SYLLABUS STRUCTURE

FOR

POST-GRADUATE PROGRAMME

IN

MATHEMATICS

(M.A./M.Sc. in Mathematics)

(2020-21)

SCHOOL OF MATHEMATICS

GANGADHAR MEHER UNIVERSITY, AMRUTA VIHAR

SAMBALPUR, ODISHA-768004, INDIA

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VISION

To foster in mathematical education and research, technical excellence, well poised between abstraction and application.

MISSION

M-1-To offer globally-relevant, research-focused, technology-enabled education at the graduate, Post-graduate and research levels in various areas of Mathematical sciences.

M-2-To contribute to the development of students as mathematical thinkers, enabling them to become lifelong learners, to continue to grow in their chosen professions, and to function as productive citizens.

M-3-To develop and conduct continuing education programs with a view to update their fundamental knowledge base and problem-solving capabilities in the various areas of core specialization of the University.

M-4-To develop comprehensive linkages with premier academic and research institutions within the country and abroad for mutual benefit.

PROGRAMME OUTCOMES
(Chosen from the allowed list as set by UGC)

The programme outcomes and attributes are attained by the postgraduate students of Gangadhar Meher University through learning acquired on completion of a programme of study. Individual programmes of study have a defined programme specific learning outcomes which needs to be attained for the award of a specific degree. The programme learning outcomes of Gangadhar Meher University focus on various aspects of knowledge and skills that prepare students for further study, employment, and citizenship. Therefore, the PG programme of this University has been designed with the objective to develop in-depth knowledge of students in frontier areas of concerned subject and seeks to achieve the following:

PO-1: Knowledge and Understanding:
Capable of demonstrating comprehensive knowledge and understanding of one or more disciplines that form a part of a post-graduate programme of study.

PO-2: General, Technical and Professional Skills:
Enable students to enhance mathematical skills and understand the fundamental concepts of pure and applied mathematics.

PO-3: Application of Knowledge and Skills:
Capability to apply analytic thought to a body of knowledge; analyze and evaluate evidence, arguments, claims, beliefs on the basis of empirical evidence; identify relevant assumptions or implications; formulate coherent arguments; critically evaluate practices, policies and theories by following scientific approach to knowledge development.

PO-4: Research Skills:
A sense of inquiry and capability for asking relevant/appropriate questions, problematizing, synthesizing and articulating; Ability to recognize cause-and-effect relationships, define problems, formulate hypotheses, test hypotheses, analyze, interpret and draw conclusions from data, establish hypotheses, predict cause-and-effect relationships; ability to plan, execute and report the results of an experiment or investigation.

PO-5: Generic Learning Outcomes:
Capable of strengthening knowledge and understanding in deeper stage and developing the art of skills. Along with this, constructing a good moral and ethics in the students.

PO-6: Constitutional, Humanistic, Ethical and moral values
Ability to embrace moral/ethical values in conducting one's life, formulate a position/argument about an ethical issue from multiple perspectives, and use ethical practices in all work. Capable of demonstrating the ability to identify ethical issues related to one's work, avoid unethical behavior such as fabrication, falsification or misrepresentation of data or committing plagiarism, not adhering to intellectual property rights; appreciating environmental and sustainability issues; and adopting objective, unbiased and truthful actions in all aspects of work.

PO-7: Employability and Job skills, Entrepreneur skills
Postgraduate study boosts the career progress and chart out the career paths. It demonstrates the ability to tackle complex and challenging assessment tasks.

PROGRAMME SPECIFIC LEARNING OUTCOME (PSO)

(Set by School of Mathematics)

PSO-1: Will have a strong foundation in both pure and applied mathematics.

PSO-2: Will be able to apply mathematical skills for solving problems and for preparing various competitive exams.

PSO-3: Will be able to communicate mathematical knowledge effectively, in writing as well as orally.

PSO-4: Will identify applications of mathematics in other disciplines, leading to enhancement of career prospects in different fields and research areas.

PSO-5: Will have basic knowledge of programming and computational techniques as required for employment.

PSO-6: Should have the knowledge of the fundamental axioms in mathematics and capability of developing ideas based on them and inculcate mathematical reasoning.

PSO-7: Will be able to locate and analyze the different mathematical texts with appropriate theoretical framework.

PSO-8: Have the knowledge of a wide range of mathematical techniques and application of mathematical methods/tools in science, social science, engineering and technology.

Matching

Matching Percentage	Level Indicator
> 70%	**3**
= 60 %	**2**
< 50%	**1**

MISSION TO PO MAPPING

	PO-1	PO-2	PO-3	PO-4	PO-5	PO6	PO7
M1	3	3	3	3	3	3	3
M2	3	2	3	3	3	2	3
M3	3	2	2	3	2	2	2
M4	1	2	1	3	1	1	2

PSO TO PO MAPPING

	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6	PO-7
PSO1	3	3	2	3	3	3	3
PSO2	1	3	3	2	3	3	3
PSO3	3	2	2	2	2	3	2
PSO4	1	2	3	3	3	2	2
PSO5	2	3	3	2	3	2	2
PSO6	1	2	2	3	1	1	3
PSO7	2	3	2	3	1	3	2
PSO8	1	2	3	3	3	2	3

Brief Overview of Syllabus

Semester	Subject Code	Subject Name	L-T-P	Credit	Maximum Marks			
					IA	EA	PA	Total
I	Paper – 101	Algebra	4-0-0	4	20	80	-	100
	Paper - 102	Ordinary Differential Equation	4-0-0	4	20	80	-	100
	Paper - 103	Real Analysis	4-0-0	4	20	80	-	100
	Paper - 104	Programming in C	4-0-0	4	20	80	-	100
	Paper - 105	Practical	0-0-4	4	00	100	-	100
		Total		**20**				**500**
II	Paper - 201	Graph Theory	4-0-0	4	20	80		100
	Paper – 202	Topology	4-0-0	4	20	80		100
	Paper – 203	Numerical Analysis	4-0-0	4	20	80		100
	Paper - 204	Programming with C++ - I	4-0-0	4	20	80		100
	Paper - 205	Practical	0-0-4	4	00	100		100
		DSE Paper (Any One)						
	Paper–206A	Mathematical Method	4-0-0	4	20	80		100
	Paper -206B	Differential Geometry	4-0-0	4	20	80		100
	Paper -206C	Advance Calculus	4-0-0	4	20	80		100
		Total		**24**				**600**
III	Paper - 301	Operation Research-I	4-0-0	4	20	80		100
	Paper- 302	Functional Analysis	4-0-0	4	20	80		100
	Paper - 303	Complex Analysis	4-0-0	4	20	80		100
	Paper - 304	Programming with C++ - II	4-0-0	4	20	80		100
	Paper - 305	Practical	**0-0-4**	4	00	100		100
		IDSE Paper (Any One)						
	Paper – 306A	Operation Research	4-0-0	4	20	80		100
	Paper – 306 B	Elements of Number Theory	4-0-0	4	20	80		100
	Paper –306 C	Elements of Computer Programming	4-0-0	4	20	80		100
		Total		**24**				**600**
IV	Paper - 401	Operation Research-II	4-0-0	4	20	80		100
	Paper - 402	Partial Differential Equations	4-0-0	4	20	80		100
	Paper - 403	Operator Theory	4-0-0	4	20	80		100
	Paper - 404	Analytic Number Theory	4-0-0	4	20	80		100
	Paper - 405	Practical/Project	0-0-4	4	0	100		100
		Total		**20**				**500**
		Grand Total		**88**				**2200**

Abbreviations Used: IA = Internal Assessment, PA = Practical Assessment, EA = End-Semester Assessment

Red-Employability Green- Entrepreneurship Blue- Skill Development

SEMESTER – I

Paper - 101: ALGEBRA (4L-0T-0P)

Full Marks: 100 (20 Mid Term + 80 End Term)

Pre-requisites:
Basic familiarity with the concepts of sets, functions, binary operation, group theory and linear algebra.

Objective:
This course is designed to give students a foundation for all future mathematics courses. The fundamentals of algebraic problem-solving are explained. Students will explore: foundations of Algebraic structures, Groups, Rings, Ideals, Fields, Homomorphisms etc. The course also fulfills the objective to make students aware of the applicability of abstract mathematics in real world problems

Syllabus-:

Unit-I **(12 Hours)**

Ideals and Quotient rings: to a field theorem of ring homomorphism, Maximal ideals, Imbedded ring to a field, The Field of Quotients of an Integral Domain, Euclidean rings: Principal ideal domains, Unit, Associates, Unique factorization theorem.

Unit-II **(12 Hours)**

Polynomial Rings: The division algorithm, Reducible and Irreducible polynomials, Polynomials over the Rational Field: Gauss's Lemma, The Eisenstein Criterion, Polynomial Rings over Commutative Rings: Rings of polynomial in the n-variables, Primitive polynomials, Unique factorization domain,

Unit-III **(12 Hours)**

Fields, Extension Fields: Algebraic extension, Roots of Polynomials, Remainder theorem, Splitting fields, Construction with Straightedge and compass.

Unit-IV **(12 Hours)**

More about root: Roots of polynomial and their derivatives, The Elements of Galois Theory: Symmetric polynomial, Elementary symmetric function, Normal extension, Solvability by Radicals: Solvable group, Solvability of symmetric group, Solvability of polynomials, Galois group, Fixed fields.

Book Prescribed:

1. I.N. Herstein, *Topics in Algebra*, John Wiley and Sons; 2nd Revised Edition, 1975.
2. J. B. Fraleigh, *A Text Course in Algebra*, Pearson, 7th Ed., 2013.

Book of References:

1. J. Gallian, Contemporary Abstract Algebra, Brooks/Cole Pub Co. 8th Edition., 2012.
2. M. Artin, *Abstract Algebra*, Pearson, 2nd Edition., 2011.
3. David S. Dummit and Richard M. Foote, *Abstract Algebra*, 3rd Edition., John Wiley and Sons (Asia) Pvt. Ltd., Singapore, 2004.

Course Outcomes:

Upon successful completion of this course students able to-:

CO 1: define ring, ideal, quotients ring, field, polynomial rings, extension field

CO 2: explain the fundamental concepts of algebra such as ideal, ring, polynomial ring and their role in modern mathematics and applied contexts

CO 3: describe the structure of field of quotients of an integral domain

CO 4: explain the notion of extension of a field

CO 5: use Galois theory to analyze the solvability of polynomial

CO-PO Mapping (Paper 101)

	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6	PO7
CO1	3	2	1	1	2	1	1
CO2	3	1	3	2	2	1	2
CO3	2	3	3	3	2	2	2
CO4	2	2	3	2	3	2	3
CO5	2	3	2	3	2	2	2

Programme articulation matrix row for Paper 101

	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6	PO-7
Course Paper 101	3	2	3	2	3	2	3

CO-PSO Mapping (Paper 101)

	PSO-1	PSO-2	PSO-3	PSO-4	PSO-5	PSO-6	PSO-7	PSO-8
CO1	3	3	3	3	3	3	2	2
CO2	3	2	3	2	2	2	3	3
CO3	3	3	3	3	2	2	3	3
CO4	2	3	3	2	3	3	2	2
CO5	2	3	2	3	3	2	3	2

Paper - 102: ORDINARY DIFFERENTIAL EQUATION (4L-0T-0P)
Full Marks: 100 (20 Mid Term + 80 End Term)

Pre-requisites:
Differential equations, fundamental matrix, Picard's theorem, oscillation, Sturm's theorem, Green's function, Boundary value theorem.

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

Syllabus-:

Unit-I **(12 Hours)**
System of Linear Differential Equations: - System of first order equations, Existence and Uniqueness theorems, Fundamental Matrix, Homogeneous and Non-Homogeneous linear Systems with constant Coefficient, linear system with periodic Coefficient.

Unit-II **(12 Hours)**
Existence and Uniqueness of Solutions: - Successive approximation Picard's Theorem, Non Uniqueness of solutions, Continuation and dependence on Initial conditions, Existence of Solutions in the large, Existence and uniqueness of solution of systems.

Unit-III **(12 Hours)**
Oscillations of second Order Equations: - Fundamental Results, Sturm's Comparison theorem of Hille wiener Oscillations of $x'' + a(t)x = 0$.

Unit-IV **(12 Hours)**
Boundary Value Problems: - Introduction; Strum Liouville's Problem Green's functions, Picard's theorem.

Book Prescribed:
S. G. Deo and V. Raghavendra, *Ordinary Differential Equations and stability theory*, TATA McGraw Hill ltd., 1982

Book of References:

1. G. Birkhoff and G. C. Rota, *Ordinary Differential Equations*, John Wiley and Sons, N.Y., 1989.
2. Coddington and Levinson, *Theory of Ordinary Differential Equations*, Krieger Pub Co, 1984
3. Tyn-Myint-U, *Ordinary Differential Equations*, Elsevier North-Holland, 1987.
4. L. Elsgolts, *Differential Equations and Calculus of Variation*, Mir Publication, 1980

Course Outcomes:

CO 1: Understand the concept of fundamental matrix and formulation of system of Differential equation of physical problems.
CO 2: Solving system of differential equations by Eigen value and vectors.
CO 3: Study the existence and uniqueness of solutions for system of equations.
CO 4: Learn to solve oscillation of second order equations.
CO 5: Provides the Concept of Sturm comparison theorem and Hille wiener oscillations.
CO 6: Solutions for Boundary value problems are developed using Green's function

CO-PO Mapping (Paper 102)

	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6	PO-7
CO1	3	2	1	1	2	1	1
CO2	3	1	3	2	2	1	2
CO3	2	3	3	3	2	2	2
CO4	2	2	3	2	3	2	3
CO5	2	3	2	3	2	2	2
CO6	2	3	3	2	1	2	3

Programme articulation matrix row for Paper 102

	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6	PO-7
Course Paper 102	3	2	3	2	3	2	3

CO-PSO Mapping (Paper 102)

	PSO-1	PSO-2	PSO-3	PSO-4	PSO-5	PSO-6	PSO-7	PSO-8
CO1	3	3	3	3	3	3	2	2
CO2	3	2	3	2	2	2	3	3
CO3	3	3	3	3	2	2	3	3
CO4	2	3	3	2	3	3	2	2
CO5	2	3	2	3	3	2	3	2
CO6	2	3	3	2	3	2	2	2

Paper - 103: REAL ANALYSIS (4L-0T-0P)
Full Marks: 100 (20 Mid Term + 80 End Term)

Pre-requisites:
Set Theory, Sequences and Series, Functions and Mapping

Objective:
To provide a basic course in Lebesgue Measure and Integration and a study of inequalities and the Lp –spaces.

Syllabus-:

Unit-I **(08 Hours)**
Measure on the Real Line: Lebesgue Outer Measure, Measurable Sets, Regularity, Measurable Functions, Borel and Lebesgue Measurability

Unit-II **(14 Hour.)**
Integration of Functions of a Real Variable: Integration of Non-negative Functions, The General Integral, Integration of Series, Riemann and Lebesgue Integrals

Unit-III **(14 Hours)**
Differentiation: The Four Derivatives, Continuous Non-differentiable Functions, Function of a bounded variations, Lebesgue's Differentiation Theorem, Differentiation and Integration, The Lebesgue Set.

Unit-IV **(12 Hours)**
Abstract Measure Space: Measure and Outer Measure, Extension of a Measure, Uniqueness of the Extension, Completion of a Measure, Measure Space, Integration with respect to a Measure.
Inequalities and the L^p space: The L^p space, Convex Functions, Jensen's inequality, The inequalities of Holder and Minkowski, Completeness of $L^p(\mu)$.

Text Book:
G. de. Barra, *Measure theory and Integration*, New Age International Private Limited, 1st Edition, 2013. Chapter – 1 (1.5 - 1.7), II, III, IV, V. VI.

Reference Books:
1. E. Hewitt and K. Stromberg, *Real and Abstract Analysis*, Springer; 1975
2. W. Rudin, *Real and Complex Analysis*, Tata Mc Graw Hill, 2017.

Course Outcomes:
After the successful completion of this course the students will be able to-:

CO1: Demonstrate understanding of the basic concepts underlying the definition of the general Lebesgue measure in real line and properties.

CO2: Demonstrate understanding of the statements of the main results on integration on Real line and an ability to apply these in examples.

CO3: Apply the theory of the concept of differentiation to solve a variety of problems at an Appropriate level of difficulty.

CO4: Demonstrate skills in communicating mathematics orally and in writing of abstract measure

CO-PO Mapping (Paper 103)

	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6	PO-7
CO1	3	2	1	1	2	1	1
CO2	3	1	3	2	2	1	2
CO3	2	3	3	3	2	2	2
CO4	2	2	3	2	3	2	3

Programme articulation matrix row for Paper 103

	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6	PO-7
Course Paper 103	3	2	3	2	3	2	3

CO-PSO Mapping (Paper 103)

	PSO-1	PSO-2	PSO-3	PSO-4	PSO-5	PSO-6	PSO-7	PSO-8
CO1	3	3	3	3	3	3	2	2
CO2	3	2	3	2	2	2	3	3
CO3	3	3	3	3	2	2	3	3
CO4	2	3	3	2	3	3	2	2

Paper - 104: PROGRAMMING IN C (4L-0T-0P)
Full Marks: 100 (20 Mid Term + 80 End Term)

Pre-requisites:
Basic computer skills, Logic building skills

Objective:
The course is designed to provide complete knowledge of C language. Students will be able to develop logics which will help them to create programs, applications in C. Also by learning the basic programming constructs they can easily switch over to any other language in future.

Syllabus-:

Unit-I **(12 Hours)**
Overview of C, Constants, Types of constants, Variables, Types of variables, Rules for constructing variable names, Data types, Operators and Expressions, Managing I/O operators.

Unit-II **(12 Hours)**
Decision making and Branching, Looping: for, do, while, do…while loops, Arrays: Defining and manipulating arrays, Array variable, Syntax rules for arrays, Use of multiple subscripts in arrays, for loops with array, Character, Strings.

Unit–III **(12 Hours)**
User defined Functions: Introduction, Defining and using functions, Syntex rules for functions declaration, arrays in functions.

Unit-IV **(12 Hours)**
Structure and Union: Definition, using structures, Use of structure in arrays and arrays in structure, create union variables, access members of a union, Pointers: Pointer data type, pointers and array, pointers and functions.

Book Prescribed:
E. Balagurusamy, *Programming in ANSI C*. McGraw Hill Education; 8th Edition, 2019

Reference Books:

1. Y. Kanetkar, *Let us C*, BPB Publications; 15th Edition, 2016.
2. Venugopal, *Mastering in C*, McGraw Hill Education; 1st Edition 2006.
3. V. Rajaraman, *Computer Programming in C*, Prentice Hall India Learning Private Limited 1994.

Course Outcome:
After course completion the students will have the following learning outcomes:
- **CO 1**: define and manage data structures based on problem subject domain and work with textual information, character and strings, arrays of complex objects
- **CO 2**: explain the concepts of object thinking within the framework of functional model
- **CO 3:** describe defensive programming concepts
- **CO 4**: asses to handle possible errors during program.

CO-PO Mapping (Paper 104)

	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6	PO-7
CO1	3	2	1	1	2	1	2
CO2	3	1	3	2	2	1	3
CO3	2	3	3	3	2	2	2
CO4	2	2	3	2	3	2	3

Programme articulation matrix row for Paper 104

	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6	PO-7
Course Paper 104	3	2	3	2	3	2	3

CO-PSO Mapping (Paper 104)

	PSO-1	PSO-2	PSO-3	PSO-4	PSO-5	PSO-6	PSO-7	PSO-8
CO1	3	3	3	3	3	3	2	2
CO2	3	2	3	2	2	2	3	3
CO3	3	3	3	3	2	2	3	3
CO4	2	3	3	2	3	3	2	2

Paper - 105: PRACTICAL - PROGRAMMING IN C (0L-0T-4P)

Full Marks: 100 (20 Mid Term + 80 End Term)

Pre-requisites:

Baic knowledge of computer, concept of Turboo C, Quadratic equation, Fibonacci series, matrices, GCD and LCM of a number, Prime number, factorial, series expansion of number

Students have to practice the following programme in turbo c and verify the correct result;

1. Write a program in C to find the root of the Quadratic equation $ar^2 + br + c = 0$ for given value of a,b,c.
2. Write a program in C to enter the value of a and b, then swap the value of a and b with using the third variable.
3. Write a program in C to find the list of 'n' terms of a fibanacci series.
4. Write a program in C to test whether a no is perfect or not.
5. Write a program in C to test whether a no is palindrome or not.
6. Write a program in C to test whether a no is strong or not.
7. Write a program in C to arrange 10 given numbers in ascending order.
8. Write a program in C to arrange 10 given number in descending order.
9. Write a program in C to find the product of two matrices.
10. Write a program in C to add two given matrices.
11. Write a program in C to find the transpose of a matrix.
12. Write a program in C to find the GCD and LCM of a number.
13. Write a program in C to test whether a number is prime or not.
14. Write a program in C to find the factorial of a number.
15. Write a program in C to find series expansion of e^x for a given value of x correct upto y decimal places.

Course Outcome:

After the successful completion of all programmes, the students will be able to

CO1: write any programme of above type and apply to solve practical problem.

CO2: create similar type programming for other type of problems

CO3: apply the techniques and methods to analyses others problems

CO4: analyze the problems minutely and create their own algorithms to solve many mathematical problem

CO-PO Mapping (Paper 105)

	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6	PO-7
CO1	3	2	1	1	2	1	1
CO2	3	1	3	2	2	1	2
CO3	2	3	3	3	2	2	2
CO4	2	2	3	2	3	2	3

Programme articulation matrix row for Paper 105

	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6	PO-7
Course Paper 105	3	2	3	2	3	2	3

CO-PSO Mapping (Paper 105)

	PSO-1	PSO-2	PSO-3	PSO-4	PSO-5	PSO-6	PSO-7	PSO-8
CO1	3	3	3	3	3	3	2	2
CO2	3	2	3	2	2	2	3	3
CO3	3	3	3	3	2	2	3	3
CO4	2	3	3	2	3	3	2	2

SEMESTER- II

Paper - 201: GRAPH THEORY (4L-0T-0P)

Full Marks: 100 (20 Mid Term + 80 End Term)

Pre-requisites:
Basic logic, set operations, elementary number theory, basic knowledge of linear algebra

Objective:
To understand and apply the fundamental concepts in graph theory To apply graph theory based tools in solving practical problems. To familiar with the major viewpoints and goals of graph theory: classification, extremality, optimization and sharpness, algorithms, and duality.

Syllabus-:

Unit-I **(12 Hours)**

Introduction: Graph, Applications of graphs, Finite and infinite graphs, Incidence and Degree, Isolated vertex, Pendant vertex, Null graph, Paths and Circuits: Isomorphism, Sub graphs, Walks, Paths, Circuits, connected graphs, Disconnected graphs, Components, Euler graphs, Operations on Graph, Hamiltonian paths and circuits.

Unit-II **(12 Hours)**

Trees: Trees, some properties of trees, Pendant vertices in a tree, Distance and centers in a tree, Rooted and binary tree, on counting tree, spanning trees.

Unit-III **(12 Hours)**

Fundamental circuits: Spanning tree of a graph, spanning tree in a weighted graph, cut sets and Cut Vertices: Cut sets, some properties of cut set, cut sets in a graph, Fundamental circuits and cut sets, Connectivity, Separability, Network flows, 1-Isomorphism, 2-Isomorphism.

Unit-IV **(12 Hours)**

Planar and Dual graphs: Combinatorial vs Geometric graph, Planer graphs, Kurotowski's two graphs, Different representation of a planar graph, Detection of planarity, Geometric dual, Combinatorial dual, Criteria of planarity, Thickness and crossings.

Books for Prescribed:

1. N. Dec, *Graph Theory and its Application to Engineering and Computer Science*, Prentice Hall India Learning Private Limited; New edition, 1979.
2. F. Harury, *Graph Theory*, Addison Wesley Publishing company,1969.
3. R. J. Wilson, *Introduction to Graph Theory*, Longman Group, Ltd., 5th Edition, 1985.

Book of References:

1. R. Balakrishnan and K. Ranganathan, *A Textbook of Graph Theory*, 2nd Edition., Springer, New York, 2012.
2. Richard J.Trudeau, *Introduction to Graph Theory*, Dover Publication Inc., 2nd Edition., 1999.
3. J.A Bondy, U.S.R Murty, *Graph Theory with Applications*, Elsevier Science Ltd, 1976.

Course Outcomes:

Upon successful completion of this module students able to

CO 1: Defines a graph, bipartite graph, Eulerian graph, Hamitonian graph

CO 2: Identify edges, vertices, subgraphs, matching, covers in graphs and construct examples and to distinguish examples from non-examples;

CO 3: Solve problems using basis graph theory, involving vertices and edge, connectivity, planarity, crossing numbers and edge coloring

CO 4: interpret theoretical knowledge and independent mathematical thinking in creative investigation of questions in graph theory

CO 5: explain basic results about coloring vertices, 4 color problem, planar graph notion, dual Graphs

CO-PO Mapping (Paper 206B)

	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6	PO-7
CO1	3	2	1	1	2	1	1
CO2	3	1	3	2	2	1	2
CO3	2	3	3	3	2	2	2
CO4	2	2	3	2	3	2	3
CO5	2	3	2	3	2	2	2

Programme articulation matrix row for Paper 206B

	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6	PO-7
Course Paper 206B	3	2	3	2	3	2	3

CO-PSO Mapping (Paper 206B)

	PSO-1	PSO-2	PSO-3	PSO-4	PSO-5	PSO-6	PSO-7	PSO-8
CO1	3	3	3	3	3	3	2	2
CO2	3	2	3	2	2	2	3	3
CO3	3	3	3	3	2	2	3	3
CO4	2	3	3	2	3	3	2	2
CO5	2	3	2	3	3	2	3	2

Paper - 202: TOPOLOGY (4L-0T-0P)
Full Marks: 100 (20 Mid Term + 80 End Term)

Pre-requisites:
Knowledge of Sets, partially ordered Sets, Totally Ordered Sets, Calculus, Real line, Sequences, Convergence of sequences.

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

Syllabus-:

Unit-I **(12 Hours)**

Basic concepts of Topology, Examples, Bases, Subbases, Closed sets, Limit Points, Continuous functions, Subspace topology, Hausdorff Topological Spaces.

Unit-II **(12 Hours)**

Product topology, Box Topology and Quotient topology, Connectedness, Local connectedness, Path-connectedness.

Unit-III **(12 Hours)**

Compact Spaces, compactness in metric spaces, locally compacts spaces, One point Compactification of a Topological Space, Compact open topology

Unit-IV **(12 Hours)**

First and Second Countable Topological Spaces, Properties, Separation axioms, Regular and completely regular space, Normal spaces, Urysohn Lemma, Urysohn metrization Theorem

Books Prescribed:

J.R. Munkres-*Topology - A First Course in Topology*, Pearson 2nd Edition, 2000.

Books for Reference:

1. M. A. Armstrong, *Basic Topology*, Springer-Verlag New York Inc, 1st Edition.1983.
2. TW Gamelin and RE Greene. *Introduction to Topology*. 2nd Edition, Dover Publications, 1999.
3. Stephen Willard, *General Topology*, Dover Publication, 2004.

Course Outcomes:

After completing this course successfully, the student will be able to:

CO1: Understand basic problems in the Topology of R, Topology of Metric Spaces and Hausdorff spaces.

CO2: Apply the concepts of metric spaces and topological spaces, and their role in mathematics. Demonstrate familiarity with a range of examples of these structures.

CO3: Understand separability, completeness, connectedness, compactness.

CO4: Express regularity and normality separation axioms and use them to prove various properties

CO-PO Mapping (Paper 202)

	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6	PO-7
CO1	3	2	1	1	2	1	1
CO2	3	1	3	2	2	1	2
CO3	2	3	3	3	2	2	2
CO4	2	2	3	2	3	2	3

Programme articulation matrix row for Paper 202

	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6	PO-7
Course Paper 202	3	2	3	2	3	2	3

CO-PSO Mapping (Paper 202)

	PSO-1	PSO-2	PSO-3	PSO-4	PSO-5	PSO-6	PSO-7	PSO-8
CO1	3	3	3	3	3	3	2	2
CO2	3	2	3	2	2	2	3	3
CO3	3	3	3	3	2	2	3	3
CO4	2	3	3	2	3	3	2	2

Paper - 203: NUMERICAL ANALYSIS (4L-0T-0P)

Full Marks: 100 (20 Mid Term + 80 End Term)

Pre-requisites:

Iteration methods, algebraic equations, transcendental equations, Interpolation, Difference operator, order of convergence, Numerical integration, solution of system of linear equations

Objective:

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

Syllabus-:

Unit-I **(12 Hours)**

Errors: Root finding for non-linear equations: Bisection method, Iteration methods based on first degree equations (Secant method, Regula-Falsi method, Newton Raphson method), Iteration methods based on second degree equation (Muller method, Chebysev method), Rate of convergence, Iteration methods.

Unit-II **(12 Hours)**

Interpolations: Lagrange and Newton interpolations, Finite differences, interpolating polynomials using finite differences, Hermite interpolation, Piecewise and Spline interpolation.

Unit-III **(12 Hours)**

Differentiation: Methods based on Interpolation, Methods based on Finite Differentials, Method based on undetermined coefficients, optimum choice of step length, Interpolation method. Integration: Methods based on Interpolation (Trapezoidal rule, Simpson's rule), Method based on undetermined coefficients (Gausses Legendre Integration method, Lobatto integration method, Radon integration method, Gauss-Chebysev Integration method (without derivation), Gauss-Laguerre Integration method (without derivation) , Gauss-Hermite Integration methods(without derivation), Composite integration methods.

Unit-IV **(12 Hours)**

Numerical Solution of system of linear equations: Direct methods, Gauss Elimination methods, Gauss-Jordan Elimination method, Triangularization method, Cholesky method, Iteration methods (Jacobi iteration method, Gauss-Seidel iteration method, Iterative method for A^{-1}) Eigen value problems (Jacobi method for symmetric matrices) Givers Method for symmetric matrices, Rutishauser method for arbitrary matrices). Numerical solution of ordinary differential equation: Euler Method, Backward Euler method, Mid-point method, Single Step Methods (Tayler series method, Range-Kutta method (Second order, Fourth order method)

Prescribed Books: -

M.K. Jain, S.R.K Iyengar, R.K. Jain: *Numerical Methods for Scientific and Engineering Computation,* Willey Eastern Ltd. New Delhi (1995), (2.1-2.6,3.1-3.5, 4.5-4.10, 5.1-5.9, 6.1-6.3)

Book of References:

1. B. Bradie, *A Friendly Introduction to Numerical Analysis*, Pearson Education, 1st Edition India, 2007.
2. Kendall E. Atkinson: *An Introduction to Numerical Analysis*, Wiley India Private Limited; 2nd Edition, 2008.
3. C. F. Gerald and P. O. Wheatley, *Applied Numerical Analysis*, Pearson Education, India, 7th Edition, 2008
4. S. D. Conte & S. de Boor: *Elementary Numerical Analysis: An Algorithmic Approach*, McGraw Hill / Asia; 3rd Edition, 1980.

Course Outcomes:

CO 1: Concept of error analysis in data handling.

CO 2: Study of numerical methods to solve algebraic, transcendental equations and system of equations

CO 3: Use of difference operators and different numerical methods to interpolate and extrapolate the given set of data.

CO 4: Numerical evaluation of differentiations and integrations.

CO 5: Know the concept of solving numerically the initial and boundary value problems of ODEs.

CO 6: Solve ODE numerically by single step and multi-step method.

CO-PO Mapping (Paper 203)

	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6	PO-7
CO1	3	2	1	1	2	1	1
CO2	3	1	3	2	2	1	2
CO3	2	3	3	3	2	2	2
CO4	2	2	3	2	3	2	3
CO5	2	3	2	3	2	2	2
CO6	2	3	3	3	2	2	2

Programme articulation matrix row for Paper 203

	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6	PO-7
Course Paper 203	3	2	3	2	3	2	3

CO-PSO Mapping (Paper 203)

	PSO-1	PSO-2	PSO-3	PSO-4	PSO-5	PSO-6	PSO-7	PSO-8
CO1	3	3	3	3	3	3	2	2
CO2	3	2	3	2	2	2	3	3
CO3	3	3	3	3	2	2	3	3
CO4	2	3	3	2	3	3	2	2
CO5	2	3	2	3	3	2	3	2
CO6	2	2	3	3	3	3	3	2

Paper - 204: PROGRAMMING WITH C++ - I (4L-0T-0P)
Full Marks: 100 (20 Mid Term + 80 End Term)

Pre-requisites:
Programming Language, Language C

Objective:
To expose the students to various tools in solving numerical problems. To enable the students to apply these methods in a computer environment using C++.

Syllabus-:

Unit-I **(12 Hours)**

Principles of object-oriented programming, Object oriented programming paradigm, Basic concept of OOP, benefits of OOP, applications of OOP. Structure of a C++ program - creating a source file, compiling and linking a C++ program.

Unit-II **(12 Hours)**

Tokens, Expression and Control structures - Key words, Identifiers, Data types. User defined data types, Derived data types, Symbolic constant, Variables, and Operators in C++.

Unit-III **(12 Hours)**

Function in C++, Function prototyping, Call by reference, Inline function, Default argument, Function overloading. Classes and Objects Defining class and member function.

Unit-IV **(12 Hours)**

Structures of a C++ program with class, nesting of member, memory allocation for objects, static data member, static member function, Friend function, pointers to data member.

Book Prescribed:
E. Balagurusamy, *Object Oriented Programming with C++*, McGraw Hill; 8th Edition, 2020, (Chapter 1 to 5).

Reference Books:
1. Robert Lafore, *Object Oriented Programming Turbo C++*, Galgotia Publications Pvt Ltd,1991.
2 K. Venugopal, *Mastering in C++*, McGraw Hill Education, 1997.

Course Outcomes:
CO1: Understanding about object-oriented programming.
CO2: Gain knowledge about the capability to store information together in an object.
CO3: Understand the capability of a class to rely upon another class.
CO4: Learn how to store one object inside another object and use of one method can be used in variety of different ways.
CO5: Understanding the process of exposing the essential data to the outside of the world and hiding the low-level data.

CO-PO Mapping (Paper 204)

	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6	PO-7
CO1	3	2	1	1	2	1	3
CO2	3	1	3	2	2	1	3
CO3	2	3	3	3	2	2	2
CO4	2	2	3	2	3	2	2
CO5	2	3	2	3	2	2	3

Programme articulation matrix row for Paper 204

	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6	PO-7
Course Paper 204	3	2	3	2	3	2	3

CO-PSO Mapping (Paper 204)

	PSO-1	PSO-2	PSO-3	PSO-4	PSO-5	PSO-6	PSO-7	PSO-8
CO1	3	3	3	3	3	3	2	2
CO2	3	2	3	2	2	2	3	3
CO3	3	3	3	3	2	2	3	3
CO4	2	3	3	2	3	3	2	2
CO5	2	3	2	3	3	2	3	2

Paper - 205: PRACTICAL- PROGRAMMING WITH C++ - I (0L-0T-4P)

Full Mark – 100

Pre-requisites:

Basic mathematical calculation skills and logic skills, C++ programming knowledge

Syllabus-:

Following Programs Should be done in C ++

1. Write a program to enter a number and find the factorial.
2. Write a program to display the sum of digits of a number.
3. Write a program to find the sum of 1+2+3+…+n for given values of n.
4. Write a program to interchange the value of a and b.
5. Write a program to solve $ax^2 + bx + c = 0$ for given value of a,b,c.
6. Using function overloading find the area of a circle, rectangle and square.
7. Test whether a given number is prime or not.
8. Test whether a given year is a leap year or not.
9. Find the largest of three given numbers.
10. Illustrate switch-case statement.
11. Find the grade of a student.
12. Find the largest of n given number.
13. Sort a list of n numbers in ascending order.
14. Using reference variable swap the values of two variables.
15. Test whether a given string is palindrome or not.

Course Outcome:

After the successful completion of all programmes, the students will be able to

CO1: write any programme of above type and apply to solve practical problem.

CO2: create similar type programming for other type of problems

CO3: apply the techniques and methods to analyse others problems

CO4: analyze the problems minutely and create their own algorithms to solve many mathematical problem

CO-PO Mapping (Paper 205)

	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6	PO-7
CO1	3	2	1	1	2	1	1
CO2	3	1	3	2	2	1	2
CO3	2	3	3	3	2	2	2
CO4	2	2	3	2	3	2	3

Programme articulation matrix row for Paper 205

	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6	PO-7
Course Paper 205	3	2	3	2	3	2	3

CO-PSO Mapping (Paper 205)

	PSO-1	PSO-2	PSO-3	PSO-4	PSO-5	PSO-6	PSO-7	PSO-8
CO1	3	3	3	3	3	3	2	2
CO2	3	2	3	2	2	2	3	3
CO3	3	3	3	3	2	2	3	3
CO4	2	3	3	2	3	3	2	2

Paper - 206A: MATHEMATICAL METHOD(3L-1T-0P)

Full Marks: 100 (20 Mid Term + 80 End Term)

Pre-requisites:
Sequence and series, Function, Limit, Continuity, differentiation, integration

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

Syllabus-:

Unit-I **(14 Hours)**

Laplace Transforms:
Laplace Transform. Linearity. First Shifting Theorem (*s*-Shifting), Transforms of Derivatives and Integrals. ODEs, Unit Step Function (Heaviside Function). Second Shifting Theorem (*t*-Shifting), Short Impulses. Dirac's Delta Function. Partial Fractions, Convolution. Integral Equations, Differentiation and Integration of Transforms. ODEs with Variable Coefficients, Systems of ODEs Laplace Transform: General Formulas

Unit-II **(10 Hours)**

Volterra Integral Equations:
Basic concepts, Relationship between Linear differential equations and Volterra integral equations, Resolvent Kernel of Volterra Integral equations, Solution of Integral equations by Resolvent Kernel, The Method of successive approximations, Convolution type equations, Solutions of integral differential equations with the aid of Laplace transformations.

Unit-III **(10 Hours)**

Fredholm Integral equations:
Fredholm equations of the second kind Fundamental, Iterated Kernel, Constructing the resolvent Kernel with the aid of iterated Kernels, Integral equations with degenerate Kernels, Characteristic numbers and eigen functions, solution of homogeneous integral equations with degenerate Kernel- non homogeneous symmetric equations Fredholm alternative.

Unit-IV **(14 Hours)**

Calculus of Variation:
Variation & its Properties, Euler equation, Variational Problems for Functional of the Form, Functional Dependence on Higher Order derivatives, Functional Dependence on Functions of Several Independent Variable, Variational Problems in parametric Form

Books Prescribed:

1. Erwin Kreyszig, *Advanced Engineering Mathematics*, Wiley, Eastern Ltd, 5thEdition, 1983, Chapters - 5 and 10.
2. A. S. Gupta, *Calculus of Variations with Application*s, PHI Learning,1990. Chapter – (Art 1, 2 only).

Course Outcome:

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

CO1: the methods to solve differential equations using Laplace transform

CO2: understand Fourier series expansion of a functions and apply to solve many practical problems

CO3: gain the Fourier transform and apply transform technique to solve problems

CO4: gain knowledge a new method to solve differential equation using Euler's equation

CO-PO Mapping (Paper 206A)

	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6	PO-7
CO1	3	2	1	1	2	1	1
CO2	3	1	3	2	2	1	2
CO3	2	3	3	3	2	2	2
CO4	2	2	3	2	3	2	3

Programme articulation matrix row for Paper 206A

	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6	PO-7
Course Paper 206A	3	2	3	2	3	2	3

CO-PSO Mapping (Paper 206A)

	PSO-1	PSO-2	PSO-3	PSO-4	PSO-5	PSO-6	PSO-7	PSO-8
CO1	3	3	3	3	3	3	2	2
CO2	3	2	3	2	2	2	3	3
CO3	3	3	3	3	2	2	3	3
CO4	2	3	3	2	3	3	2	2

Paper – 206B: DIFFERENTIAL GEOMETRY (4L-0T-0P)

Full Marks: 100 (20 Mid Term + 80 End Term)

Pre-requisites:
Multivariable calculus, linear algebra and differential equations

Objective:
The objective of this course is to make students familiar with basic concepts of differential geometry so as to deal with geometry of curves and spaces using the methods of differential calculus.

Syllabus-:

Unit-I **(12 Hours)**

Review of calculus in R^n, Inverse and implicit function theorem, Rank theorem. Review of local theory of curves and surfaces, Serret Frenet formula, first fundamental forms, Normal curvature, Geodesic curvature, Gauss formula, second fundamental form, Weiengarten map, principal curvatures, Gaussian curvature mean curvature.

Unit-II **(12 Hours)**

Introduction to Manifolds, Differential manifolds, Examples, Submanifolds, Tangent vector and tangent space at a point of the manifold, vector fields, Integration on manifolds, Stoke's theorem.

Unit-III **(12 Hours)**

Multi linear Algebra (Dual space, tenser of type (r.s), Operations with tenser, contractions, metric tenser, symmetric and antisymmetric tenser) Exterior Algebra.

Unit-IV **(12 Hours)**

Calculus of forms. Riemannian manifold, Riemannian metric, co-variant differentiation, Levi Civita Connection, Curvature, parallel transport, Fundamental theorem of Riemannian Geometry.

Books for Prescribed:

1. T. J. Willmore, *An Introduction to Differential Geometry*, Oxford University Press, (17^{th} Impression) New Delhi, 2002 (Indian Print).
2. J.A Thorpe, *Elementary Topics in Differential Geometry*, Springer-Verlag New York Inc. 1^{st} Edition. 1979.
3. A. Pressley, *Elementary Differential Geometry*, 2^{nd} Edition, Springer International Edition,2014

Books of References:

1. E. Kreyszig, *Differential Geometry*, Dover Publication, New York, 2003.
2. B. O' Neill, *Elementary Differential Geometry*, 2^{nd} Edition., Academic Press, 2004.
3. S. Lang, *Fundamentals of Differential Geometry*, 1^{st} Edition, Springer-Verlag, New York Inc, 1999.

Course Outcome:

Upon successful completion of this module students able to

CO 1: defines surfaces, their properties, parametrization of surfaces and tangent spaces of surfaces

CO 2: lists topological aspects of surfaces

CO 3; recognize the basis of notions of the local theory of space curves and the local theory of surfaces

CO 4: explain concepts of curvature and Sernet-Frenet frame for space curves and the notion of torsion of a space curve

CO 5: explain the normal curvature and second fundamental form

CO 6: defines geodesic-equation of geodesic, geodesic on sphere, geodesic as distance minimizing curves

CO-PO Mapping (Paper 206B)

	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6	PO-7
CO1	3	2	1	1	2	1	1
CO2	3	1	3	2	2	1	2
CO3	2	3	3	3	2	2	2
CO4	2	2	3	2	3	2	3
CO5	2	3	2	3	2	2	2
CO6	2	2	2	2	3	3	3

Programme articulation matrix row for Paper 206B

	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6	PO-7
Course Paper 206B	3	2	3	2	3	2	3

CO-PSO Mapping (Paper 206B)

	PSO-1	PSO-2	PSO-3	PSO-4	PSO-5	PSO-6	PSO-7	PSO-8
CO1	3	3	3	3	3	3	2	2
CO2	3	2	3	2	2	2	3	3
CO3	3	3	3	3	2	2	3	3
CO4	2	3	3	2	3	3	2	2
CO5	2	3	2	3	3	2	3	2
CO6	3	3	3	2	2	3	3	3

Paper - 206 C: ADVANCED CALCULUS(4L-0T-0P)

Full Marks: 100 (20 Mid Term + 80 End Term)

Pre-requisites:
Functions, Derivative of function in one variable**.**

Objective:
Develop ability to solve problems in the geometry and analysis using in differential forms, develop capacity to both prove results and solve problems. Develop skills as a critical judge of mathematical arguments. Recognize the place of differential calculus in mathematics and the greater realm of scientific thoughts.

Syllabus-:

Unit-I **(12 Hours)**
Derivatives for Function on R^n- Differentiation of Composite Functionsand Taylor's Theorem

Unit-II (**12 Hours)**
Transformation, Linear function and Transformations, Differentials of Transformation, Inverse Transformations.

Unit-III **(12 Hours)**
Implicit Function Theorems, Functional dependence, set Functions and Transformation of Multiple Integrals.

Unit-IV **(12 Hours)**
Curve and Arc-Length, Surfaces and surface Area, Integrals over**,** Curves and Surfaces, Differential Forms, Theorem of Green, Gauss and Stokes, Exact forms and Closed forms

Books Prescribed
R.C Beck, *Advance Calculus*, 3rd Edition, Mc Graw Hill Publication, 1956.
Chapter-3 (3.3 to 3.8), 7 (7.2 to 7.7), 8 (8.2 to 8.6), 9 (9.2, 9.4, 9.5)

Course Outcome:
After the successful completion of this course the students will be able to
CO1: extend their ability of differentiation of functions in Euclidean space R^n
CO2: develop their mind transformation and their properties in general space.
CO3: analyze the implicit and multiple integrals in generalized form
CO4: get and think the physical interpretation of solid figures in n-dimensional space.

CO-PO Mapping (Paper 206C)

	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6	PO7
CO1	3	2	1	1	2	1	1
CO2	3	1	3	2	2	1	2
CO3	2	3	3	3	2	2	2
CO4	2	2	3	2	3	2	3

Programme articulation matrix row for Paper 206C

	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6	PO-7
Course Paper 206C	3	2	3	2	3	2	3

CO-PSO Mapping (Paper 206C)

	PSO-1	PSO-2	PSO-3	PSO-4	PSO-5	PSO-6	PSO-7	PSO-8
CO1	3	3	3	3	3	3	2	2
CO2	3	2	3	2	2	2	3	3
CO3	3	3	3	3	2	2	3	3
CO4	2	3	3	2	3	3	2	2

SEMESTER – III

Paper 301: Operation Research-I (4L-0T-0P)

Full Marks: 100 (20 Mid Term + 80 End Term)

Pre-requisites:
Real Analysis

Objective:
This module aims to introduce students to use quantitive methods and techniques for effective decisions–making; model formulation and applications that are used in solving business decision problems.

Syllabus-:

Unit-I **(12 Hours)**
Introduction to Operations Research (OR), Introduction to Foundation mathematics and statistics, Linear Programming (LP), LP and allocation of resources, LP definition, Linearity requirement, Maximization Then Minimization problems, Graphical LP Minimization solution, Introduction, Simplex method definition, formulating the Simplex model.

Unit-II **(12 Hours)**
Concept of Duality, writing Dual of given LPP. Solutions to L.P.P by Dual Simplex Method.

Unit- III **(12 Hours)**
Meaning –(Initial Basic Feasible Solution)Assumptions -Degenerate Solution -North -West Corner Method- Least Cost Method -Vogels Approximation Method -Assignment Problems-Features -Transportation Problem Vs Assignment Problem -Hungarian Method (Simple Problems Only)

Unit-IV **(12 Hours)**
Formulation, Solutions to assignment problems by Hungarian method, Special cases in assignment problems, unbalanced, Maximization assignment problems. Travelling Salesman Problem (TSP). Difference between assignment and T.S.P, Finding best route by Little's method. Numerical Problems.

Book Prescribed:
S. D. Sharma, *Operations Research*, Kedar Nath Ram Nath; 2020th Edition, 2014.

Reference Books:

1. Hamdy A. Taha, *Operations Research, An Introduction*, 7th Edition, PHI Private Limited, 2006.
2. G. Hadley, *Non-Linear and Dynamic Programming*: Addison-Wesley Educational Publishers Inc, 1964.
3. Operation Research: Kanti Swarup. Sulthan & Chand, 2010.

Course Outcome:
CO 1: Solve linear programming problems using appropriate techniques and optimization solvers, interpret the results obtained.
CO 2: Determine optimal strategy for Minimization of Cost of shipping of products from source to Destination/ Maximization of profits of shipping products using various methods, Finding initial basic feasible and optimal solution of the Transportation problems
CO 3: Optimize the allocation of resources to Demand points in the best possible way using various techniques
CO4- Students can minimize the cost or time of completion of number of jobs by number of persons.

CO-PO Mapping (Paper 301)

	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6	PO-7
CO1	3	2	1	1	2	1	1
CO2	3	1	3	2	2	1	2
CO3	2	3	3	3	2	2	2
CO4	3	2	3	2	3	2	3

Programme articulation matrix row for Paper 301

	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6	PO-7
Course Paper 301	3	2	3	2	3	2	3

CO-PSO Mapping (Paper 301)

	PSO-1	PSO-2	PSO-3	PSO-4	PSO-5	PSO-6	PSO-7	PSO-8
CO1	3	3	3	3	3	3	2	2
CO2	3	2	3	2	2	2	3	3
CO3	3	3	3	3	2	2	3	3
CO4	2	3	1	3	3	2	2	2

Paper - 302: FUNCTIONAL ANALYSIS (4L-0T-0P)
Full Marks: 100 (20 Mid Term + 80 End Term)

Pre-requisites:
Ordered Sets, Metric Spaces, Linear Algebra, Basis, Dimension, Transformations, Complex Analysis.

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

Syllabus-:

Unit–I **(12 Hours)**

Review of Metric spaces, L^p - spaces, Inequalities in L^p - spaces, Completeness of L^p, Normed linear spaces, Inner product spaces, examples, properties of Normed linear spaces and inner product spaces, Continuity of linear maps.

Unit–II **(12 Hours)**

Hilbert spaces, Examples, orthonormal sets, Gram-Schist orthonormalizations, orthonormal polynomials, Bessel's inequality, Riesz-Fisher Theorem, Orthonormal basis, Fourier Expansion, Parseval's formula, Projection theorem, Riesz Representation Theorem.

Unit –III **(12 Hours)**

Banach Spaces, Hahn Banach Theorem, Baire's category theorem, Open mapping Theorem, Closed graph theorem, Uniform boundedness Principle, duals and transpose dual of $L^p[a, b]$ and C [a,b], Reflexivity.

Unit –IV **(12 Hours)**

Bounded Linear Operators on Banach Spaces, Banach algebra, definition, Examples, Spectrum of a bounded operator, Resolvent Set, Compact operators on Banach spaces, spectrum of a Compact operator, Elementary ideas on integral equations, Unbounded Operators and fixed-point theorems.

Books Prescribed: -

1. Kreyszig E., *Introductory Functional Analysis with Applications*, Wiley; Edition, 2007.
2. Limaye, B.V., *Functional Analysis*, 3rd Edition, New Age International Private Limited, 2014.

Reference Books:

1. Goffman and Pedrick *A First Course in Functional Analysis*- Prentice Hall, 1965.
2. Bachmen and Narici, *Functional Analysis*, Dover Publications Inc. 2nd Edition 2003.

Course Outcomes:

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

CO1: To learn to recognize the fundamental properties of normed spaces and of the transformations between them.

CO2: Understand the notions of dot product and Hilbert space and apply the spectral theorem to the resolution of integral equations.

CO3: Correlate Functional Analysis to problems arising in Partial Differential Equations, Measure Theory and other branches of Mathematics.

CO4- Students will be able to relate different abstract space with their different structures

CO-PO Mapping (Paper 302)

	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6	PO-7
CO1	3	2	1	1	2	1	1
CO2	3	1	3	2	2	1	2
CO3	2	3	3	3	2	2	2
CO4	3	3	2	3	3	2	2

Programme articulation matrix row for Paper 302

	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6	PO-7
Course Paper 302	3	2	3	2	3	2	3

CO-PSO Mapping (Paper 302)

	PSO-1	PSO-2	PSO-3	PSO-4	PSO-5	PSO-6	PSO-7	PSO-8
CO1	3	3	3	3	3	3	2	2
CO2	3	2	3	2	2	2	3	3
CO3	3	3	3	3	2	2	3	3
CO4	2	3	3	3	2	2	2	2

Paper - 303: DIFFERENTIAL GEOMETRY(4L-0T-0P)
Full Marks: 100 (20 Mid Term + 80 End Term)

Pre-requisites:
A strong back ground in calculus of one and several real variables: Real analysis, Multivariable calculus

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

Syllabus-:

Unit-I **(12 Hours)**

Introduction to analytic and harmonic Functions, Necessary and sufficient conditions for functions to be analytic, stereographic projection, Luca's theorem on zeros of polynomials, mappings of complex functions, elementary transformations, cross ratio, fractional linear transformation, conformal mappings.

Unit-II **(12 Hours)**

Complex integration*:* line integrals, index of a point with respect to a closed curve, Cauchy theorems for rectangle, triangles and disc, Fundamental theorems, Cauchy's Integral Formula, Higher derivatives, Morera's theorem, Liouville's theorem, fundamental theorem of algebra, open mapping theorem, zero of complex functions.

Unit-III **(12 Hours)**

Power series representation and local properties of analytic functions: Taylor's series, Laurent's series, types of singularities, zero and poles, calculus of residues.

Unit-IV **(12 Hours)**

Evaluation of real integrals using complex integration, the argument principle, Rouche's theorem, Maximum principle, Schwarz's lemma.

Books for Prescribed:

1. Lars. V. Ahlfors, *Complex Analysis*, McGraw Hill Education, 3rd Edition, 2017.
2. J. B. Conway, *Function of one Complex Variable*, 2nd Edition, Narosa Publishing House, 1980.

Book of References:

1.J.W. Brown, R. V. Churchill, *Complex Variables and Application*, 8th Edition, McGraw-Hill International Edition, 2009.
2.S. Ponnuswamy, *Complex Variables with Applications*, Herb Silverman, Bizkhauser Baston, USA, 2006.
3.J. Bak, Donald. Newman, *Complex Analysis*, 2nd Edition., Springer-Verlag, New York, 1997.

Course Outcome:

Upon successful completion of this module students able to

CO 1; work with functions (polynomials, reciprocals, exponential, trigonometric. hyperbolic) of single complex variable and describe mappings in the complex plane

CO 2: work with multi-valued functions (logarithmic, complex power) and determine branches of these functions

CO 3: evaluate a contour integral using parameterization, fundamental theorem of calculus and Cauchy's integral formula, find the Taylor series of a function and determine its circle or annulus of convergence

CO 4: compute the residue of a function and use the residue theory to evaluate a contour integral

CO 5: recognize and apply the Liouville's theorem, the mean-value property of a function and the maximum modulus principle, Rouches theorem, Argument principle, fundamental theorem of algebra

CO-PO Mapping (Paper 201)

	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6	PO-7
CO1	3	2	1	1	2	1	1
CO2	3	1	3	2	2	1	2
CO3	2	3	3	3	2	2	3
CO4	2	2	3	2	3	2	3
CO5	2	3	2	3	2	2	2

Programme articulation matrix row for Paper 201

	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6
Course Paper 201	3	2	3	2	3	2

CO-PSO Mapping (Paper 201)

	PSO-1	PSO-2	PSO-3	PSO-4	PSO-5	PSO-6	PSO-7	PSO-8
CO1	3	3	3	3	3	3	2	2
CO2	3	2	3	2	2	2	3	3
CO3	3	3	3	3	2	2	3	3
CO4	2	3	3	2	3	3	2	2
CO5	2	3	2	3	3	2	3	2

Paper - 304: PROGRAMMING IN C++ - II(4L-0T-0P)
Full Marks: 100 (20 Mid Term + 80 End Term)

Pre-requisites:
Programming in C, C++-I and Object-oriented Programming features

Objective:
The objective of course is to develop programming skills of students, using object-oriented programming concepts, learn the concept of class and object using C++ and develop classes for simple applications.

Syllabus-:

Unit–I **(12 Hours)**

Constructors and destructors – Default constructors and parameterized constructor, copy constructor, dynamic constructor, constructor with default arguments, dynamic initialization of objects, constructors overloading, destructors and its function.

Unit–II **(12 Hours)**

Operator overloading and type conversation - Defining operators overloading, overloading unary and binary operators, overloading binary operators using friend function, manipulation of strings using operators, rule for overloading operators, type conversions.

Unit–III **(12 Hours)**

Inheritance: Extending classes - Defining derived classes, single inheritance, making a private member inheritable, multiple inheritance, Hierarchical inheritance, Hybrid inheritance,

Unit–IV **(12 Hours)**

Virtual base class, Abstract classes, constructors in derived classes, Nesting of classes. Pointers, Virtual functions and polymorphisms - pointers to objects, this pointer, pointers to derive data classes, virtual functions, pure virtual function.

Book Prescribed:
E. Balagurusamy, Object *Oriented Programming with C++*, McGraw Hill; 8th Edition 2020, (Chapter 6 to 9).

Reference Books:
1. Robert Lafore, *Object Oriented Programming in Turbo C++*, Galgotia Publications Pvt Ltd, 1991.
2. K. Venugopal, *Mastering in C++*, McGraw Hill Education, 1997.

Course Outcome:
Upon successful completion of this module students able to
CO1: Understand about constructors which are special type of functions. Learn how to write code in a way that it is independent of any particular type.
CO2: Learn to derive a new class from the existing class.
CO3: Learn about one of the key features of class inheritance is that a pointer to a derived class is type-compatible with a pointer to its base class.
CO4: Create and process data in files using file I/O functions

CO-PO Mapping (Paper 304)

	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6	PO-7
CO1	3	2	1	1	2	1	1
CO2	3	1	3	2	2	1	2
CO3	2	3	3	3	2	2	2
CO4	2	2	3	2	3	2	3

Programme articulation matrix row for Paper 304

	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6	PO-7
Course Paper 304	3	2	3	2	3	2	3

CO-PSO Mapping (Paper 304)

	PSO-1	PSO-2	PSO-3	PSO-4	PSO-5	PSO-6	PSO-7	PSO-8
CO1	3	3	3	3	3	3	2	2
CO2	3	2	3	2	2	2	3	3
CO3	3	3	3	3	2	2	3	3
CO4	2	3	3	2	3	3	2	2

Paper - 305: PRACTICAL (0L-0T-4P)
PROGRAMMING WITH C++ - II
Full Mark - 100

The candidates should be able to do the following programmes by using C^{++}Languages

1. Matrix Algebra:
   (a) Matrix addition using function or pointer
   (b) Matrix multiplication using function or pointer
   (c) Matrix Inverse
2. Solution of System of linear equation by following method
   (a) Gauss Elimination Method
   (b) Gauss Seidal iteration Method
   (c) Gauss Jordan Elimination Method
3. Rank of a matrix
4. Determinant of a Matrix
5. Solution of System of linear equation by Crammers Rule
6. Eigen value and Eigen vector of a matrix
7. Differential Equations: Solution of Initial value problem using following methods:
   (a) Euler's Method
   (b) Backward Euler Method
   (c) Eulere-Richardson's Method
   (d) Second order Ranga-Kutta Method
   (e) Milne's predictor corrector Method
   (f) (f) Gauss predictor corrector Method
8. Solution of boundary value problem.
9. Following curve should be trace using "graphic.h" in C
   (i) Circle (ii) Elipse (iii) Hyperbola (iv) Sine Curve (v) Cosine curve (vi) Cissoid (vii) Cardioid (r = a(1+cos(t)) (viii) Limacon (r= a+bcos(t)) (xi) Laminscate ($a(x^2 + y^2) = (x^2 + y^2)^2$)
10. Linear Programming Problem:
    (a) Solution of LPP by Simplex Method

(b) Solution of LPP by Revise Simplex Method

11. Transportation Problem

12. Assignment Problem

The students may use Mathematica, matlab to run some of the above programs

Course Outcome:

After the successful completion of all programmes, the students will be able to

CO1: write any programme of above type and apply to solve practical problem.

CO2: create similar type programming for other type of problems

CO3: apply the techniques and methods to analyze others problems

CO4: analyze the problems minutely and create their own algorithms to solve many mathematical problem

CO-PO Mapping (Paper 305)

	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6	PO-7
CO1	3	2	1	1	2	1	1
CO2	3	1	3	2	2	1	2
CO3	2	3	3	3	2	2	2
CO4	2	2	3	2	3	2	3

Programme articulation matrix row for Paper 305

	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6	PO-7
Course Paper 305	3	2	3	2	3	2	3

CO-PSO Mapping (Paper 305)

	PSO-1	PSO-2	PSO-3	PSO-4	PSO-5	PSO-6	PSO-7	PSO-8
CO1	3	3	3	3	3	3	2	2
CO2	3	2	3	2	2	2	3	3
CO3	3	3	3	3	2	2	3	3
CO4	2	3	3	2	3	3	2	2

Paper - 306A: OPERATION RESEARCH (4L-0T-0P)

Full Marks: 100 (20 Mid Term + 80 End Term)

Pre-requisites:
Linear programming, simplex methods, artificial variables, primal, dual, transportation, assignment problem, travelling salesman problem.

Objective:
This module aims to introduce students to use quantitative methods and techniques for effective decisions–making; model formulation and applications that are used in solving business decision problems

Syllabus-:

Unit-I **(12 Hours)**

Introduction to linear Programming problem, Theory of simplex method, optimality and unboundedness, the simplex algorithm, simplex method in tableau format, introduction to artificial variables, two-phase method, Big-M method and their comparison.

Unit-II **(12 Hours)**

Duality, formulation of the dual problem, primal-dual relationships, Fundamental Theorem of Duality, economic interpretation of the dual.

Unit-III (**12 Hours)**

Transportation problem and its mathematical formulation, northwest-corner method least cost method and Vogel approximation method for determination of starting basic solution, algorithm for solving transportation problem.

Unit-IV **(12 Hours)**

Assignment problem and its mathematical formulation, Hungarian method for solving assignment problem and Travelling Salesman Problem.

Book Prescribed:
S. D. Sharma, *Operations Research*, Kedar Nath Ram Nath, 2020th Edition, 2014

Reference Books:

1.S. I. Gass, Linear Programming and Application: *Methods and Applications*, 5th Edition, Dover Publications Inc, 2011.
2.G. Hadley, *Nonlinear and Dynamic Programming*, Addison-Wesley Pub. Co.; First Edition, 1964
3. Kanti Swarup, *Operation Research*, Sultan & Chand, 2010.

Course Outcome:

CO 1: Solving LPP and its formulation

CO 2: Solution of LPP by graphical method and simplex iterations using slack and surplus variables

CO 3: Solution of Transportation problem and its optimal solution by Modi method

CO 4: Assignment problem has solved using Hungarian method

CO5: Study of revised simplex iteration

CO-PO Mapping (Paper 306A)

	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6	PO-7
CO1	3	2	1	1	2	1	1
CO2	3	1	3	2	2	1	2
CO3	2	3	3	3	2	2	2
CO4	2	2	3	2	3	2	3
CO5	2	3	2	3	2	2	2

Programme articulation matrix row for Paper 306A

	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6	PO-7
Course Paper 306A	3	2	3	2	3	2	3

CO-PSO Mapping (Paper 306A)

	PSO-1	PSO-2	PSO-3	PSO-4	PSO-5	PSO-6	PSO-7	PSO-8
CO1	3	3	3	3	3	3	2	2
CO2	3	2	3	2	2	2	3	3
CO3	3	3	3	3	2	2	3	3
CO4	2	3	3	2	3	3	2	2
CO5	2	3	2	3	3	2	3	2

Paper - 306B: ELEMENTS OF NUMBER THEORY (4L-0T-0P)
Full Marks: 100 (20 Mid Term + 80 End Term)

Pre-requisites:
Number system, Function,

Objective:
The main goal of the course is to provide an introduction to elementary and contemporary number theory. It will include many examples of intermediate and advanced techniques, methods of proofs, and rigorous analytic thinking used in upper-level mathematics.

Syllabus:

Unit-I (**12 Hours)**

Divisibility Theory in Integers and Distribution of Primes:
Early Number Theory, the Division Algorithm, the Greatest Common, Divisor, the Euclidean Algorithm, The Fundamental Theorem of Arithmetic, The Sieve of Eratosthenes, The Goldbach Conjecture

Unit-II: (14 Hours)

The Theory of Congruence and Fermat's Theorem:
Basic Properties of Congruence, Binary and Decimal Representation of Integers, Linear Congruence and the Chinese Remainder Theorem, Fermat's Little Theorem and Pseudo primes, Wilson's Theorem, The Fermat- Kraitchik Factorisation Method

Unit-III: (14 Hours)

Number-Theoretic Functions and Euler's Generalization
Fermat's Theorem: The sum and Number of Divisors, The Mobious Inversion Formula, The Greatest Integers Function, An Application to the Calendar

Unit-IV: (**10 Hours)**

The Quadratic Reciprocity Law:
Euler's Criterion, the Legendre Symbol and its Properties, Quadratic Reciprocity, Quadratic Congruence and Composite Moduli

Book Prescribed:
Elementary number theory by David M. Burton, Tata Mc.HGraw Hill Edn. Pvt.Ltd.
Chapter-2 (2.2 to 2.4), 3(3.1, 3.2), 4(4.2, 4.4), 5(5.2, 5.3), 6(6.1 to 6.3), 7(7.2, 7.3), 9(9.1 to 9.4)

Reference Books:

1. Hardy and Wright, *An Introduction to the Theory of Numbers*, Oxford University Press; 6th Edition (2008)
2. K. Chandrashekaram, *Introduction to Analytic Number Theory*, Springer-Verlag Berlin and Heidelberg GmbH & Co. K; Softcover reprint of the original 1st Edition. 1968
3 K. Chandrashekaram, *Arithmetical Functions*, Springer-Verlag Berlin and Heidelberg GmbH & Co. K; 1970th edition, 2012.

Course Outcome:

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

CO1: get knowledge of divisibility in integers and existence and properties of primes in integers

CO2: understand and analyze the congruence and apply in number theoretic system.

CO3: analyze and think of many number theory functions in number theory

CO4: apply the concept of congruence and their properties for some standard formulas and apply the formulas in practical problems.

CO-PO Mapping (Paper 306B)

	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6	PO-7
CO1	3	2	1	1	2	1	1
CO2	3	1	3	2	2	1	2
CO3	2	3	3	3	2	2	2
CO4	2	2	3	2	3	2	3

Programme articulation matrix row for Paper 306B

	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6	PO-7
Course Paper 306B	3	2	3	2	3	2	3

CO-PSO Mapping (Paper 306B)

	PSO-1	PSO-2	PSO-3	PSO-4	PSO-5	PSO-6	PSO-7	PSO-8
CO1	3	3	3	3	3	3	2	2
CO2	3	2	3	2	2	2	3	3
CO3	3	3	3	3	2	2	3	3
CO4	2	3	3	2	3	3	2	2

Paper 306C: ELEMENTS OF COMPUTER PROGRAMMING
(4L-0T-0P)
Full Marks: 100 (20 Mid Term + 80 End Term)

Pre-requisites:
Computer skills, Basic mathematical calculation skills and logic skills

Objective:
The course is designed to provide complete knowledge of basics for Computer Programming. Students will be able to develop logics which will help them to create programs. Also they will learn the Algorithms, Flow chart for different numerical methods, which helps to write program in future.

Syllabus:

Unit-I **(12 Hours)**

Binary system, Octal and Hexadecimal systems, Conversion to and from Decimal systems. Codes, Bits, Bytes and Words, Memory of a computer, Arithmetic and Logical operations on numbers, Precisions, AND, OR, XOR, NOT and Shift operators, Basic logic gates and Truth Tables.

Unit-II **(12 Hours)**

Boolean Algebra, Normal Forms, Representation of unsigned integers, Signed integer, Real, Double precisions numbers, long integers.

Unit-III **(12 Hours)**

Algorithm and Flow chart for solving the following Numerical Analysis problems**.**

Solution of algebraic an transcendental equation of one variable by Bisection, Regula-Falsi and Newton-Raphson methods. Solution of system of linear equations by Gaussian elimination and Gauss-Jordan (direct), Gauss Seidel (iterative) methods. Newton's (forward and backward), Lagrange's interpolation methods.

Unit IV **(12 Hours)**

Numerical integration by Trapezoidal rule, Simpson's rules, Gaussian quadrature formula., Numerical solution of ordinary differential equations by Euler and Runga-Kutta methods.

Books for prescribed:

1. C. Xavier, *C Language and Numerical Methods*, New Age International Publishers, 1999.
2. E. Balagurusamy. *Computer Oriented Statistical & Numerical Methods*, MacMillan India Limited, 2000.
3. K. Rosen, *Discrete Mathematics*, 8th Edition., McGraw Hill Education, New York, 2019.

Reference Books:

1. Andrew S, *Structured Computer Organization*, Pearson Education India; 6th Edition. 2016
2. M. K. Gupta, *Discrete Mathematics*, Krishna Prakashan, 2023.

Course Outcome

Upon completion of this course, students will acquire knowledge about:

CO 1: explain the algorithm and draw flowcharts for solving Mathematical and Engineering problems

CO 2: design and develop computer programs, analyzes and interprets the concepts of pointers, declaration, initialization, operations on pointers and their usage

CO 3: define data types and use them in simple data processing applications also he/she must able to use the concepts of array of structures

CO 4: develop confidence for self -education and ability to life- long learning needed for computer language

CO-PO Mapping (Paper 306C)

	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6	PO-7
CO1	3	2	1	1	2	1	1
CO2	3	1	3	2	2	1	2
CO3	2	3	3	3	2	2	2
CO4	2	2	3	2	3	2	3

Programme articulation matrix row for Paper 306C

	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6	PO-7
Course Paper 306C	3	2	3	2	3	2	3

CO-PSO Mapping (Paper 306C)

	PSO-1	PSO-2	PSO-3	PSO-4	PSO-5	PSO-6	PSO-7	PSO-8
CO1	3	3	3	3	3	3	2	2
CO2	3	2	3	2	2	2	3	3
CO3	3	3	3	3	2	2	3	3
CO4	2	3	3	2	3	3	2	2

SEMESTER – IV

Paper - 401: OPERATION RESEARCH -II (4L-0T-0P)

Full Marks: 100 (20 Mid Term + 80 End Term)

Pre-requisites:

Integer programming, bounded methods, dynamic programming, zero-sum game, dominance principle, arithmetic methods, convex programming, and quadratic programming.

Objective:

The objective of this course is to develop an ability in the students to understand and analyze managerial problems in industry so that they are able to use resources (capitals, materials, staffing, and machines) more effectively, formulate mathematical models for quantitative analysis of managerial problems in industry, develop skills in the use computer tools in solving real problems in industry.

Syllabus-:

Unit-I **(12 Hours)**

Upper Bounding Technique, Integer Programming Problems, Branch & Bounds, Gomary's cutting plane Method.

Unit-II **(12 Hours)**

Recursive approach, characteristics of Dynamic Programming, solution of discrete Dynamic Programming problem, solution of LPP by Dynamic Programming

Unit-III **(12 Hours)**

Two-person zero sum game, some basic terms, maxmini-minimax principle, Games without saddle point-mixed strategies, graphic solution of $2 \times n$ and $m \times 2$ games, dominance property, Arithmetic method, rectangular games.

Unit-IV **(12 Hours)**

Kuhn-Tucker necessary and sufficient Conditions with non-negative constraints, graphical solution, Quadratic Programming, Wolfe's method, Beale's method, separable convex programming.

Book Prescribed:

S. D. Sharma, Operations Research, Kedar Nath Ram Nath, 2020th Edition, (2014)

Reference Books:

1. S. I. Gass, Linear Programming and Application: *Methods and Applications*: 5th Edition., Dover Publications Inc, 2011.
2. G. Hadley, *Nonlinear and Dynamic Programming*, Addison-Wesley Pub. Co.; 1st Edition. 1964
3. Kanti Swarup, Operation Research, Sultan & Chand, 2010

Course Outcomes:

CO 1: Solving Integer LPP by branching and cutting plane method.

CO 2: Discrete DPP and Solution of LPP dynamic programming.

CO 3: Study of nonlinear programming problem with Kuhn-Tucker conditions

CO 4: Solution of quadratic programming problem with and without Kuhn-Tucker conditions

CO-PO Mapping (Paper 401)

	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6	PO-7
CO1	3	2	1	1	2	1	1
CO2	3	1	3	2	2	1	2
CO3	2	3	3	3	2	2	2
CO4	2	2	3	2	3	2	3

Programme articulation matrix row for Paper 401

	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6	PO-7
Course Paper 401	3	2	3	2	3	2	3

CO-PSO Mapping (Paper 401)

	PSO-1	PSO-2	PSO-3	PSO-4	PSO-5	PSO-6	PSO-7	PSO-8
CO1	3	3	3	3	3	3	2	2
CO2	3	2	3	2	2	2	3	3
CO3	3	3	3	3	2	2	3	3
CO4	2	3	3	2	3	3	2	2

Paper - 402: PARTIAL DIFFERENTIAL EQUATIONS (4L-0T-0P)

Full Marks: 100 (20 Mid Term + 80 End Term)

Pre-requisites:

Partial differential equation, Lagrange method, Charpit's method, Integral surface, complete integral, Monge cone, D'Alembert's solution, Dirichlet problem

Objective:

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

Syllabus-:

Unit-I **(12 Hours)**

Meaning of Partial differential equation, Classification of first order Partial differential equations, Semi-linear and quasi-linear equations, Pfaffian differential equations, Lagrange's method, Compatible systems, Charpit's method, Jacobi's method,

Unit-II **(12 Hours)**

Integral surfaces passing through a given curve, Cauchy problem, method of characteristics for quasi-linear and nonlinear partial differential equation, Monge cone, characteristic strip. First order non-linear equations in two independent variables, complete integral.

Unit-III **(12 Hours)**

Linear Second order partial Differential Equations: Origin of second order p.d.e's, Classification of Second order Partial Differential Equations, One dimensional Wave equation, Vibration of an infinite string, origin of the equation, D'Alembert's solution, Vibrations of a semi finite string, Vibrations of a string of finite length, existence and uniqueness of solution, Riemann method

Unit-IV **(12 Hours)**

Laplace equation, Boundary value problems, Maximum and minimum principles, Uniqueness and continuity theorems, Dirichlet problem for a circle, Dirichlet problem for a circular annulus, Neumann problem for a circle, Theory of Green's function for Laplace equation, Heat equation, Heat conduction problem for an infinite rod, Heat conduction in a finite rod, existence and uniqueness of the solution, Classification in higher dimension, Kelvin's inversion theorem, Equipotential surfaces.

Book Prescribed:

Tyn-Myint-U - *Partial Differential Equations*, North Holland Publication, New York,1987.

Books for Reference:

1. Phoolan Prasad and Renuka Ravindran, *Partial, Differential Equations*, 1st Edition. New Age International, 1985.
2. F. John, *Partial Differential Equations*, Springer-Verlag, NewYork, 3rd Edition, 1978.

3.Tyn-Myint-U, *Partial Differential Equations*, North Holland Publication, New York,1987.

4 T. Amarnath, *An Elementary Course In Partial Differential Equation*, Alpha Science International, 2003.

Course Outcomes:

CO 1: Use knowledge of partial differential equations (PDEs), modelling, the general structure of solutions, and analytic and numerical methods for solutions.

CO 2: Formulate physical problems as PDEs using conservation laws.

CO 3: Understand analogies between mathematical descriptions of different (wave) phenomena in physics and engineering.

CO 4: Classify PDEs, apply analytical methods, and physically interpret the solutions.

CO 5: Solve practical PDE problems with finite difference methods, implemented in code, and analyse the consistency, stability and convergence properties of such numerical methods.

CO-PO Mapping (Paper 402)

	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6	PO-7
CO1	3	2	1	1	2	1	1
CO2	3	1	3	2	2	1	2
CO3	2	3	3	3	2	2	2
CO4	2	2	3	2	3	2	3
CO5	2	3	2	3	2	2	2

Programme articulation matrix row for Paper 402

	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6	PO-7
Course Paper 402	3	2	3	2	3	2	3

CO-PSO Mapping (Paper 402)

	PSO-1	PSO-2	PSO-3	PSO-4	PSO-5	PSO-6	PSO-7	PSO-8
CO1	3	3	3	3	3	3	2	2
CO2	3	2	3	2	2	2	3	3
CO3	3	3	3	3	2	2	3	3
CO4	2	3	3	2	3	3	2	2
CO5	2	3	2	3	3	2	3	2

Paper - 403: OPERATOR THEORY (4L-0T-0P)

Full Marks: 100 (20 Mid Term + 80 End Term)

Pre-requisites:
Functional Analysis, Banach Space, Hilbert Space, Operators, Abstract Algebra

Objective:
To teach the fundamentals of Banach Algebras and Spectral Operator Theory which are necessary for a deeper understanding of many adjacent mathematical fields (integral and differential equations, mathematical physics, harmonic analysis, operator theory etc.)

Syllabus:

Unit–I **(12 Hours)**
Banach Algebra: Introduction, Complex homomorphism, Basic properties of spectra.

Unit-II **(12 Hours)**
Commutative Banach Algebra: Ideals, and homomorphism, Gelfand transform, Involution

Unit-III **(12 Hours)**
Bounded operators in a Hilbert Space: Basic facts, Bounded operators, Fuglede-Putnam – Rosenblum Theorem, Resolution of the identity.

Unit-IV **(12 Hours)**
The Spectral Theorem, Eigen – values of normal operators, Positive operators and square roots

Books Recommended:
Walter Rudin, *Functional Analysis*, Tata McGraw Hill, 2nd Edition, 2017.
{Ch – 10 (10.1 – 10.20), Ch-11 (11.1 – 11.20), Ch-12 (12.1 – 12.36)}

Reference Books:

1. I. Gohberg and S. Goldberg, *Basic Operator Theory*, Birkhauser Boston Inc; 1st Edition. 1981.
2. M. Schecter, *Principle of Functional Analysis*, American Mathematical Society; 2nd Edition. 2002
3. N. I. Akhiezer and I. M. Glazman, *Theory of Linear Operator*, Vol. I, II, Pitman Publishing House.
4. N. Donford and J.T. Schwarz, *Linear Operator*, Vol. I, II, III, Wiley-Interscience; 1st Edition. 1988
5. J. Weildman, Linear *Operator on Hilbert Spaces*, Springer, 1980.

Course Outcomes:

CO1: Understand the Banach Algebra, and properties of homomorphism on a Banach algebra, Basic properties of Spectra.
CO2: Learn Commutative Banach Algebra and mapping on the Space.
CO3: Analyze the Properties of bounded linear operators on Hilbert spaces.
CO4: Understand the spectrum and characterize the eigenvalues of normal, positive, Unitary operators.

CO-PO Mapping (Paper 403)

	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6	PO-7
CO1	3	2	1	1	2	1	1
CO2	3	1	3	2	2	1	2
CO3	2	3	3	3	2	2	2
CO4	2	2	3	2	3	2	3

Programme articulation matrix row for Paper 403

	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6	PO-7
Course Paper 403	3	2	3	2	3	2	3

CO-PSO Mapping (Paper 403)

	PSO-1	PSO-2	PSO-3	PSO-4	PSO-5	PSO-6	PSO-7	PSO-8
CO1	3	3	3	3	3	3	2	2
CO2	3	2	3	2	2	2	3	3
CO3	3	3	3	3	2	2	3	3
CO4	2	3	3	2	3	3	2	2

Paper - 404: ANALYTIC NUMBER THEORY (4L-0T-0P)

Full Marks: 100 (20 Mid Term + 80 End Term)

Pre-requisites:

Number system, infinite series, Divisibility, Prime Numbers, Working knowledge of Group and ring theory.

Objective:

To illustrate how general methods of analysis can be used to obtain results about integers and prime numbers. To investigate the distribution of prime numbers. To consolidate earlier knowledge of analysis through applications

Syllabus-:

Unit-I: (**12 Hours)**

Arithmetical function and Dirichlet multiplication:

Introduction, The Mobius Function, The Euler-totient function, A relation connecting Phi and Mu, A Product Formula for Phi, The Dirichlet product of arithmetical function, Dirichlet, inverses and The Mobius Inversion Formula, The Mangoldt Function, Multiplicative Function, Multiplicative functions and Dirichlet multiplication, The inverse of a completely multiplicative function, Liouville's function, The Divisor function, Generalized convolution, Bell series and Dirichlet multiplication, Derivative of an arithmetic function, The Selberg Identity

Unit-II (10 Hours)

Averages of arithmetic Functions:

The big O Notation, Asymptotic equality of functions, Euler Summation formula, Some elementary asymptotic formulas, The average order of d(n), The average order of divisior function $\sigma_s(n)$, The average order of phi(n)an application of to the distribution of lattice points visible from the origin, The average order of mu(n) and gamma (n)

Dirichlet's Theorem on Primes in Arithmetic Progressions:

Introduction, Dirichlet's theorem for prime of the form 4n-1 and 4n+1, The plan of proof of Dirichlet's theorem, Proof of Lemma 7.4, Proof of Lemma 7.5, Proof of Lemma 7.6, Proof of Lemma 7.7, Distribution of primes in arithmetic progression

Unit–III (12 Hours)

Congruence :

Definition and basic properties of congruence, Residue classes and complete residue system, Linear congruence, Reduced residue system and the Euler-Fermat theorem, Polynomial congruence modulo p, Lagrange's theorem, Application of Lagrange's theorem, Simultaneous linear congruence, Chinese Remainder Theorem. Application of Chinese Remainder Theorem

Quadratic Residues and the Quadratic Reciprocity Law:

Quadratic Residue, Legendre's symbol, and its properties, Evaluation of (-1/p) and (2/p), Gauss Lemma, The quadratic reciprocity law, Applications of the reciprocity law, The Jacobi symbol,

Unit-IV **(14 Hours)**

Dirichlet Series and Euler Product:

Introduction, The half plane of absolute convergence of a Dirichlet series, The function defined by a Dirichlet series, Multiplication of Dirichlet series, Euler products, The half plane of convergence of a Dirichlet series, Analytical properties of Dirichlet series, Dirichlet series with nonnegative coefficients, Dirichlet series expressed as exponential of Dirichlet series, Mean value theorem for Dirichlet series, An integral formula for the coefficients of a Dirichlet series, An integral formula for the partial sums of a Dirichlet series

The Function $\zeta(s)$ and $L(s, \chi)$:

Introduction, Properties of the gamma function, Integral representation for the Hurwitz zeta function, A contour integral representation for the $\zeta(s)$ and $L(s, \chi)$, Hurwitz's formula for $\zeta(s, a)$, The functional equation for the Riemann zeta function , A functional equation for the Hurwitz zeta function, The functional equation for L-function,

Book Prescribed:

T. M. Apostol, *Introduction to Analytic Number Theory*: (Springer, International students End) Narosa Publ. House. Chapter – 2(2.1 to 2.14, 2.16, 2.17), 5 (5.1 - 5.8), 7(7.2 to 7.9), 8(8.1 to 8.12), 9 (9.1-9.10) , 11(11.1-11.12), 12(12.1-10)

Reference Books:

1. G.H. Hardy and E. M. Wright, *An Introduction to the Theory of Numbers*, Oxford University Press; 6th Edition, 2008
2. K. Chandrashekaram, *Introduction to Analytic Number Theory*, Springer-Verlag Berlin and Heidelberg GmbH & Co. K; Softcover reprint of the original 1st ed. 1968 edition (2012)
3. K. Chandrashekaram, *Arithmetical Functions*: Springer-Verlag Berlin and Heidelberg GmbH & Co. K; 1970th edition (2012)

Course Outcome:

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

CO1: understand different types of arithmetic functions with applications

CO2: apply congruence to solve many problems for different arithmetic functions

CO3: analyze periodic arithmetic functions and Gauss sums

CO4: evaluate many numbers theoretic problems using reciprocity law

CO-PO Mapping (Paper 404)

	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6	PO-7
CO1	3	2	1	1	2	1	1
CO2	3	1	3	2	2	1	2
CO3	2	3	3	3	2	2	2
CO4	2	2	3	2	3	2	3

Programme articulation matrix row for Paper 404

	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6	PO-7
Course Paper 404	3	2	3	2	3	2	3

CO-PSO Mapping (Paper 404)

	PSO-1	PSO-2	PSO-3	PSO-4	PSO-5	PSO-6	PSO-7	PSO-8
CO1	3	3	3	3	3	3	2	2
CO2	3	2	3	2	2	2	3	3
CO3	3	3	3	3	2	2	3	3
CO4	2	3	3	2	3	3	2	2

Paper - 405 (PROJECT + VIVA-VOCE) (4L-0T-0P)

MARKS - (50 +50)

Objective

The main objective of the paper is increase the creativity of students. They can develop cognitive skills and independently navigate in the information space. Apart from these, they can produce and design knowledge independently.

Course Outcomes

At the end of this project, students will

CO1- engage in the study or research of a topic that is beyond the regular math department offerings in both rigor and content

CO2- produce a document (paper or honors thesis) that exhibits both the background and the conclusions reached as a result such study or research.

CO3- can develop the skill of presentation

CO4- can compile existing work and learn to prepare report using Latex.

CO-PO Mapping (Paper 405)

	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6	PO-7
CO1	3	2	1	1	2	1	1
CO2	3	1	3	2	2	1	2
CO3	2	3	3	3	2	2	2
CO4	2	2	3	2	3	2	3
CO5	2	3	2	3	2	2	2

Programme articulation matrix row for Paper 405

	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6	PO-7
Course Paper 405	3	2	3	2	3	2	3

CO-PSO Mapping (Paper 405)

	PSO-1	PSO-2	PSO-3	PSO-4	PSO-5	PSO-6	PSO-7	PSO-8
CO1	3	3	3	3	3	3	2	2
CO2	3	2	3	2	2	2	3	3
CO3	3	3	3	3	2	2	3	3
CO4	2	3	3	2	3	3	2	2
CO5	2	3	2	3	3	2	3	2