# Himachal Pradesh University, Shimla
**(‘A’ Grade, NAAC Accredited)**

Syllabus and Scheme of Examination

of

Ph.D. Course Work (Mathematics)

**DEPARTMENT OF MATHEMATICS & STATISTICS**

Ph.D. Course Work (2024-25)

For Batches Admitted in November-December 2024 Onwards

# Ph.D. Course Work (2024-2025) (Mathematics)
## (For Batches Admitted in November -December 2024 Onwards)

The Ph.D. Course work will consist of **three courses** (12 credits):

**I. Course- 1:** Research and Publication Ethics, RPE (common for all HPU's Ph.D. programs) with the credit weightage of 2*.

**II. Course- 2:** Research Methodology (Discipline-wise) with a credit weightage of 5. The course will consist of 5 modules/units

**III. Course-3:** Discipline-specific research oriented Elective course with a credit of 5. The course will consist of 5 modules/units.

***The course & scheme for Course-1: Research and Publication Ethics, (common for all HPU's Ph.D. programs) has been notified vide Notification No. 7-1/2024-HPU (Acad.) dated 3rd February, 2025. (Appended as annexure- B)**

| Paper Code | Paper Title | Credits | Workload per Week | Exam Time (Hrs.) | External Marks | Max. Marks |
|---|---|---|---|---|---|---|
| ***Course 2: Research Methodology(Discipline-wise)*** | | | | | | |
| | Research Methodology in Mathematics | 5 | 5 | 3 | 100 | 100 |
| ***Course 3: Discipline- specific Elective Subjects*** | | | | | | |
| E01 | Hydrodynamic and Hydromagnetic Stability-I | 5 | 5 | 3 | 100 | 100 |
| E02 | Hydrodynamic and Hydromagnetic Stability-II | 5 | 5 | 3 | 100 | 100 |
| E03 | Fluid Instabilities, MHD and Plasma Dynamics | 5 | 5 | 3 | 100 | 100 |
| E04 | Groups, Rings and Modules | 5 | 5 | 3 | 100 | 100 |
| E05 | Advanced Matrix Analysis | 5 | 5 | 3 | 100 | 100 |
| E06 | Boundary Layer Theory | 5 | 5 | 3 | 100 | 100 |
| E07 | Cryptography | 5 | 5 | 3 | 100 | 100 |
| E08 | Advanced Mechanics of Solids | 5 | 5 | 3 | 100 | 100 |

**The students can opt for (all three courses) MOOCS/SWAYAM and other accredited online platforms courses, with prior approval of relevant bodies**

**Evaluation scheme:** At the end of the course, a final written examination of 100 marks will be conducted.

a) Students with at least 75% attendance will be eligible for the final written examination.
b) The exam will be conducted for a three-hour duration.

**Note for paper setting:** There will be 11 questions covering all units. The first 10 questions of explanatory answers of 12 marks each will consist of one question from each unit with internal choice provided, meaning there will be two questions from each unit *(*5x2*=10)*. The students will be required to attempt one question from each unit. The $11^{th}$ question will consist of 10 short answer type questions using Roman numerals (i, ii,iii…..x) each with 5 marks covering with all the units. The students will be required to attempt any 8 questions out of 10.

# Research Methodology in Mathematics L:5 T:0 P:0

***Course Objectives:***

This course aims to provide students with a comprehensive understanding of research methodologies, including basic, applied, interdisciplinary, and multidisciplinary approaches. It highlights the significance of literature review and introduces students to key research databases like MathSciNet, Scopus, and Web of Science. The course enhances scientific writing skills, covering research paper and thesis preparation while also addressing effective communication of research findings. Students will gain practical knowledge of LaTeX and Scientific WorkPlace for professional documentation. Additionally, the course develops proficiency in MATLAB for mathematical modeling, numerical analysis, and data visualization, fostering computational research skills.methodologies, techniques, and ethical considerations relevant to the field.

***Course Outcomes****:* By the end of this course, the student will be able to:

**CO1**. Demonstrate a clear understanding of various research methodologies, including basic, applied, interdisciplinary, and multidisciplinary approaches in mathematical sciences.

**CO2**. Effectively conduct a literature review using key research databases such as MathSciNet, Scopus, Web of Science, and Google Scholar to support their research.

**CO3**. Develop scientific writing skills for preparing research papers, dissertations, and theses, along with effective communication of research findings in academic and professional settings.

**CO4.** Utilize LaTeX and Scientific WorkPlace for structured and professional research documentation, including mathematical notation, formatting, referencing, and bibliography management.

**CO5.** Apply MATLAB for mathematical modeling, numerical analysis, and data visualization, enhancing their ability to conduct computational research in applied mathematics.

**Unit I**

**Fundamentals of Research Methodology:** Concepts and General introduction, Different approaches to research, Basic, Applied, Interdisciplinary, Multidisciplinary research. Hypothesis, Theories, Laws, Mathematics & Science.

**Unit II**

**Review of Literature:** Importance of Literature Review in Research, Sources of Literature: Journals, Books, Conference Proceedings, Online Databases, Digital Libraries: MathSciNet, Scopus, Web of Science and Google Scholar.

**Unit III**

**Scientific Methods and Writing:** Examples of the scientific methods, The role of computers in scientific process, and use of computers in obtaining proofs of mathematical results, Writing a paper for conference and journals. Communicating research, Obtaining offprints of papers, Preparing Ph.D Thesis.

## Unit IV

**Introduction to LaTeX and Scientific WorkPlace:** Basics of LaTeX: Installation an Overview, Document Structure in LaTeX: Sections, Subsections, and Formatting, Mathematical Symbols, Equations, and Theorems in LaTeX, Table of Contents, Figures, and Tables in LaTeX, Referencing and Bibliography Management in LaTeX, Overview of Scientific WorkPlace: Features and Comparison with LaTeX, Writing Research Papers and Theses using LaTeX and Scientific WorkPlace.

## Unit V

**MATLAB for Mathematical Research:** Introduction to MATLAB: Basics and Environment, MATLAB Programming: Variables, Operators, Loops, and Functions, Matrix Operations, Symbolic Computation, and Numerical Methods, Solving Ordinary and Partial Differential Equations using MATLAB, Graphical Representations and Data Visualization in MATLAB, MATLAB Applications in Applied Mathematics and Computational Research.

**Recommended Books:**


1. Research Methodology for scientist and Engineers, J. N. Kapur, Mathematical Science Trust Society, (1997).
2. How to write and publish a scientific paper, Robert A. Day, Cambridge University Press Fourth Edition (1996).
3. MATLAB: A Practical Introduction to Programming and Problem Solving- Stormy Attaway, Butterworth-Heinemann is an imprint of Elsevier (Boston), Fourth Edition (2017).
4. LaTeX Beginner's guide, S. Kottwitz, Packt Publishing Ltd.(2011).
5. A Gallery of Document Shells for Scientific WorkPlace and Scientific Word Version 5, Susan Bagby and George Pearson MacKichan Software, Inc.,(2003)

## E01: Hydrodynamic and Hydromagnetic Stability-I L:5 T:0 P:0

***Course Objectives:*** This course aims to provide a comprehensive understanding of thermal instability in fluid layers, focusing on the fundamental concepts and mathematical formulations involved. It introduces students to the analysis of normal modes, non-dimensional parameters, and stability principles governing fluid motion. The course covers the classical Bénard problem, exploring the effects of rotation and magnetic fields on thermal convection using perturbation techniques and variational principles. Students will gain insight into stationary convection and overstability under various physical conditions, including free boundary cases. Additionally, the course delves into the Rayleigh-Taylor instability, examining the stability of superposed fluids under the influence of viscosity, rotation, and magnetic fields, thereby equipping students with analytical tools essential for advanced research in fluid dynamics.

***Course Outcomes****:* By the end of this course, the student will be able to:

**CO1.** Demonstrate a clear understanding of normal mode analysis, non-dimensional parameters, and stability principles in fluid dynamics.

**CO2.** Apply mathematical techniques to study the Bénard problem and evaluate the effects of rotation and magnetic fields on thermal convection.

**CO3.** Formulate and solve characteristic value problems governing marginal stability, including exact and variational solutions for different boundary conditions.

**CO4.** Analyze the onset of convection under stationary and overstable conditions, incorporating the effects of physical forces such as viscosity, rotation, and magnetic fields.

**CO5.** Assess the stability of superposed fluid layers, understanding the influence of viscosity, rotation, and vertical magnetic fields on fluid stratification

### Unit-I (Two Questions)

**Basic Concepts**: Introduction, Basic concepts, Analysis in terms of normal modes, Non- dimensional numbers.

**Thermal Instability of a Layer of Fluid Heated From Below; *Bénard Problem*:** Basic hydrodynamic equations, Boussinesq approximation, Perturbation equations, Derivation of different boundary conditions, Analysis into normal modes, Principle of Exchange of Stabilities, Equations governing the marginal state and reduction to a characteristic value problem, Exact solution of the characteristic value problem (when instability sets in as stationary convection): the case of two free boundaries.

### Unit –II (Two Questions)

**Thermal Instability of a Layer of Fluid Heated From Below; *The Effect of Rotation*:** Problem of thermal instability in a rotating fluid, Perturbation equations, Analysis into normal modes. The case when instability sets in as stationary convection, A Variational Principle, Solutions for the case when instability sets in as stationary convection, Case of two free boundaries, On the onset of convection as overstability, the case of two free boundaries.

**Unit -III (Two Questions)**

**Thermal Instability of a Layer of Fluid Heated From Below;** ***Effect of a Magnetic Field:*** *P*roblem of thermal instability in the presence of magnetic field, Perturbation equations, Case when instability sets in as stationary convection, A variational principle, Solutions for when instability sets in as stationary convection, Case of two free boundaries, On the onset of Convection as overstability.

**Unit -IV (Two Questions)**

**The Thermal Instability of a Layer of Fluid Heated From Below;** ***Effect of Rotation and Magnetic Field:*** Problem of thermal instability in the presence of rotation and magnetic field, Perturbation equations, Case when instability sets in as stationary convection, Case of two free boundaries, Case when instability sets in as overstability, Case of two free boundaries.

**Unit -V (Two Questions)**

**Stability of Superposed Fluids;** ***Rayleigh-Taylor instability***: Introduction, Character of the equilibrium of a stratified heterogeneous fluid, Perturbation equations, Inviscid case, the case of two uniform viscous fluids separated by a horizontal boundary, the effect of rotation, the effect of vertical magnetic field.

<u>**Recommended Text Book:**</u>

S. Chandrasekhar: Hydrodynamic and Hydromagnetic Stability, Dover Publication, New York, 1981.

Chapter 1: § 1to 4.

Chapter II: § 5 to 12 & §15(a).

Chapter III: § 24, 25, 26, 27(a), and § 29.

Chapter IV: § 41, 42, 43(a), § 44(a) and § 46.

Chapter V: § 41, 42, 43(a), § 44(a) and § 46.

Chapter X: § 90, 91, 92, 94, 95 and § 96.

## E02: Hydrodynamic and Hydromagnetic Stability-II L:5 T:0 P:0

***Course Objectives:*** This course aims to equip students with a thorough understanding of fluid dynamics, focusing on thermal and magnetically driven convection instabilities. Key concepts such as normal mode analysis, perturbation equations, and non-dimensional numbers will be explored, with an emphasis on the thermal instability in a fluid layer heated from below (Bénard problem). Students will also study magnetoconvection, including Chandrasekhar's methods and the exchange principle. The course will further cover double-diffusive convection, instability mechanisms, and the reformulation of classical instability theories, including thermohaline instabilities. By the end, students will be proficient in applying these theories to analyze and solve complex convection problems.

***Course Outcomes:*** By the end of this course, the student will be able to:

**CO 1.** Analyze fluid instabilities using normal mode and perturbation methods.

**CO 2.** Solve thermal and magnetoconvection problems, including Bénard and magnetohydrodynamic instabilities.

**CO 3.** Apply the exchange principle and Chandrasekhar's methods to complex fluid systems.

**CO 4.** Perform stability analysis on double-diffusive and thermohaline convection.

**CO 5.** Apply modified approaches to real-world problems.

### Unit-I

**Basic Concepts**: Introduction. Basic Concepts. Analysis in terms of normal modes. Non-dimensional numbers.

**The Thermal Instability of a Layer of Fluid Heated from Below:** Bénard Problem. Basic hydrodynamic equations. Boussinesq approximation. Perturbation equations. Analysis into normal modes. Principle of exchange of stabilities. Equations governing the marginal state. Exact solution when instability sets in as stationary convection for two free boundaries.

### Unit-II

**Initiation of Magnetoconvection-I:** Review of the simple Bénard instability problem. Magnetohydrodynamic simple Bénard instability problem. The governing equations and Thompson's condition for the Exchange Principle. Extension of viscous case and Chandrasekhar's first method. Chandrasekhar's second method and his conjecture. A Sufficient condition for the exchange principle. Some illustrative examples.

### Unit-III

**Initiation of Magnetoconvection-II:** Resolutions of Chandrasekhar's conjecture concerning the two energies. Solutions for the case when exchange principle is valid. Solutions for the case when overstability is valid. Some illustrative examples.

**Double-Diffusive Convection:** The stability problem. The mechanism of instability. Linear stability analysis. The form of the convection cells.

### Unit-IV

**Reformulation of the Simple Bénard and Thermohaline Instability Problems -I:** 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 Bénard instability problem and thermohaline instability problem. The eigenvalue problem. Some illustrative examples.

## Unit-V

**Reformulation of the Simple Bénard and Thermohaline Instability Problems -II:** Characterization of the marginal state and the marginal state solution. Some illustrative examples.

**Text Books :**

**1**. Hydrodynamic and Hydromagnetic Stability, S. Chandrasekhar, Dover Publication, INC. New York, 1981, Chapter-1: § 1 to 4. Chapter-II: § 5 to 12 & 15(a)
2. Buoyancy Effects in Fluids, J.S. Turner, Cambridge University Press, Cambridge, 1973, Chapter-8: §8.1.1 to 8.1.3
3. Studies in Hydrodynamic and Hydromagnetic Stability, M. B. Banerjee and J.R. Gupta, Silver Line Publication, Shimla, 1999 Chapter-I: § 1.1 to 1.8. Chapter-II: §:2.1 to 2.8. Chapter-III § 3.1 to 3.10

## E03: Fluid Instabilities, MHD and Plasma Dynamics L:5 T:0 P:0

***Course Objectives:*** This course provides a comprehensive understanding of fundamentals of MHD and plasma dynamics. The course will help students to understand the different types of fluid dynamical instabilities. The topics included in the course structure are necessary to understand the structure formations at large scale in astrophysical systems.

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

- **CO1.** Comprehend the fundamental equations governing Magneto hydrodynamics (MHD).
- **CO2**. Analyze the thermal instability of a fluid layer heated from below and its implications.
- **CO3**. Derive and interpret the conditions for gravitational collapse in the interstellar medium (ISM) and its role in star formation.
- **CO4**. Evaluate the stability of superposed fluid layers and the underlying physical mechanisms.
- **CO5**. Understand key plasma processes in astrophysical environments, including their fundamental principles and applications.

### Unit-I (Two Questions)

**MHD and Plasmas:** Magnetohydrodynamics (MHD), Introduction, Maxwell's equations for moving media, Magnetic induction equation and Maxwell's equations, Basic equations of MHD, Concept of ideal and non-ideal effects in MHD and its astrophysical relevance, Concept of Alfven waves, Fast and Slow magneto-sonic waves, Plasma as fourth state of matter, General characteristics of motion of a charged particle, The motion of a charged particle in a uniform magnetic field, The equations of motion of a charged particle in crossed electric and magnetic fields.

### Unit-II (Two Questions)

**Stability Analysis of a Layer of Fluid Heated From Below: Thermal Instability:** Introduction of stability and instability, the analysis in terms of normal modes, Non-dimensional number, The Boussinesq approximation, The perturbation equations, normal modes analysis, The principle of exchange of stabilities, The equations governing the marginal state and reduction to a characteristic value problem, Exact solution of the characteristic value problem (when instability sets in as stationary convection), the case of two free boundaries.

### Unit-III (Two Questions)

**Structure formations in Interstellar Medium (ISM): Gravitational instability:** ISM, Molecular clouds, nebulae, star formation, gravitation collapse, Jeans instability, Jeans mass, Jeans length, The perturbation equations; The effect of rotation; The effect of uniform magnetic field, Simultaneous effect of rotation and magnetic field.

**Unit-IV (Two Questions)**

**Stability of Superposed Fluids: Rayleigh-Taylor instability:** Introduction, The character of the equilibrium of a stratified heterogeneous fluid, The perturbation equations, The inviscid case, The effect of rotation, The effect of a horizontal magnetic field.

**Unit-V (Two Questions)**

**Stability of Superposed Fluids: Kelvin-Helmholtz Instability:** Introduction, The Perturbation equations and boundary conditions, The case of two uniform fluids in relative horizontal motion separated by a horizontal boundary, Discussions in the absence and presence of surface tension, The effect of rotation, The effect of a horizontal magnetic field.

**Recommended Text Books:**


1. Hydrodynamics and Hydromagnetic Stability, S. Chandrasekhar, Dover Publications, NewYork (1981), Chapter I, Chapter II: §§5, 6, 7, 8, 9, 10, 11, 12, 15(a), Chapter X: §§90,91,92,95, 97, Chapter XI: §§100,101,105,106, Chapter XIII: §§119,120(a)-(c).
2. An Introduction to Magneto-Fluid Mechanics, V.C.A. Farraro and C.Plumpton, Oxford University Press (1966).
3. Fundamentals of Plasma Physics, J. A. Bittencourt, Third Edition, Springer, (2010).

The Physics of Fluids and Plasmas, A. R. Choudhari, Cambridge University Press, (2012), Chapter 7.

## E04: Groups, Rings and Modules L: 5 T: 0 P: 0

***Course Objectives*****:** The goal of this course is to discuss some advanced topics of groups, rings and modules. In particular, the advanced study of some important topics like, ideals characters of finite groups, local rings, radicals and semi simplicity, which play central role in research and advancement of various topics in Mathematics.

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

**CO1.** Have knowledge about characters of finite abelian groups, quotient rings, their ideals and localization of rings.

**CO2.** Understand the radical theory and its benefits.

**CO3**. Acquire knowledge regarding semi simplicity of rings and applications of the Wedderburn's theorem.

**Unit-1 (Two Questions)**

Finitely generated modules over a PID: Decomposition theorem and its uniqueness, Applications to finitely generated abelian groups, Rational canonical form and generalized Jordan form over any field.

**Unit -II (Two Questions)**

Maximal Ideal, Generators, Basic Properties of Ideals, Algebra of Ideals, Quotient Rings, Ideal in Quotient Rings, Local Rings.

**Unit-III (Two Questions)**

Modules; The radical of a ring, Jacobson Radical, Artinian rings.

**Unit-IV (Two Questions)**

Semi simple Artinian rings, The density theorem.

**Unit -V (Two Questions)**

Semi simple rings, Applications of The Wedderburn's theorem.

**Recommended Text Books:**


1. Non-Commutative Rings, I.N. Herstein, John Wiley and Sons, Inc., Chapters: I&II, pages 1 to 68.
2. Introduction to Rings and Modules 2nd Edition, C. Musili, Narosa Publishing House, New Delhi; Chapter-II: Pages 33 to 65.
3. Basic Abstract Algebra, P. B. Bhattacharya, S.K. Jain S.R. Nagpaul ,Cambridge University Press, IInd edition: chapter 21: pages 402-426.
4. Introduction to Analytic Number Theory, Tom M. Apostol., Narosa Publishing House, New Delhi, Chapter-VI: Pages 129 to 136.

## E05: Advanced Matrix Analysis L:5 T:0 P:0

***Course Objective:*** This course aims to provide a comprehensive understanding of advanced matrix theory, focusing on eigenvalue characterizations, spectral properties, tensor and Hadamard products, positive and nonnegative matrices, and positive linear maps. The course emphasizes fundamental theorems, inequalities, and their applications in linear algebra and operator theory.

***Course Outcomes:*** Upon completing the course, students will be able to:

**CO1.** Analyze the properties and characterizations of Hermitian matrices and apply key theorems like Rayleigh-Ritz, Courant-Fisher, and Weyl's theorem.
**CO2**. Understand the field of values of a matrix, its fundamental properties, and apply the Toeplitz-Hausdorff theorem.
**CO3.** Compute and interpret the tensor and Hadamard products of matrices, along with their spectral properties.
**CO4.** Apply Perron's theorem and spectral radius bounds to study positive and nonnegative matrices.
**CO5.** Understand and work with positive linear maps, including Choi's theorem and completely positive linear maps.

### Unit-I (Two Questions)

Properties and characterizations of Hermitian matrices, Variational characterization of eigenvalues of Hermitian matrices, Rayleigh-Ritz theorem, Courant-Fisher theorem (Min-Max Principal), Some applications of the variational characterization, Weyl theorem, Schur majorization theorem, Interlacing theorem, Inclusion principle.

### Unit-II (Two Questions)

The field of values, basic properties of the field of values, compactness, convexity, translation, projection, spectral containment and unitary similarity invariance and isometric properties, The field of values of normal matrices, Toeplitz-Hausdorff theorem.

### Unit-III (Two Questions)

The Tensor Product of matrices, Definition and basic properties, Eigenvalues of the Tensor product of two square matrices.

The Hadamard product of matrices, Some basic observations, The Schur product theorem.

### Unit-IV (Two Questions)

Positive and nonnegative matrices, Inequalities and generalities, Bounds for the spectral radius of a nonnegative matrix, Perron's theorem for positive matrices, Perron root of a nonnegative matrix. Operator Monotone and Operator Convex Functions.

### Unit-V (Two Questions)

Positive linear maps, Examples and properties of positive maps, Kadison's inequality, Choi's theorem, Choi's inequality, Inequality complementary to Choi's inequality, Definition and examples of completely positive linear maps.

**Recommended Text Book:**

**1. Matrix Analysis:** Roger A. Horn and Charles R. Johnson. Second Edition (2013), Cambridge University Press. **Chapter 4, 4.1:** Definitions 4.1.1, 4.1.9, 4.1.11, 4.1.12. Theorem 4.1.2-4.1.10.

Proposition 4.1.13., **4.2:** Theorem 4.2.2, 4.2.6, 4.2.10. Lemma 4.2.3, 4.2.4 Observation 4.2.5 Corollary

4.2.12.,**4.3:** Theorem 4.3.1, 4.3.17, 4.3.28, 4.3.45. Corollary 4.3.3, 4.3.5, 4.3.7, 4.3.12, 4.3.15, 4.3.34.

Definition 4.3.41, 4.3.43. **Chapter 8:** 8.1, 8.2, 8.3.

**2.** Topics in Matrix Analysis: Roger A. Horn and Charles R. Johnson, (1991), Cambridge Univ. Press.
Chapter 1, 1.0, 1.0.1, 1.0.2, 1.0.2.1, 1.0.3, 1.0.3.1, 1.1, 1.1.1-1.1.4, 1.2, 1.2.1-1.2.12, 1.3, 1.3.3, 1.3.4, 1.3.5

Chapter 4, 4.2, 4.2.1-4.2.13, Chapter 5, 5.0 (5.0.1, 5.0.2, 5.0.3a, 5.0.5), 5.1 & 5.2.

**3.** Matrix Analysis: Rajendra Bhatia, (1997), Springer, Chapter V, V.I.
**4.** Positive Definite Matrices: Rajendra Bhatia, (2007), Hindustan Book Agency. Chapter 2, 2.2, 2.3 (2.3.1-2.3.6) & 2.7 (2.7.6-2.7.9

## E06: Boundary Layer Theory L:5 T:0 P:0

***Course Objective:*** This course aims to develop a strong foundation in the Navier-Stokes equations and their applications in fluid dynamics. It covers exact solutions, boundary layer theory, control techniques, and perturbation methods to analyze and solve complex flow problems.

***Course Outcomes:*** By the end of this course, students will be able to:

**CO1.** Understand the fundamental properties and interpretations of the Navier-Stokes equations.

**CO2**. Derive and analyze exact solutions for specific flow problems like Couette and Hagen-Poiseuille flow.

**CO3**. Apply boundary layer theory to describe and predict laminar flow behavior.

**CO4.** Implement boundary-layer control techniques for improved aerodynamic performance.

**CO5.** Use perturbation methods to solve complex fluid dynamics problems.

### Unit-I

**General properties of the Navier-Stokes equations**

Derivation of Reynolds principle of similarity from Navier-Stokes equations, Frictionless flow as the solution of the Navier Stokes equations, The Navier Stokes Equation interpreted as vorticity transport equations, the limiting case of large viscosity, the limiting case of very small viscous force.

### Unit-II

**Exact solution of the Naiver-Stokes equation**

Parallel flow through straight channel and Couette flow, Hagen Poiseuille theory of flow through pipe, The flow between two concentric rotating cylinders, Flow formation in Couette motion

### Unit-III

**Laminar boundary layers**

Boundary layer equation for two-dimensional flow, derivation of boundary layer on a flat plate, separation of boundary layer, skin friction , boundary layer along a plate, dependence of boundary layer on the Reynolds number, similar solution of boundary layer, *Boundary-Layer formation after impulsive start of motion, Boundary-Layer formation in accelerated motion.*

### Unit-IV

**Boundary-layer control in laminar flow**

1. Motion of the solid wall. 2. Acceleration of the boundary layer (blowing). 3. Suction
4. Injection of a different gas. 5. Prevention of transition by the provision of suitable shapes\ Laminar aerofoils 6. Cooling of the wall, 7 Boundary-Layer suction.

### Unit-V

**Perturbation methods**

Parameter perturbation, co-ordinate perturbation, order symbols and Gauge functions, asymptotic expansions and sequences. Convergent versus Asymptotic series, Non Uniform expansions. The Method of successive approximations, C.C.Lin's method for periodic external flows, C.C. Lin's theory of harmonic oscillations

**Recommended Books:**

1. Boundary-Layer Theory, Dr. Hermann Schlichting, Mc GRAW-HILL Book Company, New York.
2. Perturbation Methods, A.N. Nayfeh, A Willey-Inter Science Publication.

## E07: Cryptography L:5 T:0 P:0

***Course Objective*****:** The objective of this course is to provide a comprehensive understanding of both symmetric and asymmetric cryptographic techniques. The course introduces fundamental security goals, cryptographic attacks, and mathematical foundations necessary for cryptographic operations. It covers traditional and modern encryption techniques, including block and stream ciphers, DES, AES, and various asymmetric-key cryptosystems. Students will develop analytical and implementation skills to understand cryptographic protocols, assess security threats, and apply cryptographic methods in real-world scenarios.

***Course Outcomes*****:** By the end of this course, students will be able to:

**CO 1.** Understand the fundamental principles of cryptography, including security goals, cryptographic attacks, and encryption techniques.

**CO 2.** Apply mathematical concepts such as modular arithmetic, linear congruence's, and algebraic structures in cryptographic algorithms.

**CO 3.** Analyze traditional symmetric-key ciphers, including substitution and transposition ciphers, and their security implications.

**CO 4.** Explain the structure and security aspects of modern symmetric-key encryption algorithms like DES and AES.

### Unit -I (Two Questions)

Introduction to Cryptography: Security goals, Cryptographic Attacks, Services and mechanisms, Types of Cryptography.

Mathematics of Cryptography**:** Integer Arithmetic, Modular Arithmetic, Matrices, Linear Congruence.

Traditional Symmetric-Key Ciphers: Substitution Ciphers, Transposition Ciphers, Stream and Block Ciphers.

### Unit -II (Two Questions)

Mathematics of Symmetric-Key Cryptography: Algebraic Structures, GF (2n ) Fields.

Introduction to Modern Symmetric-Key Ciphers: Modern Block Ciphers,

Modern Stream Ciphers.

### Unit -III (Two Questions)

Data Encryption Standard (DES): DES Structure, DES Analysis, Security of DES, Multiple DES-

Conventional Encryption Algorithm.

Advanced Encryption Standard (AES): Transformations, Key Expansion, The AES Ciphers, Analysis of AES.

**Unit -IV (Two Questions)**

Encipherment Using Modern Symmetric-Key Ciphers**:** Use of Modern Block Ciphers, Use of Stream Ciphers.

Mathematics of Asymmetric-Key Cryptography: Primes, Primality Testing, Factorization, Chinese Remainder Theorem, Quadratic Congruence, Exponentiation and Logarithm.

**Unit-V (Two Questions)**

Asymmetric-Key Cryptography**:** RSA Cryptosystem, Rabin Cryptosystem, ElGamal Cryptosystem, Elliptic Curve Cryptosystem.

**Recommended Text Book:**

Forouzan, B.A. & Mukhopadhyay, D. Cryptography and Network Security", Tata McGraw Hill Publication. [Chapter 1 – Chapter 10]

## E08: Advanced Mechanics of Solids L:5 T:0 P:0

**Course Objective:** The objective of this course is to provide an advanced understanding of solid mechanics, focusing on heat conduction, thermoelasticity, and wave propagation in solids. It covers fundamental heat conduction equations, boundary and initial conditions, and temperature distribution in Cartesian, cylindrical, and spherical coordinates. The course introduces the basic equations of thermoelasticity, including stress-strain relations and governing equations, along with thermal stress analysis in rectangular and circular plates. Additionally, it explores wave propagation in plates, rods, and cylindrical shells, equipping students with analytical skills to solve real-world problems related to thermal and mechanical stresses in solid materials.

**Course Outcomes:** By the end of this course, students will be able to:

**CO1.** Understand and apply heat conduction equations, boundary and initial conditions, and solve one-dimensional heat conduction problems in Cartesian coordinates for steady-state and transient conditions

**CO2**.Analyze and solve heat conduction equations in cylindrical and spherical coordinates, including steady-state and transient temperature distributions in solid cylinders and spheres.

**CO3.** Understand and apply the basic equations of thermoelasticity, including stress, strain, and governing equations in Cartesian, cylindrical, and spherical coordinate systems, along with generalized Hooke's law.

**CO4.**Analyze thermal stresses in rectangular and circular plates using fundamental equations and solutions to understand their behavior under thermal loading.

**CO5.** Understand and analyze wave propagation in plates, circular rods, and cylindrical shells, including the behavior of continuous waves in elastic solids

### Unit-I (Two Questions)

Heat conduction equation, Boundary conditions, initial conditions, one dimensional heat conduction equation in Cartesian coordinate, one dimensional temperature in steady state in Cartesian coordinate, one dimensional transient temperature in Cartesian coordinate

### Unit-II (Two Questions)

Heat conduction equation in cylindrical coordinates, one dimensional temperature in steady state in cylindrical coordinate, one dimensional transient temperature in solid cylinder. Heat conduction equation in spherical coordinates, one dimensional temperature in steady state in spherical coordinates and one dimensional transient temperature in solid sphere

### Unit-III (Two Questions)

Basic equations of thermoelasticity: Stress in Cartesian coordinate system, strain in Cartesian coordinate system, governing equation of thermoelasticity, Stress, strain and generalized Hooke's law in cylindrical coordinate system, Stress, strain and generalized Hooke's law in spherical coordinate system.

**Unit-IV (Two Questions)**

Thermal stresses in plates: Basic equations for rectangular plate, Fundamental solution for rectangular plate, Basic equation for circular plate, Fundamental solution for circular plate.

**Unit-V (Two Questions)**

Wave propagation in plates and rods: Continuous waves in plates, waves in circular rods and cylindrical shells.

**Recommended Text Book:**

1) Thermal stresses, N. Noda, R.B. Hetnarski and Y.Tanigawa, Lastran Corporation Roachester, NY, U.S.A., (2000), PP-71-82, 96-99, 107-109, 121-136, 143-147, 148-152, 333-365.
2) Wave motion in elastic solids, K.F. Graff, Dover publications, Inc., New York, PP- 431-475