Post - Graduate Programme
in Mathematics

Courses of study, Schemes of Examinations
& Syllabi
(Choice Based Credit System)

THE DEPARTMENT OF MATHEMATICS
(DST – FIST sponsored)
BISHOP HEBER COLLEGE (Autonomous)
(Reaccredited with 'A' Grade (CGPA – 3.58/4.0) by the NAAC &
Identified as College of Excellence by the UGC)
DST – FIST Sponsored &
DBT Sponsored
TIRUCHIRAPPALLI – 620 017
TAMIL NADU, INDIA

2022 – 2023

Post – Graduate program in Mathematics

Eligibility	:	An under graduate degree in Mathematics.
Preference	:	A high first class in Part III of the UG Curriculum.

Structure of the Curriculum

Parts of the Curriculum	No. of courses	Credits
Core	14	64
Elective	5	19
Project	1	4
VLOC	1	2
Generic	1	1
Total	22	90

List of Core Courses

1. Real Analysis
2. Linear Algebra
3. Ordinary Differential Equations
4. Calculus of Variations, Integral Equations & Transforms
5. Algebra
6. Partial Differential Equations
7. Operations Research
8. Topology
9. Measure and Integration
10. Complex Analysis
11. Probability and Statistics
12. Functional Analysis
13. Numerical Analysis
14. Fluid Dynamics

List of Elective Courses

1. Graph Theory / History of Modern Mathematics
2. Python Programming / Finite Difference Methods
3. Differential Geometry / Research Methodology
4. Problem Solving in Advanced Mathematics / Data Envelopment Analysis
5. Stochastic Processes / Advanced Operations Research

List of Extra Credit Courses offered by the Department:

1. Information Theory
2. Wavelet Theory
3. Theory of Linear Operators
4. Mathematical Physics

Learning Outcomes of Post-Graduate program in Mathematics

General Outcomes	Specific Outcomes
On successful completion of the Programme the student will be 1. strong in logical thinking and reasoning to solve any problem. 2. able to take up any project from the fields of science and engineering.	On successful completion of the Post-Graduate Programme in Mathematics, the student is expected to 1. have acquired strong knowledge in the core areas of Mathematics and applications of Mathematics to continue with research. 2. be proficient in Mathematics to teach it at school and college level. 3. be skillful to take up jobs that require sound knowledge in Mathematics in different private and public sectors.

M.Sc., Mathematics
(For the candidates admitted from the academic year 2022 onwards)

Sem.	Course	Course Code	Course Title	Pre requisites	Hrs./ week	Credits	Marks		
							CIA	ESA	Total
I	Core I	P21MA101	Real Analysis		6	5	25	75	100
	Core II	P21MA102	Linear Algebra		6	5	25	75	100
	Core III	P21MA103	Ordinary Differential Equations		6	4	25	75	100
	Core IV	P21MA104	Calculus of Variations, Integral Equations and Transforms		6	4	25	75	100
	Elective I	P22MA1:A P22MA1:B	Graph Theory / History of Modern Mathematics		6	4	25	75	100
II	Core V	P21MA205	Algebra		6	5	25	75	100
	Core VI	P21MA206	Partial Differential Equations		6	4	25	75	100
	Core VII	P22MA207	Operations Research	P21MA103	6	5	25	75	100
	Elective II	P22MA2:P P22MA2:A	Python Programming Finite Difference Methods		6	4	40	60	100
	Elective III	P22MA2:B P22MA2:C	Differential Geometry Research Methodology		4	4	25	75	100
	VLO	P21VL2:1 / P21VL2:2	Religious Instructions / Moral Instructions		2	2	25	75	100
III	Core VIII	P21MA308	Topology	P21MA101 P21MA205	6	5	25	75	100
	Core IX	P21MA309	Measure and Integration	P21MA101	6	5	25	75	100
	Core X	P21MA310	Complex Analysis	P21MA101	5	4	25	75	100
	Core XI	P21MA311	Probability and Statistics		6	4	25	75	100
	Elective IV	P22MA3:A P22MA3:B	Problem Solving in Advanced Mathematics / Data Envelopment Analysis		6	4	40/25	60/75	100
	Generic Course	P22MA3G1	Principles and Methods of Teaching		1	1	-	-	-
IV	Core XII	P21MA412	Functional Analysis	P21MA101, P21MA102 P21MA308, P21MA310	6	5	25	75	100
	Core XIII	P21MA413	Numerical Analysis	P21MA103	6	4	25	75	100
	Core XIV	P22MA414	Fluid Dynamics		6	4	40	60	100
	Elective V	P22MA4:A P22MA4:B	Stochastic Processes Advanced Operations Research	P21MA311	6	4	25	75	100
	Project	P21MA4PJ	Project		6	4	40	60	100
Total						90			2100

CIA- Continuous Internal Assessment ESA- End Semester Assessment
VLOC- Value added Life Oriented Course

Core Course I - Real Analysis

Sem. I | Code : P21MA101
Total Hrs. : 90 | Credits : 5

General objectives:

On completion of this course, the learner will

1. be able to understand the real number system as a perfect set
2. be able to understand the continuity of functions and prove how the continuity of functions preserve the properties like the connectedness, compactness etc. of sets.
3. be able to understand the uniform convergence of sequences and series of real functions and nature of the limit functions.
4. be able to analyze the differentiability of various functions and use the differentiability of functions to understand their behavior in the neighborhood of limit points.

Learning outcomes:

On completion of the course, the student will

1. know the structure of the real systems, the metrics, behavior of functions at limit points etc.
2. be able to analyze metric spaces and functions defined on metric spaces.

Unit I

Metric spaces with examples – Neighbourhood – Open sets – Closed sets – Compact sets – Perfect sets – the Cantor set – Connected sets.

Unit II

Limit of functions – Continuous functions – Continuity and Compactness – Continuity and Connectedness – Discontinuities – Monotonic functions.

Unit III

The derivative of a real function – Mean value theorems – The continuity of derivatives – L'Hospital's Rule – Derivative of higher order.

Unit IV

Definition and Existence of R-S Integral – Properties of the Integral – Integration and Differentiation.

Unit V

Discussion of main problem – Uniform Convergence – Uniform Convergence and Continuity – Uniform Convergence and Integration – Uniform Convergence and differentiation – The Stone Weierstrass theorem.

Text Book

Walter Rudin, Principles of Mathematical Analysis, McGraw – Hill Book Company, New York, 3rd Edition 2013.

Unit I - Chapter 2 § 2.15 - 2.47
Unit II - Chapter 4 § 4.1 - 4.30
Unit III - Chapter 5 § 5.1 - 5.15
Unit IV - Chapter 6 § 6.1 - 6.22
Unit V - Chapter 7 § 7.1 - 7.18 & 7.26

References

1. Tom Apostal, Mathematical Analysis, Addison – Wesley Publishing Company, London 1971.
2. Richard R.Goldberg, Methods of Real Analysis, Oxford & IBH Publishing Company(Last reprint), 2017.
3. H.L.Roydan, Real Analysis, Pearson Education (Singapore) Pvt. Ltd. Third Edition, (Reprint) 2004.

Core Course II - Linear Algebra

Sem. I | Code : P21MA102
Total Hrs.: 90 | Credits : 5

General objectives:

On completion of this course, the learner will

1. be able to understand the structure of vector spaces.
2. be able to comprehend matrices as linear transformations between vector spaces.
3. know direct sum decomposition of vector spaces.
4. be able to understand inner product spaces and their properties.

Learning outcome:

On completion of the course, the student will be able to analyze vector spaces and transformations defined on vector spaces.

Unit I

Vector spaces – Subspaces – Bases and Dimension – Coordinates – Linear Transformation – Algebra of Linear Transformation.

Unit II

Isomorphism of Vector Spaces – Representation of Linear Transformations by Matrices – Linear Functional – The Double Dual – The Transpose of a Linear Transformation.

Unit III

Algebras - The Algebra of Polynomials – Polynomial Ideals – The Prime Factorization of a Polynomial - Commutative rings – Determinant Functions.

Unit IV

Characteristic Values – Annihilating Polynomials - Invariant subspaces – Direct-sum Decompositions.

Unit V

Invariant Direct sums – The Primary Decomposition Theorem – Inner Products – Inner Product Spaces – Unitary Operators – Normal Operators.

Text Book

Kenneth Hoffman and Ray Kunze, Linear Algebra, Pearson India Education Services Pvt. Ltd, 2nd Edition 2015.

Unit I Chapter 2 §2.1 – 2.4 & Chapter 3 § 3.1, 3.2

Unit II Chapter 3 § 3.3 – 3.7

Unit III Chapter 4 § 4.1 – 4.2, 4.4 – 4.5 & Chapter 5 § 5.1 – 5.2

Unit IV Chapter 6 § 6.1 – 6.4, 6.6

Unit V Chapter 6 § 6.7 - 6.8 & Chapter 8 § 8.1 – 8.2, 8.4 – 8.5

References

1. I. N. Herstein, Topics in Algebra, Wiley Eastern Limited, New Delhi, 1975.
2. David C. Lay, Linear Algebra and its Applications, Pearson Education Pvt. Ltd. Third Edition (Fifth Indian Reprint) 2005
3. I. S. Luther and I.B.S. Passi, Algebra, Vol. I – Groups, Vol. II – Rings, Narosa Publishing House (Vol. I – 1996, Vol. II - 1999)
4. N. Jacobson, Basic Algebra, Vols. I & II, Freeman, 1980 (also published by Hindustan Publishing Company).

Core Course III - Ordinary Differential Equations

Sem. I
Total Hrs.: 90

Code : P21MA103
Credits : 4

General objectives:

On completion of this course, the learner will

1. know different methods of solving ordinary differential equations.
2. be able to understand the existence of special functions and their properties.
3. be able to analyse the analytical properties of a solution of an initial value problem.
4. be able to analyse the stability and critical points of system of nonlinear equations.
5. know the applications of ordinary differential equations in physics.

Learning outcome:

On completion of the course, the student will be able to analyze the existence and behavior of solution of an initial value problem and a system of non-linear equations.

Unit I

The general solution of the homogeneous equation – The use of one known solution to find another – The method of variation of parameters – Power Series solutions. A review of power series – Series solutions of first order equations

Unit II

Second order linear equations ; Ordinary points.- Regular Singular Points – Gauss's hypergeometric equation – The Point at infinity – Legendre Polynomials

Unit III

Bessel functions – Properties of Legendre Polynomials and Bessel functions - Linear Systems of First Order Equations – Homogeneous equations with constant coefficients – The Existence and uniqueness of solutions of Initial Value Problems for First Order Ordinary Differential Equations.

Unit IV

The method of solutions of successive approximations and Picard's theorem - Oscillation theory and Boundary Value Problems – Qualitative properties of solutions – Oscillations and the Sturm separation theorem, Sturm Comparison Theorems – Eigenvalues, Eigen functions and the Vibrating String.

Unit V

Nonlinear equations: Autonomous Systems; the phase plane and its phenomena – Types of critical points; Stability – Critical points and stability for linear systems – Stability by Liapunov's direct method – Simple critical points of nonlinear systems.

Text Book

George F. Simmons, Differential Equations with Applications and Historical Notes, Tata McGraw Hill Publishing Company Limited, New Delhi, Second Edition 2003.

Unit I Chapter 3 § 14,15,16,19 & Chapter 5 § 26,27
Unit II Chapter 5 § 28,29,30,31,32 & Chapter 8 § 44
Unit III Chapter 8 § 45,46,47
Chapter 10 § 55,56
Unit IV Chapter 13 § 68,69
Chapter 4 § 24,25 & Chapter 7 § 40
Unit V Chapter 11 § 58,59,60,61,62

References

1. W.T. Reid, Ordinary Differential Equations, John Wiley & Sons, New York, 1971.
2. E. A. Coddington and N. Levinson, Theory of Ordinary Differential Equations, McGraw Hill Publishing Company, New York, 1955.

Core Course IV - Calculus of Variation, Integral Equations and Transforms

Sem. I — Code : P21MA104

Total Hrs.: 90 — Credits : 4

General Objectives:

On completion of this course, the learner will

1. know functionals and the construction of Euler's equation.
2. be able to understand variational methods for solving differential equations.
3. be able to analyze variational problems with moving boundaries.
4. know different integral equations and methods of solving them.
5. be able to use green's function in reducing boundary value problems to integral equations.
6. know methods of finding Fourier transforms and Fourier integrals.

Learning outcomes:

On completion of the course, the student will be able to

1. solve boundary value problems through integral equations using green's function.
2. find extreme values of functionals.

Unit I

The Calculus of Variations - Functionals – Euler's equations – Geodesics – Variational problems involving several unknown functions – Functionals dependent on higher order derivatives – Variational problems involving several independent variables.

Unit II

Constraints and Lagrange multipliers – Isoperimetric problems – The general variation of a functional – Variational problems with moving boundaries – Hamilton's principle –Lagrange's equations.

Unit III

Integral Equations – Introduction – Relation between differential and integral equations – Relationship between Linear differential equations and Volterra integral equations – The Green's function and its use in reducing boundary value problems to integral equations.

Unit IV

Fredholm equations with separable kernels – Fredholm equations with symmetric kernels: Hilbert Schmidt theory – Iterative methods for the solution of integral equations.

Unit V

Fourier Transform and Its Inverse – Shifting Property of Fourier Transforms – Modulation Property of Fourier Transforms – Convolution Theorem – Fourier Sine and Cosine Transforms – Linearity of Transforms – Change of Scale Property of Transforms – Transforms of Derivatives – Parseval's Identities.

Text Books:

1. Dr. M.K. Venkataraman, Higher Mathematics for Engineering and Sciences, The National Publishing Company, 2001 (Unit I, II, III and IV).

2. P. Gupta, Topics in Laplace and Fourier Transforms, Fire Wall Media, Laxmi Publications PVT Ltd. 1st Edition (2019), (Unit V).

Unit I	Chapter 9 § 1 – 13
Unit II	Chapter 9 § 14 – 19
Unit III	Chapter 10 § 1 – 5
Unit IV	Chapter 10 § 6 – 9
Unit V	Chapter 5 § 5.3 – 5.11

References

1. Krasnov, Kiselu and Marenko, Problems and Exercises in Integral Equations, MIR Publishers, 1971.
2. Francis. B. Hildebrand, Methods of Applied Mathematics, Prentice-Hall of India Pvt. Ltd., New Delhi, Second Edition 1968.
3. Ram. P. Kanwal, Linear Integral Equations - Theory and Techniques, Academic press, New York, 1971.

Elective Course I - Graph Theory

Sem. I — Code : P22MA1:A

Total Hrs.: 90 — Credits : 4

General objectives:

On completion of this course, the learner will

1. be able to understand basic concepts of graph theory.
2. know the applications of graphs in other disciplines.

Learning outcomes:

On completion of the course, the student will be able to

1. identify standard graphs and list their properties.
2. use standard graphs to model different networks and study the networks.

Unit I

Graphs and Simple Graphs – Graph Isomorphism – The Incidence and Adjacency Matrices – Subgraphs – Vertex, Degrees – Paths and Connections – Cycles. Trees – Cut edges and bonds, Cut vertices, Cayley's formula.

Unit II

Connectivity, Blocks, Euler Tours, Hamilton cycles.

Unit III

Edge Chromatic number, Vizing's Theorem, Independent Sets, Ramsey's Theorem – Turan's Theorem.

Unit IV

Chromatic number, Brook's theorem, Hajos conjucture, Chromatic Polynomials, Girth and Chromatic number, Plane and Planar Graphs, Dual Graphs – Euler's formula.

Unit V

The Five Colour Theorem and Four Colour Conjecture, Directed Graphs, Directed Paths – Directed Cycles.

Text Book

Bondy, J.A.& Murthy, U.S.R., Graph Theory with Applications, The Mac Millan Press Ltd., 1976.

Unit I Chapter 1 § 1.1 – 1.7 & Chapter 2 § 2.1 – 2.4
Unit II Chapter 3 § 3.1, 3.2 & Chapter 4 § 4.1 & 4.2
Unit III Chapter 6 § 6.1, 6.2 & Chapter 7 § 7.1 – 7.3
Unit IV Chapter 8 § 8.1 – 8.5 & Chapter 9 § 9.1 – 9.3
Unit V Chapter 9 § 9.6 & Chapter 10 § 10.1 – 10.3

References

1. Harary, Graph Theory, Narosha Publishing House, New Delhi, 1988.
2. Arumugam, S & Ramachandran, S., Invitation to Graph Theory, New Gamma Publishing House, Palayamkottai, 1993.

Elective I - History of Modern Mathematics

Sem. I — Code : P22MA1:B

Total Hrs.: 90 — Credits : 4

General objectives:

On completion of this course, the learner will

1. know the prominent movements in modern mathematics.
2. know the mathematicians' work and their valuable contributions

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Learning outcomes:

On completion of this course, the learner will

1. be motivated to continue the line of innovative thinking
2. have a better understanding over the concepts and the interlinks

Unit I

Theory of Numbers – Irrational and transcendent numbers - Complex numbers.

Unit II

Quaternions and Ausdehnungslehre – Theory of equations – Substitutions and groups.

Unit III

Determinants – Quantics – Calculus – Differential Equations.

Unit IV

Infinite series – Theory of functions – Probabilities and least squares.

Unit V

Analytic geometry – Modern geometry – Elementary geometry – non-Euclidean geometry.

REFERENCE

1. David Eugene Smith, History of Modern Mathematics, MJP Publishers, 2008.

Core Course V - Algebra

Sem. II Code : P21MA205
No. of hrs.: 90 Credits : 5

General objectives:

On completion of this course, the learner will

1. be able to understand the structure of finite abelian groups and their non-isomorphic copies.
2. be able to investigate the solvability of polynomials through Galois theory.

Learning outcomes:

On completion of the course, the student will be able to

1. analyse structure and properties of finite abelian groups, rings and modules.
2. construct finite extensions of fields.
3. investigate the resolving field of polynomilas.
4. investigate solvability of polynomials through Galois theory.

Unit I

Another counting principle – Conjugacy – Class equation and its applications – Cauchy's theorem – Partition of a positive integer 'n' – Relation between conjugate classes in S_n and number of partitions of 'n' - Sylow's theorem – Proof (First and Third proofs are omitted) and applications.

Unit II

Direct products – Internal direct products, external direct products and the relation between them - Finite abelian groups – Modules

Unit III

Extension fields- Roots of polynomials – More about roots

Unit IV

Galois theory – Fixed fields - Normal extensions - Galois group of a polynomial – Fundamental theorem of Galois theory

Unit V

Solvability by radicals – Galois Groups over the rationals

Text Book

I. N. Herstein, Topics in Algebra, Wiley – Eastern Ltd., New Delhi, 1975.

Unit I Chapter 2 § 2.11, 2.12 (Excluding the first proof & Lemmas 2.12.1,2.12.2 and 2.12.5)
Unit II Chapter 2 § 2.13, 2.14, Chapter 4 § 4.5
Unit III Chapter 5 § 5.1, 5.3, 5.5
Unit IV Chapter 5 § 5.6
Unit V Chapter 5 § 5.7, 5.8

References

1. P. M. Cohn, Algebra (Vols. – I, II, III), John Wiley & Sons, 1982, 1989, 1991.
2. N. Jacobson, W. H. Freeman, Basic Algebra (Vols. – I & II), 1980 (also published by Hindustan Publishing Company)
3. D. S. Malik, J. N. Mordeson and M. K. Sen, Fundamentals of Abstract Algebra, McGraw Hill International Edition, 1997.

Core Course VI - Partial Differential Equations

Sem. II — Code: P21MA206
No. of hours: 90 — Credits: 5

General objectives:

On completion of this course, the learner will

1. be able to analyze the origin of partial differential equations and their solutions.

2. be able to understand different methods of solving various first order and second order partial Differential equations.
3. know the applications of second order and higher order partial differential equations in physics.

Learning outcome:

On completion of the course, the student will be able to classify and solve first and second order partial differential equations.

UNIT I

First Order Partial differential equations: Curves and Surfaces – Genesis of first Order Partial differential equations – Classification of Integrals – Linear Equations of the First Order – Pfaffian Differential Equations – Compatible Systems – Charpit's Method – Jacobi's Method

UNIT II

Integral Surfaces Through a Given Curve – Quasi-Linear Equations – Non-linear First Order Partial differential equations

UNIT III

Second Order Partial differential equations: Genesis of Second Order Partial differential equations– Classification of Second Order Partial differential equations - One-Dimensional Wave Equation – Vibrations of an Infinite String –Vibrations of a Semi-infinite String –Vibrations of a String of Finite Length (Method of separation of variables)

UNIT IV

Laplace's Equation: Boundary Value Problems – Maximum and Minimum Principles – The Cauchy Problem – The Dirichlet Problem for the Upper Half Plane – The Neumann Problem for the Upper Half Plane – The Dirichlet Problem for a Circle - The Dirichlet Exterior Problem for a Circle – The Neumann Problem for a Circle – The Dirichlet Problem for a Rectangle – Harnack's Theorem.

UNIT V

Heat Conduction Problem: Heat Conduction –Infinite Rod Case – Heat Conduction-Finite Rod Case – Duhamel's Principle – Wave Equation – Heat Conduction Equation

TEXT BOOK(S)

[1] T. Amarnath, An Elementary Course in Partial Differential Equations, Narosa Publishing Company, 1997.

UNIT – I -Chapter 1: Sections 1.1 to1.8 of [1]

UNIT – II -Chapter 1: Sections 1.9 to1.11 of [1]

UNIT – III -Chapter 2: Sections 2.1 to 2.3.5, except 2.3.4 of [1]

UNIT – IV -Chapter 2: Sections 2.4.1 to 2.4.10 of [1]

UNIT – V -Chapter 2: Sections 2.4.11 to 2.6.2 of [1]

REFERENCE(S)

1. Tyn Myint-U: Partial differential equations for scientists and engineers, 3rd ed. North Holland,1989.
2. I.C. Evans, Partial Differential Equations, Graduate Studies in Mathematics, Vol. 19 AMS, 1998.
3. I.N. Snedden, Elements of Partial Differential Equations, McGraw Hill, 1985.
4. F. John, Partial Differential Equations, Springer Verlag, 1975.
5. Phoolan Prasad and Renuka Ravindran, Partial Differential Equations, Wiley-EasternLtd, 1985.
6. Lokenath Debnath and Dambaru Bhatta, Integral Transforms and Their Applications, Chapman & Hall/CRC; 2 editions, 2006.

Core Course VII - Operations Research

Sem. II | Code : P22MA207
Total Hrs.: 90 | Credits: 5

General objectives:

On completion of this course, the learner will

1. know methods of solving Integer Programming problems and Multistage programming.
2. know methods of using Operations Research techniques in decision making
3. be able to understand non-linear programming algorithms.

Learning outcomes:

On completion of the course, the student will be able to

1. Solve Integer Programming problems.
2. Construct operational research models to solve problems in decision making.

Unit I

Integer Programming.

Unit II

Dynamic (Multistage) programming.

Unit III

Decision Theory and Games.

Unit IV

Inventory Models.

Unit V

Non-linear Programming algorithms.

Text Book

1. Dr P. Mariappan, Operations Research Methods and Applications, New Century Book House, Second Edition [2002], 81-234-0716-5

   Unit I - Chapter 7;
   Unit 2 – Chapter 14;
   Unit 3 – Chapter 11

2. Hamdy A. Taha, Operations Research, Macmillan Publishing Company, 4th Edition, 1987.

Unit IV Chapter 13 § 13.1 – 13.4
Unit V Chapter 19 § 19.1, 19.2

References

1. O.L. Mangasarian, Non Linear Programming, McGraw Hill, New York, 1969 .
2. Mokther S. Bazaraa and C.M. Shetty, Non Linear Programming, Theory and Algorithms,Willy, New York, 1979.
3. Prem Kumar Gupta and D.S. Hira, Operations Research - An Introduction, S. Chand and Co., Ltd., New Delhi, 2012.
4. S.S. Rao, Optimization Theory and Applications, Wiley Eastern Limited, New Delhi,1979.

Elective Course II - Python Programming

Semester: II | Code: P22MA2:P

Total Hrs.: 75 | Credits: 4

Unit I

Introduction to Python – Statement and Expression – String Operations – Boolean Operations - Control Statements – Iteration – *while* statement.

Functions – Built-in Functions – Composition of Functions – User-defined Functions -Parameters and Arguments – Function Calls – *return* statement – Recursive Function.

Unit II

Strings – Lists - Tuples – Dictionaries.

Unit III

Files and Exceptions – Text Files – Directories – Exceptions – Exception with Arguments – User-defined Exceptions.

Unit IV

Classes and Objects – Built-in Attributes - Inheritance – Method Overriding.

Unit V

Data Visualization with Matplotlib – Line plot, Bar Chart, Histogram Plot, Scatter Plot, Stack Plot, Pie Chart.

List of Practicals:

1. a) Write a Python program to check the largest among the given three numbers.
   b) Write a function to find the HCF of some given numbers.
2. a) Write a Python program to compute the factorial of a given number using recursion.
   b) Write a function to display Fibonacci sequence using recursion.
3. Write a Python program to solve f(x) = 0 using Bisection method.
4. Write a Python program to solve y' = f(x, y) with given initial conditions using Runge-Kutta method.
5. Write a Python program that demonstrates the built-in functions.
6. Write a Python program to demonstrate various string functions and operations.
7. Write a Python program to demonstrate List functions and operations.
8. Write a Python program to demonstrate the Tuples functions and operations.
9. Write a Python program to demonstrate the Dictionaries functions and operations.
10. Write a Python program to demonstrate the file and file I/O operations.
11. Write a Python program to demonstrate Exception handling.
12. Write a Python program to demonstrate Classes and their Attributes.
13. Write a Python program to demonstrate Inheritance and Method Overriding.
14. Line plot, Bar chart, Histogram, Scatter plot, Pie chart, Contour plot, Subplots.

Text Books:

1. E. Balagurusamy, Introduction to Computing and Problem Solving Using Python, McGraw Hill Education (India) Private Limited, 2021.
2. Jann Kiusalaas, Numerical Methods in Engineering with Python 3, Cambridge University Press, 2013.
3. Dr. Ossama Embarak, Data Analysis and Visualization Using Python, Apress, UAE, 2018.

References

1. Charles R. Severance, Python for Everybody – Exploring Data in Python3, Shroff Publishers & Distributors PVT. Ltd, 2018.
2. Qingkai Kong, Timmy Siauw and Alexandre M. Bayen, Python Programming and Numerical Methods - A Guide for Engineers and Scientists, Academic Press, 2021.
3. Ashwin Pajankar, Practical Python Data Visualization: A Fast Track Approach to Learning Data Visualization with Python, India, 2021.

Elective II - Finite Difference Methods

Sem: II
Total Hrs.: 75

Code : P22MA2:A
Credits : 4

General objectives & Learning outcomes:

On completion of this course, the learner will be able

1. to understand the discretization of differential equation and to apply to solve differential equations numerically.
2. to analyse the stability theory of system of differential equations.

Unit I

Introduction, Difference Calculus – The Difference Operator, Summation, Generating functions and approximate summation.

Unit II

Linear Difference Equations – First order equations. General results for linear equations. Equations with constant coefficients. Applications, Equations with variable coefficients. Nonlinear equations that can be linearized. The z-transform.

Unit III

Stability Theory – Initial value problems for linear system. Stability of linear system. Stability of nonlinear systems, chaotic behavior.

Unit IV

Boundary value problems for Nonlinear equations – Introduction. The Lipschitz case. Existence of solutions. Boundary value problems for Differential equations.

Unit V

Partial Differential Equation – Discretization of partial Differential Equations – Solution of Partial Differential Equations.

REFERENCEs

1. Walter G. Kelley and Allan C. Peterson – Difference Equations. An Introduction with Applications. Academic press inc., Harcourt Brace Joranovich publishers, 1991.

2. Calvin Ahibrandt and Allan C. Peterson – Discrete Hamiltonian Systems. Difference Equations, Continued Fractions and Riccati Equations. Kluwer, Boston, 1996.

Elective Course III - Differential Geometry

Sem. II | Code : P22MA2:B
Total Hrs.: 75 | Credits: 4

General Objectives:

On completion of this course, the learner will

1. know the difference between plane curves and space curves.
2. be able to understand the aspects of geometry, cantered on the notion of curvature.
3. be able to apply the techniques of differential calculus in the field of geometry.

Learning outcomes:

On completion of the course, the student will

1. have the geometrical ideas over the surfaces, the normal and tangents, curvature and related equations of evolutes and involutes.
2. be able to understand the physical systems involved in partial differential equations.

Unit I

Curves in Space: Space curve - Tangent and Tangent line - Order of contact - Arc length Osculating plane - Normal plane - Rectifying plane - Fundamental planes - Curvature – Torsion Fernet Serret formulae.

Unit II

Intrinsic equations: Existence theorem and Uniqueness theorem - Helices - Osculating circle - Osculating sphere - Spherical indicatrices - Involutes and evolutes - Tangent surface.

Unit III

Curves and Surfaces: Definition of a surface - Regular point and singularities - Parametric transformations - Curves on a surface - Normal - General surface of revolution - Metric - First and second fundamental forms - Angle between the parametric curves.

Unit IV

Normal curvature - Meusnier's theorem - Principal directions - Lines of curvature - Rodrigue's formula - Euler's formula - Envelope of surfaces - Edge of Regression - Developable surfaces.

Unit V

Surface Theory: Gauss equation - Weingarten equations - Gauss characteristic equation - Mainardi-Codazzi equations – Geodesics.

Text Book:

Kailash Sinha, An Introduction to Differential Geometry, 4^{th} Edition, Shalini Prakashan Publications, 1977.

Unit I: Chapter II: Sections 2.2, 2.3, 2.5 – 2.11, 2.13 – 2.20

Unit II: Chapter II: Section 2.22 - 2.26, 2.28 - 2.33

Unit III: Chapter III: Section 3.1 – 3.11, 3.13 - 3.16

Unit IV: Chapter IV: Section 4.1 - 4.4, 4.6– 4.10, 4.14 – 4.17

Unit V: Chapter V: Section 5.2 – 5.5, 5.14 – 5.16

References:

1. Struik, D.J., Lectures on classical Differential Geometry, 2nd Edition,Addison-Wesley, 1988.

2. Willmore, T.J., An Introduction to Differential Geometry, Oxford Univ. Press, 1964.

3. Somasundaram D., Differential geometry: A first course, Narosa, 2008.

Elective III - Research Methodology

Sem: II Code: P22MA2:C

Total Hrs: 75 Credits : 4

General objectives:

On completion of this course, the learner will

1. know the process of academic writing.
2. know to write a thesis.

Learning outcome:

On completion of this course, the learner will be able to prepare a research article to report his/her research findings

Unit I

The research thesis –The intellectual content of the thesis –Typing, organizing and developing the thesis.

Unit II

Grammar, punctuation and conventions of academic writing – Layout of the thesis – The preliminary pages and the introduction.

Unit III

Literature review –Methodology.

Unit IV

The data analysis –The conclusion.

Unit V

Completing the thesis – Publishing findings during preparation of the thesis.

REFERENCE

1. Paul Oliver, Writing Your Thesis, Sage Publication, 2nd edition 2008.

Core Course VIII - Topology

Sem. III | Code : P21MA308
Total Hrs.: 90 | Credits: 5

General objectives:

On completion of this course, the learner will

1. be able to understand the meaning of a topology, different topological spaces and continuous functions.
2. know the construction of complete metric spaces through topological spaces
3. be able to analyse the existence of certain real-valued continuous functions on a topological space.
4. be able to comprehend a topological space as a generalisation of the real metric space.

Learning outcome:

On completion of the course, the student will be able to analyze various topological spaces and the properties of functions defined on these spaces.

Unit I

Topological spaces – Basis for a topology – The order topology – The product topology on X x Y – The subspace topology – Closed sets and limit points – Continuous functions – The product topology – The metric topology.

Unit II

The metric topology continued – Connected spaces – Connected subspaces of the real line – Components and local connectedness.

Unit III

Compact spaces – Compact subspaces of the real line – Limit point compactness – The countability axioms.

Unit IV

The separation axioms – Normal spaces –The Uryshon Lemma – Completely regular spaces.

Unit V

The Uryshon Metrization theorem – Complete metric spaces – Compactness in metric spaces.

Text Book

James. R. Munkres, Topology, Pearson Education Singapore Pvt. Ltd. Second Edition, (Ninth Indian Reprint), 2005.

Unit I Chapter 2 § 12 - 20
Unit II Chapter 2 § 21 &Chapter 3 § 23 - 25
Unit III Chapter 3 § 26 – 28 & Chapter 4 § 30
Unit IV Chapter 4 § 31 - 33
Unit V Chapter 4 § 34 & Chapter 7 § 43 & 45

References

1. G.F. Simmons, Introduction to Topology and Modern Analysis, McGraw Hill Company, 1963.
2. James Dugundji, Topology, Prentice Hall of India Private Limited, 1975.

Core Course IX - Measure and Integration

Sem. III Code : P21MA309
Total Hrs.: 90 Credits: 5

General objectives:

On completion of this course, the learner will

1. be able to understand the concept of measurable sets, measurable functions and the integration of such functions on the real line.
2. know abstract measure spaces and the extension of a measure.
3. be able to understand and to analyse the notion of convergence in measure and signed measures.
4. be able to understand the construction and the properties of measures in a product space and the integration with respect to a product measure.

Learning outcomes:

On completion of the course, the student will be able to

1. identify measurable sets and measurable functions.
2. identify Integrable functions and evaluate Lebesgue integrals.

Unit I

Measure on Real line – Lebesgue outer measure – Measurable sets – Regularity – Measurable function - Borel and Lebesgue measurability.

Unit II

Integration of non-negative functions – The General integral – Integration of series – Riemann and Lebesgue integrals.

Unit III

Abstract Measure spaces – Measures and outer measures – Completion of a measure – Measure spaces – Integration with respect to a measure.

Unit IV

Convergence in Measure – Almost uniform convergence – Signed Measures and Halin Decomposition – The Jordan Decomposition.

Unit V

Measurability in a Product space – The Product Measure and Fubini's Theorem.

Text Book

G. De Barra, Measure Theory & Integration, New Age International Pvt. Ltd.,2003.

Unit I Chapter 2 § 2.1 – 2.5
Unit II Chapter 3 § 3.1 – 3.4
Unit III Chapter 5 § 5.1 – 5.6
Unit IV Chapter 7 § 7.1, 7.2 & Chapter 8 § 8.1 & 8.2
Unit V Chapter 10 § 10.1 & 10.2

References

1. M.E. Munroe, Measure and Integration, Addison – Wesley Publishing Company, Second Edition 1971.
2. P.K.Jain, V.P.Gupta, Lebesgue Measure and Integration, New Age International Pvt. Ltd. Publishers, New Delhi, 1986 (Reprint 2000).
3. Richard L. Wheeden and AntoniZygmund, Measure and Integral: An Introduction to Real Analysis, Marcel Dekker Inc. 1977.
4. Inder, K. Rana, An Introduction to Measure and Integration, Narosa Publishing House, New Delhi, 1997.

Core Course X – Complex Analysis

Sem. III | Code : P21MA310
Total Hrs.: 90 | Credits : 4

General objectives:

On completion of this course, the learner will

1. be able to comprehend the local and global properties of analytic functions.
2. know and understand harmonic functions and their basic properties.
3. be able to understand properties of entire functions.

Learning outcomes:

On completion of the course, the student will be able to

1. evaluate radius of convergence of a given power series.
2. identify and Analyze properties of analytic functions, meromorphic functions.
3. evaluate definite complex integrals

Unit I

Power series – Abel's limit theorem – Cauchy's theorem for a rectangle.

Unit II

Higher derivatives – Morera's theorem – Liouville's theorem – Cauchy's estimates – Fundamental theorem of algebra – Local properties of analytical functions – Removable singularities – Taylor's theorem – Zeros and poles – Meromorphic functions – Essential singularities.

Unit III

The general form of Cauchy's theorem – Chains and cycles - Simply connected sets – Homology – The general statement of Cauchy's theorem and its proof – Locally exact differentials – Multiply connected regions – The residue theorem – The Argument principle – Evaluation of definite integrals.

Unit IV

Harmonic functions – Basic properties – Polar form – Mean value property – Poisson's formula – Schwartz's theorem – Reflection principle.

Unit V

Partial fractions – Infinite products – Canonical products – Entire functions – Representation of entire functions – Formula for sin z and gamma functions – Jensen's formula.

Text Book

L.V.Ahlfors, Complex Analysis, McGraw Hill International, Third Edition, 1979.

Unit I Chapter 2 § 2.4, 2.5 & Chapter 4 § 1.4
Unit II Chapter 4 § 2.3, 3.1 & 3.2
Unit III Chapter 4 § 4.1 - 4.7, 5.1 - 5.3
Unit IV Chapter 4 § 6.1 - 6.5
Unit V Chapter 5 § 2.1 - 2.4 & 3.1

References

1. S. Ponnusamy, Foundations of Complex Analysis, Narosa Publishing House, 1997.
2. Churchill, R.V. Brown J. W., Complex Variables and Application, McGraw Hill Publishing Pvt. Ltd., 4th edition, 1984.
3. S. Lang, Complex Analysis, Addison Wesley, 1977.
4. S.G Venkatachalapathy, Complex Analysis, Margham Publications, 1st Edition, 2012.

Core Course XI - Probability & Statistics

Sem. III — Code : P21MA311

Total Hrs.: 90 — Credits : 4

General objective:

On completion of this course, the learner will

1. know probability and to understand probability as a continuous set function.
2. be able to understand the notion of a random variable and to know discrete and continuous random variables, their probability functions, distribution functions and expectations.
3. be able to analyse the construction of moment generating functions and to understand different results on random variables.

Learning outcomes:

On completion of the course, the student will be able to

1. calculate the probability for any event and use it to estimate certain possibilities.
2. identify the distributions depending on the nature of the data and derive inferences.

Unit I

Basic concepts – Sample space and events – Axioms of probability – Some simple propositions – equally likely outcomes – Probability as a continuous set function - Probability as a measure of belief.

Unit II

Conditional probabilities – Baye's formula – Independent events – P (. /F) is a probability – random variables – Expectation of a function of a random variable – Bernoulli, Binomial and Poisson random variables.

Unit III

Discrete probability distributions – Geometric, Negative Binomial and Hypergeometric random variables – the zeta (z;pf) distribution – continuous random variables – the uniform and normal random variables – exponential random variables – other continuous distributions – the distribution of a function of a random variable.

Unit IV

Joint Distribution functions – Independent random variables – Their sums – conditional distribution – Joint probability distribution of functions – expectation – variance – covariance – conditional expectation and prediction.

Unit V

Moment generating function – general definition of expectation – limit theorems – Chebyshev's inequality – weak law of large numbers – central limit theorems – the strong law of large numbers – other inequalities

Text Book

Sheldon Ross, A First Course in Probability, Maxwell MacMmillar International Edition, Maxmillar, New York, 6th Edition, 2008.

Unit I	Chapter 2	
Unit II	Chapter 3 & Chapter 4 § 4.1 – 4.7	
Unit III	Chapter 4 § 4.8	& Chapter 5
Unit IV	Chapter 6 § 6.1 – 6.5	&Chapter 7 § 7.1 – 7.5
Unit V	Chapter 7 § 7.6 – 7.8	& Chapter 8 § 8.1 – 8.5

Reference

1. Perumal Mariappan, Statistics for Business, CRC Press, Taylor & Francis Group, 2019.
2. Geoffery Grimmell and Domenic Welsh, Probability – An Introduction, Oxford University Press, 1986.

Elective IV: Problem Solving in Advanced Mathematics

Sem. III | Code : P22MA3:A
Total Hrs.: 75 | Credits: 4

Course Outcomes :

1. Problem Solving Tehniques in Real Analysis
2. Problem Solving Techniques in Complex Analysis
3. Problem Solving Techniques in Algebra
4. Problem Solving Techniques in Lineae Algebra
5. Problem Solving Techniques in Differential Equations
6. Skills required to clear NET/SET/GATE Examinations

Unit-I: Real Analysis

Séquences and series, Convergence, limsup, liminf, Bolzano Weierstrasss theorem, Hernie Borel theorem, Continuity, uniform continuity, differentiability, mean value theorem, Sequences and series of functions, uniform convergence, Riemann sums and Riemann integral, Improper Integrals, Monotonic functions, types of discontinuity, functions of bounded variation, Lebesgue measure, Lebesgue Integral.

Unit-II: Complex Analysis

Analytic functions, Cauchy- Riemann equations, Contour Integral, Cauchy's theorem, Cauchy's Integral formula, Liouville's theorem, Maximum modulus principle, Schwarz lemma, Open mapping theorem, Taylor series, Laurent series, calculus of residues.

Unit-III: Algebra

Groups, Subgroups, normal subgroups, quotient groups, homomorphisms,cyclic groups, permutation groups, Cayley's theorem, Class equations, Sylow theorems, Rings, Ideals, Prime and maximal ideals, quotient rings, unique factorization domain, principal ideal domain, Euclidean domain, Fields, Field extensions, Galois Theory.

Unit IV: Linear Algebra

Vector spaces, subspaces, linear dependence, basis, dimension, algebra of linear transformations, Algebra of matrices, rank and determinant of matrices, linear equations, Eigen values and eigen vectors, Cayley-Hamilton theorem, Matrix representation of linear transformations, Inner Product Spaces.

Unit V: Differential Equations

Existence and uniqueness of solutions of initial value problems for first order ordinary differential equations, singular solutions of first order ODE's, System of first order ODE's, Lagrange and Charpit methods for solving first order PDEs, Cauchy problem for first order PDEs, Classification of second order PDEs, General solution of higher order PDEs with constant coefficients.

Text Books :

1. Info Study's Real Analysis by A.P.Singh Info study Publications
2. Info Study's Complex Analysis by A.P.Singh Info study Publications
3. Info Study's Modern Algebra by A.P.Singh Info study Publications
4. Info Study's Linear Algebra by A.P.Singh Info study Publications
5. Info study's Differential Equation by Dr. A. P. Singh Info study Publications

References:

1. Walter Rudin , Principles of Mathematical Analysis, Third Edition, McGraw-Hill Inter National Book Company, New York, 1976
2. John B. Conway, Functions of one Complex Variable, Second Edition, Springer Graduate Text in Mathematics, NewYork,1978
3. Joseph. A. Gallian, Contemporary Abstract Algebra, 7th Edition Katherine Tegen Books.
4. Seymour Lipschutz and Marc Lipson, Schaum's Outlines Linear Algebra Third Edition
5. Gilbert Strang, Introduction to Linear Algebra Fourth Edition, Wellesley Cambridge Press.
6. Earl A.Coddington, An Introduction to Ordinary Differential Equations, Prentice-Hall of India,NewDelhi,1992.
7. M.D Raisinghania, Advanced Differential Equations, S. Chand and Company ltd, New Delhi, 2001.

Elective IV : Data Envelopment Analysis

Sem: III — Code :P22MA3:B
Total Hrs: 75 — Credits : 3

Course Outcomes:

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

1. Analyze Decision Making Units, Linear Programming Problems, Fractional Programming Problems
2. Describe Mathematical Modeling of DEA
3. Formulate CRS DEA and VRS DEA
4. Examine DEA Application in an Educational Institute
5. Demonstrate DEAP Software
6. Evaluation of DEA Problems through DEAP Software

Unit I Introduction

Introduction to Data Envelopment Analysis [DEA] – Decision Making Units [DMUs] – Fundamental Concepts of Effectively Evaluation – Operations Research – Models of Operations Research – Scope of Operations Research – Phase of Operations Research Methodology – General Model of the Linear Programming Problem – Assumptions of Linear Programming Problem – The Temporary Ordered Routing Algorithm (TORA) – Operations Research Software – Fractional Programming Problem – Performance Based on single input and single output – Performance Based on two input and a single output – Strongly and Weakly Efficient DMUs

Unit II Mathematical Modeling of DEA

Procedural Application of DEA – How to choose the DMUs for the study? – Selection of the Inputs and Outputs – Formulation of a Mathematical Structure of additive type – Dual concept in a Linear Programming – DEAP Version 2.1 – Economy of Scale

Unit III CRS DEA and VRS DEA Models

Constant Returns to Scale DEA Model [CRS DEA] – Variable Returns to Scale DEA Model [VRS DEA] – Technical and Scale Efficiencies.

Unit IV

DEA Application in an Educational Institute

Introduction – Review of Literature – Research Methodology – Constant Return to Scale [CRS Model] – Empirical Result – Constant Return to Scale [CRS Model] – Variable Return to Scale [VRS Model] – Overall Efficiency – Summary and Research Findings.

Unit V

DEA Software

Text Book

Unit 1 – 4: Introduction to Data Envelopment Analysis [DEA] by Perumal Mariappan, LAP LAMBERT Academic Publishing, 2016

Unit 5: A Data Envelopment Analysis (Computer) Program by Tim Coelli

REFERENCE(s)

An Introduction to Data Envelopment Analysis: A tool for performance measurement, sage publications.

Generic Course : Principles and Methods of Teaching

Sem: III | Code : P22MA3G1
Total Hrs: 15 | Credits : 1

Course Outcomes:

At the end of the students will be able to:

1. Understand the process of teaching & its various components.
2. Identify the appropriate methods & techniques of teaching.
3. Describe the process of teaching and methods of communication in the classroom.
4. Determine the relevant models of teaching.
5. Employ the methods of teaching in the field of teaching.
6. Prepare lesson plan and academic calendar for their subject of teaching.

Unit I: Teaching as a Communication Process

Meaning & Nature – Phases & Level of teaching – Communication process – Means of communication – Factors affecting Communication.

Unit II: Teaching Skills

Various Teaching Skills: Introducing a lesson – Questioning; Stimulus variation, Illustration, Explanation – Demonstration, Reinforcement, Closure of a topic – Teaching under constructivist approach – Simulated teaching.

Unit III: Models of Teaching

Meaning and Features – Types: Concept attainment, concept formation, Advanced organizer, Inquiry teaching – Simulated Teaching, Flanders's Interaction Analysis Cybernetics, Team teaching.

Unit IV: Methods of Teaching

Brainstorming, dialog & Participatory method – Project method, Constructivist method – Problem solving, Role playing

Unit V: Programmed instruction

Small group instruction – Resource Centre based leaning – Preparing Lesson Plan – Academic Planning

REFERENCES

Agarniai, J.C. (2009) : Principles & Methods of Teaching, Vikas Publishing House Pvt Limited, Noida.

Agarwal, J. C. (2014) : Essentials of Educational Technology (3rd Edition), Vikas Publushing House Pvt Limited, Noida.

Bruce & Joyce (2009) : Models of Teaching, Pearson Publishers, Pennsylvania

Kochhlar, S.K (1985) : Methods & Techniques of teaching, Sterling Low Price Edition, New Delhi.

Core Course XII - Functional Analysis

Sem. IV — Code : P21MA412
Total Hrs.: 90 — Credits: 5

General objectives:

On completion of this course, the learner will

1. be able to understand different algebraic structures of operators.
2. be able to comprehend the importance of theory of operators in solving initial value problems, boundary value problems and integral equations.
3. know spectral theory and the importance of its establishment.

Learning outcomes:

On completion of the course, the student will be able to

1. analyze various properties of Banach & Hilbert spaces.
2. analyze properties of operators defined on these spaces.
3. construct Banach algebras through Banach spaces.

Unit I

Banach Spaces: The definition and some examples – Continuous linear transformations – The Hahn-Banach theorem – The natural imbedding of N in N^{**} - The open mapping theorem – The conjugate of an operator.

Unit II

Hilbert Spaces: The definition and some simple properties – Orthogonal complements – Orthonormal sets – The conjugate space H^* - The adjoint of an operator – Self-adjoint operators – Normal and unitary operators – Projections.

Unit III

Finite-Dimensional Spectral Theory: Matrices – Determinants and the spectrum of an operator – The spectral theorem – A survey of the situation.

Unit IV

General Preliminaries on Banach Algebras: The definition and some examples – Regular and singular elements – Topological divisors of zero – The spectrum – The formula for the spectral radius – The radical and semi-simplicity.

Unit V

The Structure of Commutative Banach Algebras: The Gelfand mapping – Applications of the formula $r(x) = \lim||x^n||^{1/n}$ – Involutions in Banach Algebras – The Gelfand-Neumark theorem.

Text Book

G.F. Simmons, Introduction to Topology and Modern Analysis, Tata McGraw-Hill Publishing Company Ltd.,2006.

Unit I Chapter 9
Unit II Chapter 10
Unit III Chapter 11
Unit IV Chapter 12
Unit V Chapter 13

References

1. B.V. Limaye, Functional Analysis, Wiley Eastern Limited, Bombay, 2nd Print, 1985.
2. Walter Rudin, Functional Analysis, Tata McGraw Hill Publishing co., New Delhi, 1977.
3. K. Yosida, Functional Analysis, Springer-Verlag, 1974.
4. Laurent Schwarz, Functional Analysis, Courent Institute of Mathematical Sciences, New York University, 1964.

Core Course XIII – Numerical Analysis

Sem. IV — Code : P21MA413

Total Hrs: 90 — Credits : 4

Unit I

Transcendental and polynomial equations: Rate of convergence-Muller method and Chebyshev method. Polynomial Eequations: Descarte's rule of signs – Iterative methods: Birge-vieta method, Bairstow's method-Direct method: Graffe's root squaring method.

Unit II

System of Linear Algebraic equations and Eigen Value Problems: Error Analysis of Direct methods-Operational count of Gauss Elimination, Vector Norm, Matrix Norm, Error Estimate. Iteration methods- Jacobi iteration method, Gauss seidel iteration method, Successive over Relaxation method- Convergence analysis of iterative methods, Optimal relaxation parameter for the SOR method. Finding eigen values and eigen vectors – Jacobi method for symmetric matrices and power methods only.

Unit III

Interpolation and Approximation: - Hermite Interpolations, Piecewise and Spline Interpolation- Piecewise linear Interpolation, piecewise quadratic interpolation, piecewise cubic interpolation (excluding piecewise cubic interpolation using Hermite Type Data), spline interpolation- cubic spline interpolation. Bivariate Interpolation – Lagrange Bivariate interpolation. Least Square approximation.

Unit IV

Differentiation and Integration: Numerical Differentiation – Methods based on finite difference operators; Methods based on undetermined coefficients – Optimum choice of step length – Extrapolation methods – Partial Differentiation. Numerical Integration: Methods based on undetermined coefficients- Gauss Legendre Integration method and Lobatto Integration methods only.

Unit V

Ordinary differential equations – Single step methods: Local truncation error or Discretization Error, Order of a method, Taylor's series method, Runge-Kutta methods – Minimization of Local Truncation Error, system of equations, Implicit Runge-Kutta methods. Stability analysis of single step methods (RK methods only)

Text Book

M.K Jain, S.R.K Iyengar and R.K Jain, Numerical Methods for Scientific and Engineering Computation, New Age International (p) Limited Publishers, New Delhi, Sixth Edition 2012.

Unit I	Chapter 2 : sec 2.5 (pages 43-52), 2.9(pages 83-99)
Unit II	Chapter 3 : sec 3.3 (pages 134-140), 3.4 (pages 146-164), 3.5(pages 170-173),

3.7 (pages 179-185) and 3.11 (pages 196-198)

Unit III Chapter 4 : sec 4.5 – 4.7 & 4.9 (pages 284-290)

Unit IV Chapter 5 : sec 5.2 - 5.5 (Page 328-345) and 5.8 (pages 361-365 and 380-386)

Unit V Chapter 6 : sec 6.4 (pages 434-459) and 6.5 (pages 468 - 475)

References

1. Perumal Mariappan, Numerical Methods for Scientific Solutions, New Century Book House, 2020.
2. Kendall E.Atkinson, An introduction to Numerical Analysis, II Edn., John Wiley & Sons, 1998.
3. M.K Jain, Numerical Solution of Differential Equations, II Edn., New Age International Pvt Ltd., 1983.
4. Samuel.D.Conte, Carl.De Boor, Elementry Numerical Analysis, McGraw-Hill International Edn.,1983.

Core Course XIV - Fluid Dynamics

Sem. IV | Code : P22MA414

Total Hrs. : 90 | Credits : 4

General objectives:

On completion of this course, the learner will

1. be able to understand the kinematics of a fluid through equations of motion of the fluid.
2. be able to analyse some two dimensional and three-dimensional flows.
3. be able to understand Navier- Stokes equations of motion of a viscous fluid and some solvable problems in viscous flow.
4. be able to understand the importance of complex analysis in the analysis of flow of fluids.

Learning outcome:

On completion of the course, the student will be able to analyze the technical characteristics like pressure, velocity, viscosity of two dimensional and three-dimensional flows and their media.

Unit I

Real fluids and Ideal Fluids – Velocity of a fluid at a point – Streamlines and Pathlines: Steady and Unsteady Flows – The Velocity potential – The Vorticity vector – Local and particle rates of change – The equation of Continuity – worked examples – Acceleration of a fluid.

Unit II

Pressure at a point in a fluid at rest – Pressure at a point in a moving fluid – Euler's equations of motion – Bernoulli's equation – Discussion of the case of Steady Motion under Conservative Body forces – Some potential theorems – Impulsive motion.

Unit III

Sources, sinks and doublets – Images in a rigid infinite plane – Images in Solid spheres – Axisymmetric flows; Stoke's Stream function.

Unit IV

The stream function – The complex potential for two dimensional, irrotational, incompressible flow – Complex velocity potentials for standard two-dimensional flows – Some worked examples – Two-dimensional image systems – The Milne Thomson circle theorem.

Unit V

Stress Components in a Real Fluid – Relations between Cartesian components of stress - Translational Motion of Fluid element – The Coefficient of Viscosity and Laminar Flow – The Navier-Stokes equations of Motion of a Viscous Fluid, Some solvable problems in Viscous flow.

Text Book

Chorlton.F, Text Book of Fluid Dynamics, CBS Publishers & Distributors, Delhi, 2004.

Unit I Chapter 2 § 2.1 – 2.9
Unit II Chapter 3 § 3.1, 3.2, 3.4 – 3.8, 3.11
Unit III Chapter 4 § 4.2 – 4.5
Unit IV Chapter 5 § 5.3 – 5.8.1, 5.8.2
Unit V Chapter 8 § 8.1 – 8.3, 8.8 – 8.10

References

1. H. Schlichting, Boundary Layer Theory, McGraw Hill Company, New York, 1979.
2. Rathy R.K, An Introduction to Fluid Dynamics, Oxford and IBH Publishing Company, New Delhi,1976.

Elective Course V - Stochastic Processes

Sem. IV | Code : P22MA4:A
Total Hrs. : 90 | Credits : 4

General objectives:

On completion of this course, the learner will

1. be able to understand various elements of Stochastic Processes.
2. be able to understand renewal processes and their applications.
3. be able to understand queuing processes and know methods of deriving the programme measures of queuing models.

Learning outcomes:

On completion of the course, the student will be able to

1. identify and classify various stochastic processes.
2. construct queueing models and derive programme measures of a queueing model.

UNIT I: Stochastic Processes

Some notions - Specifications of stochastic processes- Stationary processes- Markov Chains – Definition and examples-Higher transition probabilities.

UNIT II: Markov Chains

Generalization of Independent Bernoulli trials- Sequences of chain –Dependent trails - Classification of states and chains - determination of higher transition probabilities- Stability of Markov system - Graph theoretic approach - Markov chain with denumerable number of states.

UNIT III: Markov Process with Discrete State Space

Poisson process: Poisson process and related distributions – Generalizations of Poisson process – Birth and death process – Markov process with discrete state space (Continuous time Markov chain).

UNIT IV: Renewal Processes and Theory

Renewal Processes - Renewal Processes with continuous time – Renewal equation –Wald's equation: stopping time- Renewal theorems.

UNIT V: Stochastic Processes in Queueing

Queuing process systems: General concepts- The queuing model M/M/1: Steady state behavior – Transient behavior of M/M/1 model.

TEXT BOOK

Medhi J. (1994), STOCHASTIC PROCESSES, Second Edition, Wiley Eastern Ltd New Delhi.

UnitI: Chapter 2 (Sections 2.1 to 2.3) & Chapter 3 (Sections 3.1, 3.2)

UnitII: Chapter 3 (Sections 3.3 to 3.8)

Unit III: Chapter 4 (Sections 4.1 to 4.5)

Unit IV: Chapter 6 (Sections 6.1 to 6.5)

Unit V: Chapter 10 (Sections 10.1 to 10.3)

REFERENCE BOOKS

1. Samuel Karlin & Howard M.Taylor(1981.), A FIRST COURSE IN STOCHASTIC PROCESSES, Academic Press.

2. Samuel Karlin & Howard M.Taylor(1981), A SECOND COURSE IN STOCHASTIC PROCESSES, Academic Press.

3. Basu A. K (2003), INTRODUCTION TO STOCHASTIC PROCESS, Narosa Publishing House, New Delhi.

4. Richard Bron Son, GovindasamiNaadimuthu (2004), OPERATIONS RESEARCH Second Edition , Tata Mc.Graw Hill Publishing Company Ltd.,New Delhi. (for topics in Queuing Theory)

5. Sheldon M. Ross, Stochastic Processes. 2nd Edition John Wiley and Sons, Inc.2004.

6. Srinivasan SK .& Medhi J.(1978), STOCHASTIC PROCESS, Second Edition, Tata Mc Graw-Hill Publishing Company ltd.

7.U.Narayanan Bhat, Elements of Applied Stochastic Processes, John Wiley & Sons, 1984.

Elective V: Advanced Operations Research

Sem: IV — Code: P22MA4:B

Total Hrs: 90 — Credits : 4

Unit I
Linear Programming Problem – Revised Simplex Method – Post Optimal Analysis – Transshipment Problems – Sentivity Analysis for Transportation Problems.

Unit II
Markov Chain – Introduction to Markov Chain – Stochastic Process – Markov Process – One stage transition Probability – Markov Chain – State transition Matrix – Long-Run properties of Markov chains – Markov chain modelling through graph-Empherical Queuing Models-Classification of Queues – [M/M/c]:[GD/∞/∞]-[M/M/c]:[GD/N/∞] Model for C<=N.

Unit III
Sequencing – Goal Programming.

Unit IV
Simulation – Quadratic Programming Problem – Wolfe's Method -Beals Method

Unit V
Network and Replacement Models – Introduction to Network Models – Graphic Theoretic Concepts – The Shortest Path Problem – Minimal Spanning Tree problem – Replacement models.

Text Books
1. Operations Research Methods and Applications, Dr.P.Mariappan – New Century Publications.
   Unit I Chapter 2 : Section 2.16
   Chapter 4: Sections 4.8 & 4.9
   Unit III Chapter 16 & 9
   Unit IV Chapter 17
   Chapter 13: Sections 13.6, 13.7, 13.8
2. Advanced Operations Research, Dr P Mariappan – Bharathidasan University Study Material
   Unit II Chapter 2
   Unit V Chapter 5

REFERENCE(s)
Introduction to Operations Research [4th Edition], Hamdy A.Taha, Tata McGraw hill

Project

Sem. IV	Code : P21MA4PJ
Total Hrs. : 90	Credits : 4

Post Graduate - Extra Credit Courses
(For the candidates admitted from the academic year 2022 onwards)

Course	Code	Title	Credits	Marks	
				ESA	TOTAL
I	P21MAX:1	Information Theory	2	100	100
II	P21MAX:2	Wavelet Theory	2	100	100
III	P21MAX:3	Theory of Linear Operators	2	100	100
IV	P21MAX:4	Mathematical Physics	2	100	100

Extra Credit Course I - Information Theory

Code: P21MAX:1 Credits : 2

General objectives & Learning outcomes:

On completion of this course, the learner will

1. know the classification of channels and their information processes.
2. be able to understand the basic concepts of information theory and coding theory.

Unit I

Measure of Information – Axioms for a measure of uncertainty. The Shannon entropy and its properties. Joint and conditional entropies. Transformation and its properties.

Unit II

Noiseless coding – Ingredients of noiseless coding problem. Uniquely decipherable codes. Necessary and sufficient condition for the existence of instantaneous codes. Construction of optimal codes.

Unit III

Discrete Memory less Channel-Classification of channels. Information processed by a channel. Calculation of channel capacity. Decoding schemes. The ideal observer. The fundamental theorem of information theory and its strong and weak converses.

Unit IV

Continuous Channels – The time-discrete Gaussian channel. Uncertainty of an absolutely continuous random variable. The converse to the coding theorem for time-discrete Gaussian Channel. The time-continuous Gaussian channel. Band-limited channels.

Unit V

Some imuitive properties of measure of entropy-Symmetry, normalization, expansibility, boundedness, recursivity maximality, stability, additivity, subadditivity, nonnegative, continuity, branching etc. and interconnections among them. Axiomatic characterization of Shannon entropy dur to Shannon and Fadeev.

References

1. R.Ash, Information Theory, Inter science Publishers, New York, 1965.
2. F.M.Reza, An Introduction to Information Theory, McGraw-Hill Book Company Inc.,1961.
3. J.Aczel and Z.Daroczy, On Measures of Information and Their Characterization, Academic Press, New York,1975.

Extra Credit Course II - Wavelet Theory

Code : P21MAX:2 Credits : 2

General objectives & Learning outcomes:

On completion of this course, the learner will

1. know the basic concepts of wavelet theory.
2. be able to understand construction of wavelets.
3. be able to comprehend wavelets on the real line.

Unit I

Different ways of constructing wavelets-Orthonormal bases generated by a single function: the Balian –Low theorem. Smooth projections on L2 (R). Local sine and cosine bases and the construction of some wavelets. The unitary folding operators and the smooth projections.

Unit II

Multire solution analysis and construction of wavelets. Construction of compactly supported wavelets and estimates for its smoothness. Band limited wavelets.

Unit III

Orthonormality. Completeness. Characterization of Lemarie-Meyer wavelets and some other characterization. Franklin wavelets and Spline wavelets on the real line. Orthonormal bases of piecewise linear continuous functions and Spline wavelets on the real line.

Unit IV

Orthonormal bases of piecewise linear continuous functions for L2(T) Orthonormal bases of periodic splines., Periodizations of wavelets defined on the real line.

Unit V

Characterizations in the theory of wavelets – The basic equations and some of its applications. Characterizations of MRA wavelets, low-pass filters and scaling functions.

References

1. Eugenio Hernandez and Guido Weiss, A First Course on Wavelets, CRC Press, New York,1996.
2. C.K. Chui, An Introduction to Wavelets, Academic Press, 1992
3. I. Daubechies, Ten Lectures on Wavelets, CBS-NSF Regional Conferences. In Applied Mathematics,61, SIAM,1992.
4. Y.Meyer, Wavelets, Algorithms and Applications (translated by R.D.Rayan, SIAM,) 1993.
5. M.V.Wickerhauser, Adapted Wavelet Analysis from Theory to Software, Wellesley, MA,A.K.Peters,1994.
6. Mark A.Pinsky, Introduction to Fourier Analysis and Wavelets, Thomson, 2002.

Extra Credit Course III - Theory of Linear Operators

Code : P21MAX:3 Credits : 2

General objectives & Learning outcomes:

On completion of this course, the learner will

1. know the theory of linear operators and their properties in normed spaces
2. be able to understand the characteristics of linear operators.

Unit I

Spectral theory of linear operators in normed spaces – Spectral theory on finite dimensional normed spaces – basic concepts – Spectral properties of bounded linear operators – properties of resolvent and spectrum – Banach Algebra.

Unit II

Compact linear operators on normed spaces – properties – Spectral properties of compact linear operators on normed spaces.

Unit III

Operator equations involving compact linear operators – theorems of Fredholm Type – Fredholm alternative.

Unit IV

Spectral properties of bounded self-adjoint linear operator – positive operators – square roots of a positive operators.

Unit V

Projection operators – their properties – spectral family of bounded self-adjoint linear operators.

References

1. Erwin Kreyszig, Introductory Functional Analysis with its Applications, John Wiley & Sons; Reprint edition (5 April 1989).
2. K.Yosida, Functional Analysis, Springer-Verlag, 1974.
3. P.R.Halmos, Introduction to Hilbert Space and the Theory of Spectral Multiplicity, second edition, Chelsea Publishing Co., New York, 1957.

Extra Credit Course IV - Mathematical Physics

Code : P21MAX:4 Credits : 2

General objectives & Learning outcomes:

On completion of this course, the learner will

1. be able to comprehend some special mathematical functions and their relevance in other fields.
2. be able to analyse boundary value problems and their applications in other fields.

Unit I

Boundary value problems and series solution – examples of boundary value problems – Eigenvalues, Eigen functions and the Sturm-Liouville problem – Hermitian Operator, their Eigenvalues and Eigen functions.

Unit II

Bessel functions – Bessel functions of the second kind, Hankel functions, Spherical Bessel functions – Legendre polynomials – associated Legendre polynomials and spherical harmonics.

Unit III

Hermit polynomials – Laguerre polynomials – the Gamma function – the Dirac delta function.

Unit IV

Non homogeneous boundary value problems and Green's function – Green's function for one dimensional problems – Eigen function expansion of Green's function.

Unit V

Green's function in higher dimensions – Green's function for Poisson's equation and a formal solution of electrostatic boundary value problems – wave equation with source – the quantum mechanical scattering problem.

References

1. B. D. Gupta, Mathematical Physics, Vikas Publishing House Pvt Ltd., New Delhi, 1993.
2. Goyal AK Ghatak, Mathematical Physics – Differential Equations and Transform Theory, McMillan India Ltd., 1995.
3. Kreyszig, Advanced Engineering Mathematics, Wiley; Ninth edition (2011).