systems of Linear Equations: Gauss elimination method, Gauss-Jordan method, Triangularization method. Iterative methods for Solving Systems of Linear Equations: Jacobi method, Gauss-Seidel iteration method.	12
III	Curve fitting: Least-square approximation for fitting a straight line and polynomials of given degree.	15
IV	Numerical Differentiation: Methods based on Newton's forward difference formula, Newton's backward difference formula and Sterling's formula. Numerical Integration: Trapezoidal rule, Simpson's 1/3 rule, Simpson's 3/8 rule, Romberg integration, Newton-Cotes integration formula.	11
V	Solution of Differential Equations: Initial value problem; Taylor series method, Picard method of successive approximation, Euler's method, Runge-Kutta methods of second order and fourth order.	10

Books Recommended:

1. M. K. Jain, S.R.K. Iyengar and R.K. Jain, Numerical Methods for Scientific and Engineering Computation, 6th Edition, New Age International Publishers, 2012.
2. V. Rajaraman, Computer Oriented Numerical Methods, Fourth edition, PHI learning, 2018.
3. A. Gourdin and M. Boumahrat, Applied Numerical Methods, PHI Learning Private Ltd., 1996.
4. S.S. Sastry, Introductory Methods of Numerical Analysis, Fifth edition, PHI learning , 2012.

Note-01: All the rules and regulations for the students enrolled for the Graduation with research degree program/ PG degree program(Mathematics) in the session 2022-2023 will be as per BOS-2022.

Note-02: All the rules and regulations for the students enrolled for the PG degree program(Mathematics) in the session 2021-2022 will be as per BOS-2021.

Department of Mathematics

Prof. Rajendra Singh (Rajju Bhaiya) Institute of Physical Sciences for Study and Research

V. B. S. Purvanchal University, Jaunpur

Pre- Ph.D. Course Work

(Ordinance and Syllabus w.e.f. 2022-23)

Aim of the Course Work: The Pre-Ph.D. course work is designed to encourage the students to develop the investigative, evaluative, comprehensive, reasoning, statistical analysis, and writing abilities necessary to build a deep understanding of their chosen research subject.

General Instructions:

1. The Ph.D. Admission Committee, which was established by the University with this objective in mind, will handle all issues involving admission to this course.
2. According to university guidelines, all research scholars who are provisionally registered for the Ph.D. Program must complete a Pre-Ph.D. Course.
3. In Pre- Ph.D. Course work, the Ph.D. candidate has to pass three compulsory theory papers of total 16 credits that comprises two main papers from the subject (6 + 6 credits) in which the candidate has taken admission and one paper on Research Methodology (4 credits).
4. The Ph.D. candidate must complete one research project in addition to the three required papers in order to successfully complete the course work.
5. One semester will be allotted for the Pre-Ph. D. course work, which includes three compulsory papers and one project.
6. Examinations usually occur twice a year and are notified by the Head of the Department. Each student must complete the examination form within the time frame that has been provided by the Head of the Department.
7. The Ph.D. candidate has to obtain a minimum of 55% marks or equivalent Grades/CGPA in aggregate during the course work in order to be eligible to continue in the Ph.D. programme and submit the thesis.
8. The name of the candidates successful in the semester system in Pre- Ph.D. Course in Mathematics examination shall be arranged in the following grade system:

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लैटर ग्रेड	विवरण	अंको की सीमा	ग्रेड पॉइंट
O	Outstanding	91-100	10
A^+	Excellent	81-90	9
A	Very good	71-80	8
B^+	Good	61-70	7
B	Pass	55-60	6
F	Fail	0-54	0
AB	Absent	Absent	0
Q	Qualified		
NQ	Not Qualified		

9. The minimum attendance required during the course work period is 75% of the total courses.

Scheme of the Course (All papers are compulsory)

Paper	Title	Credits
I	Dynamics of fluids in porous media	6
II	Special Functions	6
III	Research Methodology	4

Paper Setting and Evaluation Pattern (For Paper I, II and III)

Types of Question	Total Number of Questions	Questions to be attempted	Marks	Time
Short Type	7	5	5x8=40	3 Hours
Long type	6	4	4x15=60	

Total Marks: 100

Note: As per UP government direction teachers in service are allowed to attend their Pre-Ph.D.-Course Work class either in online or in offline mode.

Syllabus

Programme/Class: **Pre-Ph.D. Course Work**	Year: **Sixth**	Semester: **Eleventh**
Subject: **Mathematics**		
Course Code: **B031101T**	Course Title: **Dynamics of fluids in porous media**	
Credits: **6**		
Max. Marks: **100**	Min. Passing Marks: **40**	
Unit	**Topics**	
I	Review of basic concepts in fluid mechanics, Lagrangian and Eulerian approaches, Equation of continuity in both approaches and their equivalences, Concept of stresses, Rate of deformation tensors, Stress invariants.	

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II	Orthogonal curvilinear coordinates, Scale factors and unit vectors, Concept of physical similarity, Geometrical similarity, Dynamical similarity, Dimensionless numbers.
III	Stokes flow, Boundary conditions, Boundary layer theory, Mechanics of fluids through porous medium.
IV	Cell model, Introduction theory of micropolar fluids, MHD flows, Maxwell equations, Magnetic Reynolds number, Phenomenon of CFD.

Suggested Readings:

1. Happel, J., and Brenner, H., Low Reynolds Number Hydrodynamics, *Martinus Nijhoff Publishers*, 1983.
2. Nield, D.A. and Bejan, A., Convection in Porous Media, *Springer*, 2006.
3. Warsi, Z.U.A., Fluid Dynamics, *CRC Press*, 2006.
4. Murphy, G.M., Ordinary Differential Equations and Their Solutions, *D. Van Nostrand Company*, 1969.
5. Lukaszewicz, G. Micropolar Fluids: Theory and Applications, *Springer*, 1999.
6. Bachelor, G.K.: An Introduction to Fluid Dynamics, *Cambridge University Press*, 2012.
7. Charlton, F., Text Book of Fluid Dynamics, *C.B.S. Publishers*, 1967.
8. Simmons, G.F., Differential Equation, *Chapman and Hall*, 2016.

Programme/Class: **Pre-Ph.D. Course work**	Year: **Sixth**	Semester: **Eleventh**
Subject: **Mathematics**		
Course Code: **B031102T**	Course Title: **Special Functions**	
Credits: **6**		
Max. Marks: **100**	Min. Passing Marks: **40**	

Unit	Topics
I	Basic Hypergeometric Series: Hypergeometric and basic hypergeometric series; The q-binomial theorem; Heine's transformation formulas; Heine's q-analogue of Gauss' summation formula; The q-gamma and q-beta functions; The *q*-integral.
II	Gamma Function, Hypergeometric Functions: Definition and special cases, convergence, integral representation, differentiation, contiguous function relations, transformations and summation theorems, The confluent Hypergeometric function: Basic properties of 1F1, Kummer's first formula. Kummer's second formula
III	Beta and Gamma matrix functions, Hypergeometric matrix functions, Appell matrix functions, Incomplete gamma functions, Incomplete Hypergeometric matrix functions and their properties.
IV	Bessel Functions: Definition, connection with hypergeometric function, differential and pure recurrence relations, generating function, Integral representation; Hermite and Laguerre polynomials; Ordinary and singular points of differential equations, Regular and irregular singular points of hypergeometric, Bessel, Legendre, Hermite and Laguerre differential equations; Examples on above topics.

Suggested Readings:

1. Rainville, E.D., Special Functions, *Chelsea Publishing Co.*, 1971.
2. Miller, W. J., Lie Theory and Special Functions, *Academic Press*, 1968.
3. McBride, E. B., Obtaining Generating Functions, *Springer*, 1971.
4. Gasper, G. and Rahman, M., Basic Hypergeometric Series, *Cambridge University Press*, 2004.

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Programme/Class: **Pre-Ph.D. Course work**	Year: **Sixth**	Semester: **Eleventh**
Subject: **Mathematics**		
Course Code: **B031103T**	Course Title: **Research Methodology**	
Credits: **4**		
Max. Marks: **100**	Min. Passing Marks: **40**	

Unit	Topics
I	Meaning of Research, Research Philosophy, importance of research methodology in research, Choosing the appropriate methodology, Selection of research topic and problem, Searching related research papers, survey articles.
II	Scope for future works with historical notes, Impact of a journal, indexing, Plagiarism, Research approach and Related Tools, Mathematical Research Projects
III	Criteria for good Research, Knowledge of useful software's: Latex Beamer etc, Accuracy and Stability in Numerical computing, Problem solving in MATLAB.
IV	Writing skills and presentations in scientific seminar; oral/poster presentations, preparing a survey article, research papers, Ph.D. thesis, dissertations, correcting gallery proofs, writing comments, preparing summary and abstract of a manuscript.

Suggested Readings:

1. Kothari, C.R., Research Methodology, *New Age International Publishers*, 2004.
2. Lamport, L., LaTeX, *Addison Wesley*, 1994.
3. Murray, R., How to write a Thesis, *Tata McGraw-Hill,*
4. David B. Resnik, 1998, The Ethics of Science: An Introduction, *Routledge publisher*.

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