DEPARTMENT OF MATHEMATICS

Scheme Ph.D. Mathematics

Course Effective from Academic Year 2022-23

The candidates qualifying the entrance test or those who are exempted from entrance test will have to pass course work before starting their research work. However, they will have to choose supervisor from University for their research. The duration of course work will be one semester and the subjects to be studied shall be decided by the student's supervisor after assessment of his/her already studied courses.

Note: A Ph. D. Scholar will be allowed to undertake creditable research after the completion of course work.

Scheme of Ph.D. Mathematics

Course Code	Title of Course	MARKS					CREDITS		
		Theory	Practical	Internal Assessment	Total Marks	L	T	P	Total
SEMESTER – I									
Compulsory Course									
RM-CC-023	Research Methodology	60	-	40	100	4	0	0	4
RPE 021	Research and Publication Ethics	30		20	50	2	0	0	2
Elective-I (Choose any one of these)									
MATH-EC- 611-I	Mathematical and Numerical Methods	60	-	40	100	4	0	0	4
MATH-EC-611-II	Stability Theory I	60	-	40	100	4	0	0	4
MATH-EC-611-III	Advanced Algebra	60	-	40	100	4	0	0	4
MATH-EC-611-IV	Advanced Number Theory	60	-	40	100	4	0	0	4
MATH-EC- 611-V	Regression Analysis	60	-	40	100	4	0	0	4
Elective-II (Choose any one of these)									
MATH-EC- 612-I	Advanced Fluid Mechanics	60	-	40	100	4	0	0	4
MATH-EC- 612-II	Stability Theory II	60	-	40	100	4	0	0	4
MATH-EC- 612-III	Matrix Analysis	60	-	40	100	4	0	0	4
MATH-EC- 612-IV	Cryptography	60	-	40	100	4	0	0	4
MATH-EC- 612-V	Advanced Time Series	60	-	40	100	4	0	0	4
MATH-EC-612-VI	Fractional Calculus and Fractional Differential Equations.	60	-	40	100	4	0	0	4
SEMESTER-II-VI									
Ph.D. Research Work	Dissertation Work/Thesis Writing	-	-	-	-	-	-	-	8* credits per semester
	Thesis Evaluation / Viva Voce Examination after the submission of thesis					-	-	8	8

*If student does satisfactory performance in Dissertation/thesis work, then He/She will be awarded credits depending upon his/her performance.

Ph.D. candidate is required to complete successfully all prescribed courses. In Semester-I (course work) there are four courses. Research Methodology and Research and Publication Ethics are the compulsory courses and Ph.D. candidate have to select other two courses as recommended by the concerned supervisor. For the Ph.D.candidate, after completion of course work, in other semesters, the candidate has to do his/her research work. He/she is required to deliver seminar before RDC at

the end of each semester for showing the progress made during that semester and submit their research work report.

*If student does satisfactory performance in Thesis work, then He/She will be awarded four 'SSSS' (equal to 8 credits) in respective semester, and if his/her research work found unsatisfactory then he/she may be awarded 'SXXX'/ 'SSXX'/'SSSX' depending upon performance.

Note: Students have to earn minimum 52 credits during the thesis work for the successful award of Ph.D Degree.

Here 'S' carries 2 credits

'X' carries 0 credit

SEMESTER – I

RM-CC- 023 (SCIENTIFIC RESEARCH METHODOLOGY)

L	T	P	Credit
4	0	0	4

Pre-requisite: Elementary Research Methodology.

Course Objectives: This course is designed to understand some basic concepts of research and its methodologies.

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

- Identify appropriate research topics.
- Select and define appropriate research problem and parameters.
- Prepare a project proposal (to undertake a project).
- Organize and conduct research (advanced project) in a more appropriate manner.
- Write a research report and thesis.
- Write a research proposal (grants).
- To understand the basic concepts of MS Office, MS Excel, MS Power Point and MATLAB.

Module 1

Methodology and Literature

Meaning of research, purpose of research, research methods: scientific methods, experimental methods, observational methods, survey and questionnaires methods, role of theory, characteristics of research. Criteria of good research. Need for research design. Types of research: fundamental or pure research, applied research, action research, experimental research. Review of work relevant to the chosen problems, Applied science and technology index. Classical and comprehensive reference works.

Module II

Abstracting and indexing services (A & I)

Current services: CA weekly issues, CA issue indexes-keyword index. General subject index, chemical substance index, formula index, index of ring systems, author index, and patent index. CA Collective indexes: Collective index (CI), volume index, quinquennial index, decennial index (DI).

Module III

Mathematical and Computational Treatment.

Data collection techniques. Classification, analysis and presentation of data. Statistical Arithmetic mean, Geometric mean treatments.

Storage and retrieval of data. Development of database structures, Data processing and basic operation, Sorting. Network protocols. Development of the web page, Use of software in structure elucidation such as MATLAB, MATHEMATICA, STATISTICA, LATEX,

CHEMWINDOW, CHEMDRAW, CHEMSKETCH, ORIGIN.

Module IV

Scientific Technical Writings

How to present the data in the form of dissertation/thesis, Lab reports, Manuals, Review papers and Research Papers. The use of quotation, footnotes in tables and figures. Referencing, appendixes, editing and evaluating the final report.

Module V

Intellectual Property Rights (IPR)

General introduction to IPR. Approach to securing patent. Protection of IPR. Patent Acts and Treaties. World Trade Organization (WTO). Trade-Related Aspects of Intellectual Property Rights (TRIPS).

***In case of those M. Phil. Pass candidates who have passed M. Phill. Degree with minimum B^+ grade as regular student and have studied paper on Scientific Research Methodology are exempted from this paper.**

Reference Books

1. Thesis and Assignment Writing – J Anderson, B.H. Dursten and M. Poole, Wiley Eastern (1977).
2. Research Methodology (Second Revised Edition) – C.R.Kothari; New Age Publishers, 2004
3. Advanced Organic chemistry- Michael B. Smith and J.March
4. Patents Act.
5. Consumer Protection Act.
6. www.cas.org.
7. How to use chemical abstracts, current abstracts of chemistry and index chemicus- Brian Livesey; Medical information technology and training Ltd., Gover.

PAPER II: Research and Publication Ethics (2+0)

RPE-021

Course structure

- The course comprises of six modules listed in table below. Each module has 4-5 units.

Modules	Unit title	Teaching hours
Theory		
RPE 01	Philosophy and Ethics	4
RPE 02	Scientific Conduct	4
RPE 03	Publication Ethics	7
Practice		
RPE 04	Open Access Publishing	4
RPE 05	Publication Misconduct	4
RPE 06	Databases and Research Metrics	7
	Total	**30**

Syllabus in detail

THEORY

- **RPE 01: PHILOSOPHY AND ETHICS (3 hrs.)**

1. Introduction to philosophy: definition, nature and scope, concept, branches
2. Ethics: definition, moral philosophy, nature of moral judgements and reactions

- **RPE 02: SCIENTIFICCONDUCT (5hrs.)**

1. Ethics with respect to science and research
2. Intellectual honesty and research integrity
3. Scientific misconducts: Falsification, Fabrication, and Plagiarism (FFP)
4. Redundant publications: duplicate and overlapping publications, salami slicing
5. Selective reporting and misrepresentation of data

- **RPE 03: PUBLICATION ETHICS (7 hrs.)**

1. Publication ethics: definition, introduction and importance
2. Best practices / standards setting initiatives and guidelines: COPE, WAME, etc.
3. Conflicts of interest
4. Publication misconduct: definition, concept, problems that lead to unethical behavior and vice versa, types
5. Violation of publication ethics, authorship and contributorship
6. Identification of publication misconduct, complaints and appeals
7. Predatory publishers and journals

PRACTICE

- **RPE 04: OPEN ACCESS PUBLISHING(4 hrs.)**

1. Open access publications and initiatives
2. SHERPA/RoMEO online resource to check publisher copyright & self-archiving policies
3. Software tool to identify predatory publications developed by SPPU
4. Journal finder / journal suggestion tools viz. JANE, Elsevier Journal Finder, Springer Journal Suggester, etc.

- **RPE 05: PUBLICATION MISCONDUCT (4hrs.)**

A. Group Discussions (2 hrs.)

1. Subject specific ethical issues, FFP, authorship
2. Conflicts of interest
3. Complaints and appeals: examples and fraud from India and abroad

B. Software tools (2 hrs.)

Use of plagiarism software like Turnitin, Urkund and other open source software tools

- **RPE 06: DATABASES AND RESEARCH METRICS (7hrs.)**

A. Databases (4 hrs.)

1. Indexing databases
2. Citation databases: Web of Science, Scopus, etc.

B. Research Metrics (3 hrs.)

1. Impact Factor of journal as per Journal Citation Report, SNIP, SJR, IPP, Cite Score
2. Metrics: h-index, g index, i10 index, altmetrics

References

Bird, A. (2006). *Philosophy of Science*. Routledge.
MacIntyre, Alasdair (1967) *A Short History of Ethics*. London.
P. Chaddah, (2018) Ethics in Competitive Research: Do not get scooped; do not get plagiarized, ISBN:978-9387480865
National Academy of Sciences, National Academy of Engineering and Institute of Medicine. (2009). *On Being a Scientist: A Guide to Responsible Conduct in Research: Third Edition*. National Academies Press.
Resnik, D. B. (2011). What is ethics in research & why is it important. *National Institute of Environmental Health Sciences*, 1–10. Retrieved from https://www.niehs.nih.gov/research/resources/bioethics/whatis/index.cfm
Beall, J. (2012). Predatory publishers are corrupting open access. Nature, 489(7415), 179–179. https://doi.org/10.1038/489179a
Indian National Science Academy (INSA), Ethics in Science Education, Research and Governance(2019), ISBN:978-81-939482-1-7. http://www.insaindia.res.in/pdf/Ethics_Book.pdf

SEMESTER – I

MATH-EC- 611-I (MATHEMATICAL AND NUMERICAL METHODS)

L	T	P	Credit
4	0	0	4

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

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

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

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

Module I

Mathematical Methods

Solution of differential equations: Separation of variable, Perturbation method.

Module II

Laplace Transform Method

Laplace transform, Inverse Laplace transforms, Heaviside's step, Modulation theorem, Convolution theorem, Derivative theorems, Transform of generalized functions.

Module III

Fourier Transform Method

Fourier transform, Inverse Fourier transforms, Discrete Fourier transform, Fast Fourier transform (FFT), Applications of FFT to solve differential equations.

Module IV

Numerical Method- I

Numerical solution of differential equations: Rayleigh-Ritz method, Galerkian method, Weighted Least square method, Weighted Tau method.

Module V

Numerical Method-II

Numerical solution of differential equations: Finite Difference Method, Finite Element Method, Shooting method.

Reference Books:

1. Methods of Applied Mathematics, F.B. Hilderbrand, Prentic-Hall..
2. The Fourier Transform, N. Ronald, McGraw Hill.
3. Theory and Problems of Laplace Transforms, Murray R. Spiegel, Schaum's series.
4. Numerical Methods for Engineers and Scientists, J. N. Sharma, Naresh Publishing House.
5. Introductory Methods of Numerical Analysis, PHI.

SEMESTER – I

MATH-EC- 611-II (STABILITY THEORY-I)

L	T	P	Credit
4	0	0	4

Pre-requisite: Fluid Dynamic and Hydrodynamic**.**
Course Objectives: This course is intended to provide a treatment of advanced concept of stability and analysis in term of normal modes .Where the students will be able to find the exact solution when instability sets for to free boundaries problem. The objective is to provide the student with knowledge of variation principle for stationary convection and perturbation equations**.**
Course Outcomes: At the end of the course, the students will be able to

- Understand the concept of stability .
- Analyze advanced problems based on hydrodynamic equations.
- Understand the concept of exact solution for to free boundaries problems.
- Understand the concept of variational principle and solve perturbation equations.

Module I

Stability Theory
Introduction and basic concepts of stability theory, Analysis in terms of normal modes, Non-dimensional number, Benard's Problem.

Module II

Basic Hydrodynamic Equations
Basic hydrodynamic equations, Boussinesq approximation, Perturbation equations, Analysis into normal modes, Principle of exchange of stabilities, Equations governing the marginal state.

Module III

Exact Solution
Exact solution when instability sets in as stationary convection for two free boundaries, Thermal instability in rotating fluid, Perturbation equations, Analysis in terms of normal modes.

Module IV

Variational Principle
Variational Principle for stationary convection, Solutions when instability sets in as stationary convection for two free boundaries, On the onset of convection as overstability, The solution for the case of two free boundaries, Thermal instability in presence of magnetic field.

Module V

Perturbation Equations
The case when instability sets in as stationary convection, A Variational principle, Solutions for stationary convection and for overstability for the case of two free boundaries, Rayleigh-Taylor instability, Perturbation equations, Inviscid case, Effect of rotation, Effect of vertical magnetic field.

Reference Books:

1. Hydrodynamic and Hydromagnetic Stability, S. Chandrasekhar, Dover Publication.

SEMESTER – I

MATH-EC- 611-III (ADVANCED ALGEBRA)

L	T	P	Credit
4	0	0	4

Pre-requisite: Foundation course of Algebra.

Course Objectives: This Course helps the students to understand the advance concept of linear algebra. This course also help students a detail study of modules, submodule, direct sum and quotient module. Students will get deeper knowledge of Algebraic structures, Groups, Rings, Ideals, Fields, Homeomorphisms etc.

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

- Apply the knowledge of Algebra to attain a good logical reasoning and enables to build mathematical thinking and skill.
- Understand the concept of Jacobson Radical Artinian ring, Semisimple Artinian ring.
- Describe different type of ideal ,polynomial ring base , dimension of a vector space and their properties.
- Design analyze and implement the concept of orthogonality.

Module I

Groups

Characters of Finite Abelian Groups, Character Group, Orthogonality Relations for Characters

Module II

Ideal

Maximal Ideal, Generators, Basic Properties of Ideals, Algebra of Ideals.

Module III

Ring

Quotient rings, Ideal in Quotient Rings, Local Rings.

Module IV

The Jacobson Radical

Modules, Radical Ring, Artinian Ring, Semisimple Artinian Rings.

Module V

Semi simple Rings

The Density Theorem, Semi simple Rings, Applications of Wedderburn's Theorem.

Reference Books:

1. Non-Commutative Rings, I.N. Herstein, John Wiley and Sons.
2. Introduction to Rings and Modules, C. Musili, Narosa Publishing House.

SEMESTER – I

MATH-EC- 611-IV (ADVANCED NUMBER THEORY)

L	T	P	Credit
4	0	0	4

Pre-requisite: Elementary Number Theory

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

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

- Understand the different types of partitions, compositions and factorization in the ring of algebraic integers.
- Students will have a working knowledge of the various types of identities
- Work with congruence's, solve congruence equations and systems of equations with one and more variables.
- Be literate in the language and notation of number theory.
- Understand the concept of for n-colour partitions

Module I

Algebraic Numbers and Algebraic Integers

Countability of set of algebraic numbers, Liouville'stheorem and its generalization.

Module II

Transcendental Numbers

Thue theorem and Roth's theorem (statement only), Algebraic number field, Theorem of primitive elements, Ring of algebraic integers, Norm and trace of algebraic numbers.

Module III

Non Degeneracy of Bilinear Pairing

Existence of integral basis, Discriminant of an algebraic number field, Ideals in the ring of algebraic integers, Explicit construction of integral basis, Sign of discriminant, Cyclotomic fields,Calculation for quadratic and cubic cases.

Module IV

Integrally closure

Noetherian rings, Characterizing of Dedekind domains, Fractional ideals and unique factorization, G.C.D. and L.C.M. of ideal, Chinese remainder theorem.

Module V

Ramified and Unramified Extensions

Different form of an algebraic number field, Factorization in the ring of algebraic integers.

Reference Books:

1. Problems in Algebraic Number theory, Jody Exmonde and M Ram Murty.
2. Algebraic Numbers Algebraic, S. Lang, Springer.

SEMESTER – I

MATH-EC- 611-V (REGRESSION ANALYSIS)

L	T	P	Credit
4	0	0	4

Pre-requisite: Elementary Regression Analysis

Course Objectives: A conceptual and practical introduction to the basic concepts and techniques of regression analysis.

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

- Understand about how to apply linear regression models in practice: identify situation where linear regression is appropriate; build and fit linear regression models with software; interpret estimates and diagnostic statistics; produce exploratory graphs.
- Learn about the theory underlying point estimation, hypothesis and confidence intervals for linear regression models.
- Use SPSS to conduct analysis.

Module I

Regression

Simple and multiple linear regression: Least squares fit, Properties and examples, Polynomial regression, Use of orthogonal polynomials.

Module II

Transformations in Regression

Assumptions of regression; diagnostics and transformations; identification of influential observations, Lack of fit, Pure error, Testing homoscedasticity and normality of errors, Durbin-watson test, Use of R2 for examining goodness of fit.

Module III

Multiple Regression Models

Concepts of Least median of squares and its applications; Concept of multicollinearity, Analysis of multiple regression models, Estimations and testing of regression parameters, Sub- hypothesis testing, restricted estimation.

Module IV

Regression Methods and Dummy Variables

Weighted least square method: Properties and examples, Use of dummy variables.

Module V

Selection of variables in Regression

Forward selection, Backward elimination, Stepwise and Stage wise regressions.

Reference Books:

1. Outliers in Statistical Data, V. Barnettand T. Lewis.
2. Regression Diagnostics- Identifying Influential Data and Sources of Collinearity, D.A. Belsley, E. Kuth and R.E. Welsch.
3. Regression Analysis by Examples, S. Chatterjee, A. Hadi and B. Price.

SEMESTER – I

MATH-EC- 612-I (ADVANCED FLUID MECHANICS)

L	T	P	Credit
4	0	0	4

Pre-requisite: Fluid and Hydrodynamics.
Course Objectives: This Course helps the students to understand the concept of motion, heat conduction and mass diffusion. In this course we introduce the concepts of various Boundary layer Theory, Suction and injection at boundary and Cooling of the wall. Also advance knowledge of rotation , magnetic field. and various important theorems.
Course Outcomes: At the end of the course, the student will be able to

- Understand different types of fluid equations Cartesian, Spherical and Polar.
- Will have the working knowledge of rotation and magnetic field on fluid.
- Find the solution of problem based on magneto hydrodynamics.
- Solve the boundary value problems related to slip and no slip conditions/
- Understand the advance topic of Geophysical Fluid Dynamics.

Module I

Fluid Dynamic
Equation of continuity, Equations of motion, Equation of heat conduction, Equation of mass diffusion: Cartesian, spherical and polar coordinates.

Module II

MHD and Plasmas
Magnetohydrodynamics (MHD), Magnetic induction equation and Maxwell's equations, Basic equations of MHD.

Module III

Effect of Rotation and Magnetic Field
Effect of rotation on fluid in motion, Basic law of rotation, Basic equation governing the rotatory flow**,** Basic equations governing the magnetorotatry flow.

Module IV

Geophysical Fluid Dynamics
Definition of porous medium, Porosity, Methods for measurement of porosity, Flow of homogeneous fluids in porous media, Darcy's law, Generalized Darcy's law, Basic equations of flow through porous media.

Module V

Boundary Layer Theory
Boundary layer theory, Suction and injection at the boundary, Cooling of the wall, Basic equations with injection/suction at boundary, Boundary conditions: slip and no slip condition, temperature jump conditions.
Reference Books:

1. Hydrodynamics and Hydromagnetic Stability, S. Chandrasekhar, Dover Publications,
2. An Introduction to Magneto-Fluid Mechanics, V.C.A. Farraro and C. Plumpton, Oxford University Press.
3. The Physics of Flow Through Porous Media, A.E. Schidegger, University of Toronto.
4. Boundary Layer Theory, Hermann Schlichting, Mc Graw-Hill.

SEMESTER – I

MATH-EC- 612-II (STABILITY THEORY-II)

L	T	P	Credit
4	0	0	4

Pre-requisite: Solid Mechanics

Course Objectives: This course is intended to provide a treatment of advanced topics in Magneto hydrodynamic simple Bernard instability problem. The objective is to provide the student with knowledge of the Chandrasekhar Conjunction.

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

- Understand the concept of Magneto convection and Benard instability
- Analyze simple problems based on Chandrasekhar| first method
- Understand the phenomenon of extension of viscous
- Understand the concept of Thermohaline Instability Problem
- Learn about the advanced Eigen value problem.

Module I

Benard's Instability

Initiation of Magneto convection, Review of the simple Benard's instability problem, Magnetohydrodynamic simple Bénard instability problem, The governing equations and Thompson's condition for the exchange principle.

Module II

Chandrasekhar's Conjecture

Extension of viscous case and Chandrasekhar's first method, Chandrasekhar's second method and his conjecture, A Sufficient condition for the exchange principle, Resolutions of Chandrasekhar's conjecture concerning the two energies.

Module III

Thermohaline Instability Problem

Solutions for the case when exchange principle is valid, Solutions for the case when over stability is valid, settlement of the recent controversy, Some illustrative examples, Reformulation of the Simple Benard and thermohaline instability problem.

Module IV

The Eigenvalue Problem

Basis of the modified theory, Inadequacy of the classical theory, Construction of the modified, Simplified governing equations, Modified equations for thermohaline instability problem, Modified Analysis of Simple Bernard instability problem and thermohaline instability problem, The eigenvalue problem, Characterization of the marginal state and the marginal state solution, Some illustrative examples, Limitations of the Complex Wave Velocity in the Instability Problem of Heterogeneous Shear.

Module V

Work of Scientists

The problem of simultaneous reduction and unification, The work of Banerjee and Jain, A reduction theorem, The work of Kochar and Jain, An illustrative example.

Reference Books:

Hydrodynamic and Hydromagnetic Stability, Mihir B. Banerjee and Jagdish, R. Gupta, Silver Line Publishers.

SEMESTER – I

MATH-EC-612-III (MATRIX ANALYSIS)

L	T	P	Credit
4	0	0	4

Pre-requisite: Basic knowledge of matrix.

Course Objectives: This Course helps the students to understand the concept of Gersgorin discs, Diagonally dominant matrices, In this course we introduce the concepts of various Properties and characterizations of Hermitian matrices. Also, the weak and strong versions of various important theorems are discussed.

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

- Describe definitions, properties, characterization of positive definite matrix.
- Understand the different types of Matrix.
- Have a working knowledge of the various types of identities used in Matrix.
- Work with the Location and Perturbation of Eigen Value in field of Gersgorin discs.
- Be literate in the language and notation of Matrix analysis.

Module I

Unitary Equivalence

Schur's unitary triangularization theorem and its real version, Some implication of Schur's theorem, Eigen values of sum and product of commuting matrices, Normal matrices, Spectral theorem for matrices, Simultaneously unitarily diagonalizable commuting normal matrices.

Module II

Hermitian Matrices

Properties and characterizations of Hermitian matrices, Variational characterization of Eigen values of Hermitian matrices, Rayleigh-Ritz theorem, Courant-Fischer theorem (Min-Max Principle), Some applications of the variational characterization, Weyl theorem, Schur mazorization theorem, Interlacing theorem, Inclusion principle.

Module III

Norms

Matrix norms, Examples, Operator norms, Matrix norms induced by vector norms, The spectral norm, Frobenius norm, Unitary invariant norm, The maximum column sum matrix norms, The maximum row sum matrix norm.

Module IV

Location and Perturbation of Eigen Value

Gersgorin discs, Diagonally dominant matrices, The Levy-Desplanques theorem.

Module V

Positive Definite Matrices

Definitions and properties, Characterizations, The positive semi-definite ordering, Inequalities for the positive definite matrices, Hadamard's inequality, Fischer's inequality, Minkowski's inequality.

Reference Books:

1. Matrix Analysis, Rajendra Bhatia, Springer-Verlag.
2. Positive Definite Matrix, Rajendra Bhatia. Hindustan Book Agency.

SEMESTER – I

MATH-EC- 612-IV (CRYPTOGRAPHY)

L	T	P	Credit
4	0	0	4

Pre-requisite: Linear Algebra, Probability Theory .
Course Objectives: Coding Theory helps to detects errors in Transmission of messages. In this course we introduce the basic concepts of Coding Theory such as, Double Error-Correcting B.C.H. code, Cyclic codes, The Group of a code, Quadratic residue codes and Bose-Chaudhuri-Hocquenghem codes.
Course Outcomes: At the end of the course, the student will be able to

- Understand the concept of Maximum-Likelihood Decoding and Syndrome Decoding.
- Analyze Double Error-Correcting B.C.H. code and Finite Fields Polynomials.
- Understand Cyclic Codes.
- Study the concept of Bose-Chaudhuri-Hocquenghem (*B.C.H.*) Codes and Weight Distributions
- Learn about basic techniques of algebraic coding theory like matrix encoding, polynomial encoding, and decoding by coset leaders etc.
- Learn how algebraic coding theory is applicable in real world problems.

Module I

Mathematics of Cryptography
Integer arithmetic, Modular arithmetic, Matrices, Linear congruence.

Module II

Traditional Symmetric-Key Ciphers
Substitution ciphers, Transposition ciphers, Stream and block ciphers, Algebraic structures, GF (2^n) fields.

Module III

Introduction to Modern Symmetric-Key Ciphers
Modem block ciphers, Modem stream ciphers, Data Encryption Standard (DES): DOS structure, DES analysis, Security of DES, Multiple DES-conventional encryption algorithm.

Module IV

Advanced Encryption Standard(AES)
Transformations, Key expansion, The AES ciphers, Analysis of AES, Encipherment using modern symmetric key ciphers, Use of modern Block ciphers, Use of stream ciphers.

Module V

Mathematics of Asymmetric
Key Cryptography: Primes. Primal its testing, Factorization, Chinese remainder theorem, Quadratic congruence, Exponentiation and logarithm congruence, RSA cryptosystem, Rabin cryptosystem. EIGamal cryptosystem, Elliptic curve cryptosystem.

Reference Books:
Cryptography and Network Security, B.A. Forouzan and D. Mukhopadhyav,McGraw Hill Publication.

SEMESTER – I

MATH-EC- 612-V (ADVANCED TIME SERIES ANALYSIS)

L	T	P	Credit
4	0	0	4

Pre-requisite: Elementary Time Series.

Course Objectives: Time Series helps to describe and verify mathematical considerations for analyzing time series, including concepts of white noise, stationarity, auto covariance, autocorrelation

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

- Apply various techniques of time series models, including the seasonal autoregressive moving average (SARIMA) models, regression with ARMA models
- Apply various techniques for the modeling: including parameter estimation, assumption verification, and residual sequence diagnosis
- Verify the properties of linear predictor operator, and apply various linear forecasting techniques
- Describe and apply techniques of selected additional topics, such as spectral analysis, state space models, ARCH and GARCH, multivariate time series, principle component analysis, process control, and other topics.
- Use R or SAS to construct time series models and conduct analysis

Module I

Multivariate Time Series

Modeling the mean, stationary VAR models; properties, estimation, analysis and forecasting, VAR models with elements of nonlinearity, Non-stationary multivariate time series: spurious regression, co-integration, common trends.

Module II

Volatility

Modelling the variance, the class of ARCH models: properties, estimation, analysis and forecasting, stochastic, volatility, realized volatility, Extensions: IGARCH, ARCH-t, ARCD, Multivariate GARCH, Time varying risk and ARCH-in-mean.

Module III

Structural time- series modeling

State space models, Kalman filter. Local level model, Local linear trend model.

Module IV

Time- series Models

Seasonal models, cyclical models. Nonlinear time-series models: Parametric and nonparametric approaches.

Module V

Time- series Approaches

Autoregressive conditional heteroscedastic model and its extension.

Reference Books:

1. Time Series Analysis: Forecasting and Control, G.E.P. Box, G.M. Jenkins and G.C. Reisel.
2. Time Series: Theory and Methods, P.J. Brockwell and R.A.Davis.
3. The Analysis of Time Series: An Introduction, C. Chatfried C. 2004.

SEMESTER – I

MATH-EC- 612-VI (FRACTIONAL CALCACULUS AND FRACTIONAL DIFFERENTIALEQUATIONS)

L	T	P	Credit
4	0	0	4

Pre-requisite: Fractional calculus and its application.

Course Objectives: Fractional calculus helps to understand about the fractional derivative/integral which is used to solve the fractional differential equations.

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

- Apply fractional derivative and fractional integral to solve the fractional differential equations.
- Understand about the special functions and their applications. Because these functions are play a key role in fractional calculus
- Understand the applications of fractional calculus and fractional differential equations.

Module I

History of fractional calculus

Introduction of fractional calculus, Contributions of L' Hospital, Letnikov, Abel, Fourier, Riemann, Liouville, Miller etc. in fractional calculus. Gamma function and its properties, Beta function, Mittag-Leffer function.

Module II

Fractional derivative and fractional integrals

Riemann-Liouville fractional derivative/integral and Caputo's fractional derivative, Conformal fractional derivative, Grunwald-Letnikov fractional derivative, Leibniz rule for fractional derivatives, Geometric and physical interpretation of fractional integration and fractional differentiation.

Module III

Properties of fractional derivative and transformations

Sequential fractional derivatives. Left and right fractional derivatives. Properties of fractional derivatives. Laplace transforms of fractional derivatives. Fourier transforms and Mellin transforms of fractional derivatives.

Module IV

Linear fractional differential equations

Fractional differential equation of a general form. Existence and uniqueness theorem as a method of solution. Dependence of a solution on initial conditions. The Laplace transform method. Sequential fractional differential equations.

Module V

Fractional differential equations

Fractional Differential Equations: Introduction, Linearly independent solutions, Solutions of the homogeneous and non-homogeneous fractional differential equations.

Reference Books:

1. Oldham K. B. & Spanier J., The Fractional Calculus: Theory and Applications of Differentiation and Integration to Arbitrary Order, Dover Publications Inc, 2006.
2. Miller K. S. & Ross. B., An Introduction to the Fractional Calculus and Fractional Differential Equations Hardcover, Wiley Blackwell, 1993.
3. Podlubny I., Fractional Differential Equations, Academic Press, 1998.