DEPARTMENT OF PHYSICS AND ASTROPHYSICS

Undergraduate Curriculum Framework 2022

- B.Sc. Physical Sciences with Physics as one of the Core Disciplines
- B.Sc. Physical Sciences with Physics & Electronics as Core Disciplines

FOR MAJOR IN PHYSICS

Semester-VII and VIII

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	Digital Signal Processing	2	0	2	43
	Nonlinear Dynamics	3	0	1	47
	Nuclear and Particle Physics	3	1	0	50
	Plasma Physics	3	1	0	53
	Sensors and Detectors	3	0	1	55
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	Weather Forecasting	1	0	1	60
	PCB Designing and Fabrication**	0	0	2	-

Note:

1. Here,
   DSC: Discipline Specific Core
   DSE: Discipline Specific Elective
   SBC: Skill-based Course

2. * Research Methodology is the same as notified as a DSE for Sem VI (DU Notification dated 16.5.2024).

3. ** Are SEC notified on 28.3.2023.

4. Students should ensure that they do not repeat a SEC course as SBC.

5. As it is NOT permissible to choose courses having similarity of the content to the tune of 30% or more, students should ensure that while opting DSEs.

B.Sc. Physical Sciences with Physics as one of the Core Disciplines

DISCIPLINE SPECIFIC CORE COURSE – DSC 7-1 : STATISTICAL MECHANICS

Course Title and Code	Credits	Credit distribution of the course			Pre-requisite of the course
		Lecture	Tutorial	Practical	
Statistical Mechanics DSC 7-1	4	3	1	0	

COURSE OBJECTIVES

The course aims to:

- Introduce the fundamental concepts of statistical physics such as phase space, microstates, macrostates, and the basic idea of ensembles.
- Provide a thorough understanding of classical (Maxwell-Boltzmann) and quantum (Bose-Einstein and Fermi-Dirac) statistics.
- Develop skills to derive thermodynamic properties of ideal and degenerate gases using partition functions and distribution functions.
- Apply statistical methods to understand physical phenomena such as Bose-Einstein condensation, photon gas and negative temperature.
- Explore the qualitative concept of white dwarf stars and Chandrasekhar mass limit.

LEARNING OUTCOMES

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

- Explain the foundational concepts of phase space, macrostates, microstates, and the basic idea of ensembles.
- Apply the Maxwell-Boltzmann distribution law to calculate thermodynamic quantities of an ideal gas using the partition function.
- Apply the law of equipartition of energy to analyze specific heat capacities of gases and explain its limitations at low temperatures.

- Describe the Bose-Einstein distribution and apply it to systems like photon gas and a two-level system, including concepts like negative temperature and Bose-Einstein condensation.

- Apply the Fermi-Dirac distribution to calculate thermodynamic functions of degenerate fermion systems and describe qualitatively the physics of white dwarf stars and the Chandrasekhar mass limit.

SYLLABUS OF DSC 7
THEORY COMPONENT
(Hours: 45)

Unit I **(6 Hours)**

Introduction to Classical Statistics
Macrostates and Microstates, Phase Space, Entropy and Thermodynamic Probability

Unit II **(12 Hours)**

Maxwell-Boltzmann distribution
Partition function, thermodynamic functions of an ideal gas, Gibbs paradox, Sackur-Tetrode equation; law of equipartition of energy (with proof) – Applications to specific heat of gases and its limitations, thermodynamic functions of a two-level system, negative temperature.

Unit III **(15 Hours)**

Bose-Einstein Statistics
Bose-Einstein distribution law, thermodynamic functions of a strongly degenerate Bose gas (non-relativistic), Bose-Einstein condensation, properties of liquid He (qualitative description only), radiation as a photon gas and thermodynamic functions of photon gas; Derivation of Planck's law using B-E statistics.

Unit IV **(12 Hours)**

Fermi-Dirac Statistics
Fermi-Dirac distribution law, thermodynamic functions of a completely and strongly degenerate Fermions (non-relativistic), specific heat of metals, relativistic Fermi gas, White dwarf stars and Chandrasekhar mass limit (qualitative concepts only).

REFERENCES

Essential Readings

1. Statistical Mechanics - R. K. Pathria & Paul D. Beale, 4th Edition, (Academic Press,2021)
2. Introduction to Statistical Physics, Kerson Huang, 2nd Edition, (Taylor and Francis 2009)
3. Thermodynamics, Kinetic theory and Statistical thermodynamics, Sears and Salinger, PHI

4. Introductory Statistical Mechanics, R. Bowley and M. Sanchez, Oxford Univ. Press
5. Concepts in Thermal Physics, Blundell and Blundell, Oxford University Press
6. Problems and Solutions on Thermodynamics and Statistical Mechanics, Lim Yung-Kou, Sarat Book House
7. Statistical and Thermal Physics, Loknathan and Gambhir, PHI

Additional Readings

1. An Introduction to Statistical Physics, W. G. V. Rosser, Wiley
2. An Introduction to Thermal Physics, D. Schroeder, Pearson
3. Statistical Mechanics, G. Sanon, Narosa Publishers

B.Sc. Physical Sciences with Physics as one of the Core Disciplines

DISCIPLINE SPECIFIC ELECTIVE COURSE – DSE 7-1 : ADVANCED MATHEMATICAL PHYSICS

Course Title and Code	Credits	Credit distribution of the course			Pre-requisite of the course
		Lecture	Tutorial	Practical	
Advanced Mathematical Physics DSE 7-1	4	3	1	0	

COURSE OBJECTIVES

The course is intended

- To impart the basic concepts of cartesian tensors to have in-depth analysis of physical system.
- To grasp the foundational principles of group theory so that students can apply it in theoretical and experimental physics.

LEARNING OUTCOMES

After completing the course the students will be able to

- Learn basic properties of cartesian tensors with physical examples such as moment of inertia tensor, stress tensor, strain tensor etc.
- Learn elementary group theory: definition and properties of groups, subgroups, Homomorphism, Isomorphism and Normal groups.

SYLLABUS OF DSE 7-1
THEORY COMPONENT
(Hours: 45)

Unit I **(10 hours)**

Cartesian Tensors
Transformation of Co-ordinates and fundamentals of Tensors. Einstein's Summation Convention. Relation between Direction Cosines. Algebra of Tensors: Sum, Difference and Product of Two Tensors. Contraction. Quotient Law of Tensors. Symmetric and Anti-symmetric Tensors. Invariant Tensors: Kronecker and Alternating Tensors. Association of Anti-symmetric Tensor of Order Two and Vectors.

Unit II **(8 Hours)**

Vector Calculus using Cartesian Tensors
Scalar and Vector Products of 2, 3, 4 vectors. Gradient, Divergence and Curl of Tensor Fields. Tensor notation of Laplacian operator. Proof of Vector Identities involving scalar and vector products and vector identities involving Del operator using Tensor notation.

Unit III **(7 Hours)**

Applications of Cartesian Tensors
Tensorial Character of Physical Quantities. Moment of Inertia Tensor. Stress and Strain Tensors: Symmetric Nature. Elasticity Tensor. Generalized Hooke's Law.

Unit IV **(20 Hours)**

Group Theory
Elementary properties of groups, Subgroup, Centre of a group, Co-sets of a subgroup, cyclic group. Permutation group. Homomorphism and Isomorphism of group. Normal and conjugate subgroups, Completeness and Kernel. Some special groups: SO(2), SO(3), SU(2), SU(3).

REFERENCES

Essential Readings

1) Vector Analysis and Cartesian Tensors, 3rd edition, D. E. Bourne, P. C. Kendall, 1992
2) Cartesian Tensors, H. Jeffreys, 1931, Cambridge University Press.
3) Mathematical Methods for Physicists, H. J. Weber and G. B. Arfken, 2010, Elsevier.
4) A Brief on Tensor Analysis, J. G. Simmonds, 1997, Springer.
5) Schaum's outlines series on Vector Analysis, M. Spiegel, 2nd edition, 2017.
6) Schaum's Outline Series on Tensor Calculus, D. Kay, Revised 1st edition, 2011.
7) An Introduction to Tensor Calculus and Relativity, D. F. Lawden, 2013, Literary Licensing
8) Matrices and tensors in physics by A. W. Joshi, 1995, New Age International Publications.
9) Group Theory and its Applications to Physical Problems, by Morton Hamermesh, Dover Publications (1989).
10) Elements of Group Theory for Physicists, by A. W. Joshi, John Wiley (1997).

Additional Readings

1) A Student's Guide to Vectors and Tensors, D. A. Fleisch, 2011, Cambridge Univ. Press.
2) The Feynman Lectures on Physics, Volume II, Feynman, Leighton and Sands, 2008, Narosa Publishing House.
3) A Primer in Tensor Analysis and Relativity, I. L. Shapiro, 1st edition, 2019, Springer.
4) Group Theory and Physics, S. Sternberg, Cambridge University Press (1994).
5) Group Theory and Quantum Mechanics, Michael Tinkham, Dover Publications (2003)

B.Sc. Physical Sciences with Physics as one of the Core Disciplines

DISCIPLINE SPECIFIC ELECTIVE COURSE – DSE 7-2 : CLASSICAL DYNAMICS

Course Title and Code	Credits	Credit distribution of the course			Pre-requisite of the course
		Lecture	Tutorial	Practical	
Classical Dynamics DSE 7-2	4	3	1	0	

COURSE OBJECTIVES

- To introduce variational principles and their application to derive equations of motion for complex systems with constraints.
- To deepen the understanding of foundational principles of Classical Mechanics including Lagrangian and Hamiltonian formalisms
- To Develop an understanding of symmetries and conservation laws through Noether's Theorem
- To Analyze the motion of particles in central force fields, including planetary motion and scattering.
- To Explore the behavior of systems undergoing small oscillations, with emphasis on coupled systems and normal modes
- To describe motion in non-inertial frames and the dynamics of rigid bodies.

LEARNING OUTCOMES

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

- Apply the calculus of variations to derive the Euler-Lagrange equations and use them to analyze constrained mechanical systems.
- Use generalized coordinates and cyclic variables to simplify and solve problems in classical dynamics.
- Formulate and analyze mechanical systems using Lagrangian and Hamiltonian formalisms.
- Construct and analyze Hamiltonian systems, including canonical equations, and Poisson brackets.
- Analyze the motion of particles under central forces and solve scattering problems.
- Understand and compute normal modes and normal frequencies in small oscillation problems, including coupled oscillators.

- Describe motion in rotating frames and identify fictitious forces like centrifugal and Coriolis forces.
- Understand the dynamics of rigid bodies.
- Develop critical thinking and problem-solving skills

SYLLABUS OF DSE 7-2
THEORY COMPONENT
(Hours: 45)

Unit I **(16 Hours)**

Lagrangian and Hamiltonian Formulation
Calculus of Variation with examples, Generalized coordinates, Hamilton's Principle and Euler-Lagrange equations of motion. Constrained systems (holonomic). Applications of Euler-Lagrange Equation. Generalised Momenta and forces, Cyclic coordinates. Noether's Theorem and Conservation Principles.
Legendre transformation, Hamilton's equations and applications. Phase space and phase trajectories. Poisson brackets and its properties.

Unit II **(12 Hours)**

Central Force and Orbital Mechanics
Feature of Motion under Central Forces. Reduction of two body problem to equivalent one body problem. Effective potential, Energy diagrams. Equation of motion under central force and its formal solution. Classification and Stability of orbits**,** Conditions for Closed Orbits (Bertrand's Theorem). Kepler's laws for planetary motion, Scattering in central force field with example of Rutherford scattering, Transformation of scattering problem to laboratory coordinates.

Unit III **(9 Hours)**

Theory of small oscillations
Stable equilibrium and small amplitude oscillations. Solution of Eigenvalue equation. Normal modes and normal frequencies of oscillations. Damped and Forced Oscillations, Coupled oscillators.
Non-Inertial Frames
Non-inertial frames and fictitious forces. Uniformly rotating frames. Centrifugal and Coriolis forces.

Unit IV **(8 Hours)**

Rigid Body Dynamics
Rotation matrices, Euler angles. Angular momentum and rotational kinetic energy of rigid bodies, Moment of Inertia Tensor. Euler's equations of motion for rigid body. Torque-free motion.

<u>**REFERENCES**</u>

Essential Readings

1. The Feynman Lectures on Physics, Volume I and II, R. P. Feynman, R. B. Leighton and M. Sands, California Institute of Technology (2010).
2. Classical Mechanics, H. Goldstein, C. P. Poole, J. L. Safko, 3/e, Pearson Education (2014).
3. Classical Mechanics, John R. Taylor, University Science Books (2005).
4. Classical Mechanics, R. Douglas Gregory, Cambridge University Press (2015).
5. Mechanics, L. D. Landau and E. M. Lifshitz, Pergamon (2010).
6. Classical Mechanics, P. S. Joag, N. C. Rana, McGraw Hall Education (2017).
7. Classical Mechanics, Tai L. Chow, CRC Press (2013).

Additional Readings

1. Analytical Mechanics: Solutions to Problems in Classical Physics, I. Merches, D. Radu, CRC Press (2015).
2. Solved Problems in Classical Mechanics, O. L. Delange and J. Pierrus, Oxford University Press (2010).
3. Classical Dynamics of particles and system, S. T. Thornton, J. B. Marion, 2012, Cengage Learning.
4. Theory and Problems of Theoretical Mechanics, Murray R. Spiegel, McGraw Hill Education (1977).

B.Sc. Physical Sciences with Physics as one of the Core Disciplines

DISCIPLINE SPECIFIC ELECTIVE COURSE – DSE 7-3: ELECTRIC CIRCUIT ANALYSIS

Course Title and Code	Credits	Credit distribution of the course			Pre-requisite of the course
		Lecture	Tutorial	Practical	
Electric Circuit Analysis DSE 7-3	4	2	0	2	

COURSE OBJECTIVES

This course covers the basic circuit concepts in a systematic manner which is suitable for analysis and design. It aims at study and analysis of electric circuits using network theorems and two-port parameters.

LEARNING OUTCOMES

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

- Explain the laws and methods of analysing DC and AC networks
- Define nodal and loop analysis
- Solve complex electric circuits using network theorems.
- Discuss resonance in series and parallel circuits and also the importance of initial conditions and their evaluation.
- Evaluate the performance of two port networks.
- Use Millman's theorem to reduce multiple voltage sources in parallel to a single equivalent voltage source.

SYLLABUS OF DSE 7-3
THEORY COMPONENT
(Hours: 30)

Unit I **(8 Hours)**

Circuit Analysis: Ideal voltage source, real voltage source, current source, Kirchhoff's current law, Kirchhoff's voltage law, node analysis, mesh analysis, Star and Delta conversion DC Transient Analysis: Charging and discharging with initial charge in RC circuit, RL circuit with initial current, time constant, RL and RC Circuits with source

Unit II **(5 Hours)**

AC Circuit Analysis: Sinusoidal voltage and current, Definitions of instantaneous, peak to peak, root mean square and average values, form factor and peak factor (for half-rectified and full-rectified sinusoidal wave, rectangular wave and triangular wave)

Unit III **(7 Hours)**

Voltage-current relationship in resistor, inductor and capacitor, phasor, complex impedance, power in AC circuits, sinusoidal circuit analysis for RL, RC and RLC Circuits, resonance in series and parallel RLC Circuits (Frequency Response, Bandwidth, Quality Factor), selectivity, application of resonant circuits

Unit IV **(10 Hours)**

Network Theorems: Principal of duality, Superposition theorem, Thevenin theorem, Norton theorem, Their applications in DC and AC circuits with more than one source, Maximum Power Transfer theorem for AC circuits, Reciprocity Theorem, Millman's Theorem, Tellegen's theorem Two Port Networks: Impedance (Z) Parameters, Admittance (Y) Parameters, Transmission Parameters, Impedance matching

PRACTICAL COMPONENT: ELECTRIC CIRCUIT ANALYSIS
(Hours: 60)

Every student must perform at least seven experiments from the following list of experiments:

1. Verification of Kirchoff's Law.
2. Verification of Superposition Theorem by using d.c. and a.c. voltage source
3. Verification of Norton's theorem.
4. Verification of Thevenin's Theorem and Maximum Power Transfer Theorem by using d.c. and a.c. voltage sources,
5. Determination of unknown capacitance using de Sauty's Bridge
6. Determination of time constant of RC and RL circuit
7. Study of frequency response of RC circuit
8. Study of frequency response of a parallel LCR Circuit and determination of its resonant frequency, impedance at resonance, quality factor and bandwidth.
9. Explore electrical properties of matter using Arduino:
    a. To study the characteristics of a series RC Circuit.
    b. To study the response curve of a series LCR circuit and determine its resonant frequency, impedance at resonance, quality factor and bandwidth

REFERENCES

1) A Textbook of Electrical Technology, B. L. Thareja, A. K. Thareja, Volume II, S. Chand
2) Fundamentals of Electric Circuits, C. Alexander and M. Sadiku, McGraw Hill (2008)
3) Electric Circuits, S. A. Nasar, Schaum's Outline series, Tata McGraw Hill (2004)
4) Electrical Circuits, K. A. Smith and R.E. Alley, 2014, Cambridge University Press
5) Electrical Circuit Analysis, K. Mahadevan and C. Chitran, 2nd Edition, 2018, PHI Learning Pvt. Ltd.

B.Sc. Physical Sciences with Physics as one of the Core Disciplines

DISCIPLINE SPECIFIC ELECTIVE COURSE – DSE 7-4 : MICROPROCESSOR

Course Title and Code	Credits	Credit distribution of the course			Pre-requisite of the course
		Lecture	Tutorial	Practical	
Microprocessor DSE 7-4	4	2	0	2	

COURSE OBJECTIVES

Students will be able to outline the types and the functions of storage, learn the characteristics of RAM and ROM and their architecture, describe the architecture of 8085 microprocessors and develop programs for microprocessor 8085

LEARNING OUTCOMES

At the end of the course, students will develop ability to,

- Define storage state the types and functions of storage
- Describe the characteristics of RAM and ROM and their architecture.
- Describe memory organization, addressing, interfacing and mapping
- Describe the architectures of 8085 microprocessors
- Draw timing diagram
- Write programs using 8085

SYLLABUS OF DSE 7-4
THEORY COMPONENT
(Hours: 30)

Unit I **(8 Hours)**

Introduction to 8085 Microprocessor

Introduction to microprocessor: Basic computer system organization, introduction, classification and applications of microprocessors, types of memory-primary memory types (SRAM, DRAM, PROM, EPROM, EEPROM), secondary memory (SSD, Optical Drive) memory organization and addressing

Unit II **(8 Hours)**

Microprocessor 8085 Architecture

Features, architecture-block diagram, general purpose registers, register pairs, flags, stack pointer, program counter, types of buses, multiplexed address and data bus, generation of control signals, pin description of microprocessor 8085, basic memory interfacing concepts, Memory mapped I/O and I/O mapped I/O.

Unit III **(7 Hours)**

8085 Programming

Operation code, operand and mnemonics, instruction set of 8085, instruction classification, addressing modes, instruction format, data transfer instructions, arithmetic instructions, increment & decrement instructions, logical instructions, branch instructions and machine control instructions, subroutine, call and return instructions, timing diagrams-instruction cycle, machine cycle, T- states, basic idea of interrupts

Unit IV **(7 Hours)**

Assembly language programming

Addition with and without carry, subtraction with and without borrow, double addition, multiplication by repeated addition, division by repeated subtraction, block data transfer and checking of parity of a binary number.

PRACTICAL COMPONENT: MICRPROCESSOR
(Hours: 60)

At least six experiments to be performed from the following list:

8085 Assembly language programs

1. Add two 8-bit numbers using Direct and Indirect Addressing Mode
2. Subtract two 8-bit numbers using Direct and Indirect Addressing Mode
3. Multiply two 8-bit numbers with and without subroutine
4. Divide two 8-bit numbers with and without subroutine
5. Add a list of 8-bit numbers
6. Transfer a Block of Data
7. Add two 16-bit numbers with DAD and without DAD
8. Convert byte to Nibble
9. Convert nibble to Byte
10. Check the parity of a given number

REFERENCES

Essential Readings for the Theory Component

1. Microprocessor Architecture Programming and applications with 8085, R. S. Gaonkar, 2002, Prentice Hall
2. Microelectronic Circuits, S. Sedra
3. Fundamentals of Microprocessor and Microcomputer, B. Ram, Dhanpat Rai Publications
4. The Intel Microprocessors - Architecture, Programming and Interfacing, B. Brey, 2003, Pearson Education

Additional Readings for the Theory Component

Microprocessors and Microcontrollers, M. Ali Mazidi, 2006, Pearson

References for the Practical Component

1. Microprocessor Architecture Programming and applications with 8085, R. S. Gaonkar, 2002, Prentice Hall.
2. Microelectronic Circuits, S. Sedra.
3. Fundamentals of Microprocessor and Microcomputer, B. Ram, Dhanpat Rai Publications.
4. Microprocessors and Microcontrollers, M. Ali Mazidi, 2006, Pearson.
5. The Intel Microprocessors - Architecture, Programming and Interfacing, B. Brey, 2003, Pearson Education.

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DISCIPLINE SPECIFIC ELECTIVE COURSE – DSE 7-5: NANOSCIENCE

Course Title and Code	Credits	Credit distribution of the course			Pre-requisite of the course
		Lecture	Tutorial	Practical	
Nanoscience DSE 7-5	4	2	0	2	

COURSE OBJECTIVES

The syllabus introduces the basic concepts of nanomaterials, their synthesis, properties exhibited by them and finally few applications. Various nanomaterial synthesis/growth methods and characterizations techniques are discussed to explore the field in detail. The effect of dimensional confinement of charge carries on the electrical, optical and structural properties will be discussed. Interesting experiments which shape this filed like conductance quantization in 2DEG (Integer Quantum Hall Effect) and coulomb blockade are introduced. The concept of micro- and nano- electro mechanical systems (MEMS and NEMS) and important applications areas of nanomaterials are discussed.

LEARNING OUTCOMES

On successful completion of the course students should be able to

- explain the difference between nanomaterials and bulk materials and their property difference.
- explain various methods for the synthesis/growth of nanomaterials.
- explain the role of confinement on the density of state function and so on the various properties exhibited by nanomaterials compared to bulk materials.
- explain the concept of Quasi-particles such as excitons and how they influence the optical properties.
- explain the direct and indirect bandgap semiconductors, radiative and non-radiative processes and the concept of luminescence.
- explain the structure of 2DEG system and its importance in quantum transport experiments, like Interger Quantum Hall Effect and conductance quantization.
- explain the conductance quantization in 1D structure and its difference from the 2DEG system.

- explain the necessary and sufficient conditions required to observe coulomb blockade, single electron transistor and the scope of these devices.
- explain how MEMS and NEMS devices are produced and their applications.

SYLLABUS OF DSE 7-5
THEORY COMPONENT
(Hours: 30)

Unit I **(11 Hours)**

Introduction
Basic Introduction to Nano-Science and Technology - Implications on nanoscience on fields like Physics, Chemistry, Biology and Engineering, Classifications of nanostructured materials as quantum dots (0D), nanowires (1D), Thin films (2D) and Multi-layered materials or super lattices. Introduction to properties like Mechanical, Electronic, Optical, Magnetic and Thermal properties and how they change at Nano scale dimensions to motivate students (qualitative only).
Nanoscale Systems
Brief review of Schrodinger equation and its applications in- Infinite potential well, potential step and potential box problems, Band Structure and Density of states of 3D and 2D systems in detail and qualitatively for 1D and 0D, confinement of charges in nanostructures their consequences on electronic and optical properties.

Unit II **(10 Hours)**

Properties of Nano Scale systems
Time and length scales (diffusion, elastic and inelastic lengths etc.) of electrons in nanostructured materials, Carrier transport in nanostructures: diffusive and ballistic transport.
2D nanomaterials: Conductance quantization in 2DEG in GaAs and integer quantum hall effect (semi-classical treatment)
1D nanomaterials: Conductance quantization in 1D structures using split gate in 2DEG system (Qualitative).
0D nanomaterials: Charging effect, Coulomb Blockade effect, Single Electron Transfer (SET) device.
Basic understanding of excitons in semiconductors and their consequence on optical properties of the material

Unit III **(5 Hours)**

Synthesis of Nanomaterials (Qualitative)
Top-down and Bottom-up approach, Ball milling, Spin Coating
Vacuum deposition: Physical vapor deposition (PVD): Thermal evaporation, Sputtering, Chemical vapor deposition (CVD). Preparation of colloidal solutions of Metals, Metal Oxide nanoparticles

Unit IV **(4 Hours)**

Applications (Qualitative)

Micro Electromechanical Systems (MEMS), Nanoelectromehanical Systems (NEMS). Applications of nanomaterials as probes in medical diagnostics and targeted drug delivery, sunscreen, lotions, and paints and other examples to give broader perspective of applications of nanomaterials.

PRACTICAL COMPONENT: NANOSCIENCE

(Hours: 60)

At least 06 experiments from the following:

1. Synthesis of metal (e.g. Ag) nanoparticles by chemical route and study its optical absorption properties.
2. Synthesis of semiconductor (CdS/ZnO/TiO_2/Fe_2O_3 etc) nanoparticles and study its Optical Absorption properties as a function of ageing time.
3. Surface Plasmon study of metal nanoparticles as a function of size by UV-Visible spectrophotometer.
4. Analysis of XRD pattern of given nanomaterial and estimate lattice parameters and particle size.
5. To study the effect of the size nanoparticles on its color.
6. To prepare composite of CNTs with other materials and study their optical absorption/Transmission properties.
7. Growth of metallic thin films using thermal evaporation technique.
8. Prepare a ceramic disc of a given compound and study its I-V characteristics, measure its dielectric constant or any other property.
9. Fabricate a thin film of nanoparticles by spin coating (or chemical route) and study its transmittance spectra in UV-Visible region.
10. Prepare thin film capacitor and measure capacitance as a function of temperature or frequency.
11. Fabricate a PN junction diode by diffusing Al over the surface of N-type Si/Ge and study its V-I characteristic.
12. Fabricate thin films (polymer, metal oxide) using electro-deposition
13. To study variation of resistivity or sheet resistance with temperature of the fabricated thin films using four probe method.

REFERENCES

Essential Readings for the Theory Component

1. C.P. Poole, Jr. Frank J. Owens, Introduction to Nanotechnology 1st edition (2003) Wiley India Pvt. Ltd..
2. S.K. Kulkarni, Nanotechnology: Principles & Practices 2nd edition (2011) (Capital Publishing Company)

3. K. K. Chattopadhyay and A. N. Banerjee, Introduction to Nanoscience and Technology (2009) (PHI Learning Private Limited).
4. Introduction to Nanoelectronics, V. V. Mitin, V.A. Kochelap and M.A. Stroscio,2011, Cambridge University Press.
5. Richard Booker, Earl Boysen, Nanotechnology for Dummies (2005) (Wiley Publishing Inc.).
6. Introductory Nanoscience by Masaru Kuno, (2012) Garland science Taylor and Francis Group
7. Electronic transport in mesoscopic systems by Supriyo Datta (1997) Cambridge University Press.
8. Fundamentals of molecular spectroscopy by C. N. Banwell and E. M. McCASH, 4th edition, McGrawHill.

Additional Readings for the Theory Component

1. Quantum Transport in semiconductor nanostructures by Carla Beenakker and HenK Van Houten (1991) (available at arXiv: cond-mat/0412664) Open Source
2. Sara Cronewett Ph.D. thesis (2001) for extra reading (Available as Arxiv).
3. Solid State Physics by J. R. Hall and H. E. Hall, 2nd edition (2014) Wiley

References for the Practical Component

1. C.P. Poole, Jr. Frank J. Owens, Introduction to Nanotechnology 1st edition (2003) Wiley India Pvt. Ltd..
2. S. K. Kulkarni, Nanotechnology: Principles & Practices 2nd edition (2011) (Capital Publishing Company)
3. K. K. Chattopadhyay and A. N. Banerjee, Introduction to Nanoscience and Technology (2009) (PHI Learning Private Limited).
4. Richard Booker, Earl Boysen, Nanotechnology for Dummies (2005) (Wiley Publishing Inc.).

B.Sc. Physical Sciences with Physics as one of the Core Disciplines

DISCIPLINE SPECIFIC ELECTIVE COURSE – DSE 7-6: QUANTUM MECHANICS

Course Title and Code	Credits	Credit distribution of the course			Pre-requisite of the course
		Lecture	Tutorial	Practical	
Quantum Mechanics DSE 7-6	4	3	1	0	

COURSE OBJECTIVES

The development of quantum mechanics has revolutionized human life. In this course, students will be exposed to the probabilistic concepts of basic non-relativistic quantum mechanics and its applications to understand the subatomic world.

LEARNING OUTCOMES

After completing this course, the students will be able to

- Solve Schrödinger equation for different 1-d potentials, such as finite square potential well, potential steps and barriers and distinguish between scattering and bound states.
- Use the algebraic method to solve the Schrödinger equation for quantum harmonic
- Solve the 3-D Schrodinger equation in spherical coordinates.
- Understand the spectrum and eigenfunctions for hydrogen atom
- Understand the angular momentum operators in position space, their commutators, eigenvalues and eigenfunctions.
- Explain the concept of spin, use Pauli matrices to describe spin-½ systems, and construct the singlet and triplet spin states for two-particle systems.

SYLLABUS OF DSE 7-6
THEORY COMPONENT
(Hours: 45)

Unit I **(12 Hours)**

Schrödinger Equation for 1- dimensional systems
General solution of 1-D Schrödinger equation for time independent potentials, Solution of Schrödinger equation for a particle in a finite square potential well, reflection and transmission across a step potential and a rectangular potential barrier.
General discussion of bound states in an arbitrary potential: Continuity of wave function, boundary conditions and emergence of discrete energy levels with Application to energy eigenstates for a particle in a finite square potential well.

Unit II **(8 Hours)**

Structure and Time Evolution of Quantum States
Momentum space wavefunction, Time evolution of Gaussian Wave packet, Superposition Principle, linearity of Schrodinger Equation, General solution as a linear combination of discrete stationary states, Observables as operators, Commutator of position and momentum operators, Ehrenfest’s theorem.
Harmonic oscillator
Energy eigenvalues and eigenstates of a 1-D harmonic oscillator using the algebraic method (ladder operators). Zero-point energy and the uncertainty principle.

Unit III **(12 Hours)**

Schrödinger Equation in three dimensions
Probability and probability densities in 3D. Schrödinger equation in spherical polar coordinates, its solution for the Hydrogen atom solution using separation of angular and radial variables. Solution of angular equation, Spherical harmonics.
Solution of radial equation using Frobenius method, Radial wavefunctions, Probability densities for ground and first excited states, quantum numbers n, l and m_l.

Unit IV **(13 Hours)**

Angular Momentum: Orbital Angular momentum operators ($\mathbf{L_x}$, $\mathbf{L_y}$ and $\mathbf{L_z}$) and ladder operators $\mathbf{L_+}$ and $\mathbf{L_-}$ as differential operators in cartesian coordinates and their commutation relations, Orbital angular momentum operators in spherical polar coordinates, their eigenvalues, eigenfunctions and identification of these with spherical harmonics.
Concept of spin: Spin angular Momentum Operator, Pauli matrices, algebraic theory of spin, General state for spin-1/2 particles, Total spin for a system of two spin-1/2 particles, singlet and triplet states.

REFERENCES

Essential Readings

1. Quantum Mechanics: Theory and Applications, Ajoy Ghatak and S. Lokanathan, Laxmi Publications (2019).
2. Introduction to Quantum Mechanics, D.J. Griffith, Pearson Education (2005).
3. A Textbook of Quantum Mechanics, P.M. Mathews and K. Venkatesan, McGraw-Hill (2010).
4. Quantum Mechanics, B. H. Bransden and C. J. Joachain, Prentice Hall (2000).
5. Quantum Mechanics: Concepts and Applications, Nouredine Zettili, John Wiley and Sons, Ltd. (2009).

Additional Readings

1. Quantum Mechanics for Scientists & Engineers, D.A.B. Miller, Cambridge University Press (2008).
2. Introduction to Quantum Mechanics, R. H. Dicke and J. P. Wittke, Addison-Wesley Publications (1966).
3. Quantum Mechanics, Leonard I. Schiff, Tata McGraw Hill (2010).
4. Quantum Mechanics, Robert Eisberg and Robert Resnick, Wiley (2002).
5. Schaum's Outlines of Quantum Mechanics, Yoav Peleg, Reuven Pnini, Elyahu Zaarur, Eugene Hecht, NcGrawHill (2010).
6. Introductory Quantum Mechanics, R. L. Liboff; 4th Ed., Addison Wesley (2003).

B.Sc. Physical Sciences with Physics as one of the Core Disciplines

DISCIPLINE SPECIFIC ELECTIVE COURSE – DSE 7-7 : SEMICONDUCTOR DEVICES - FABRICATION AND APPLICATIONS

Course Title and Code	Credits	Credit distribution of the course			Pre-requisite of the course
		Lecture	Tutorial	Practical	
Semiconductor Devices - Fabrication and Applications DSE 7-7	4	2	0	2	

COURSE OBJECTIVES

- This course provides a review of basics of semiconductors such as energy bands, doping, defects etc. and introduces students to various semiconductor and memory devices.
- Thin film growth techniques and processes including various vacuum pumps, sputtering, evaporation, oxidation and VLSI processing are described in detail.
- By the end of the syllabus, students will have an understanding of MEMS based transducers.

LEARNING OUTCOMES

At the end of this course, students will be able to achieve the following learning outcomes:

- Learn to distinguish between single crystal, polycrystalline and amorphous materials based on their structural morphology and learn about the growth of single crystals of silicon, using Czochralski technique, on which a present day electronics and IT revolution is based. Students will understand about the various techniques of thin film growth and processes.
- Appreciate the various VLSI fabrication technologies and learn to design the basic fabrication process of R, C, P- N Junction diode, BJT, JFET, MESFET, MOS, NMOS, PMOS and CMOS technology.
- Gain basic knowledge on overview of MEMS (MicroElectro-Mechanical System) and MEMS based transducers.

SYLLABUS OF DSE 7-7
THEORY COMPONENT
(Hours: 30)

Unit I **(9 Hours)**

Introduction: Review of energy bands in materials. Metal, Semiconductor and Insulator. Doping in Semiconductors, Defects: Point, Line, Schottky and Frenkel. Single Crystal, Polycrystalline and Amorphous Materials. Czochralski technique for Silicon Single Crystal Growth. Silicon Wafer Slicing and Polishing.

Vacuum Pumps: Primary Pump (Mechanical) and Secondary Pumps (Diffusion, Turbomolecular, Cryopump, Sputter - Ion)– basic working principle, Throughput and Characteristics in reference to Pump Selection. Vacuum Gauges (Pirani and Penning).

Unit II **(10 Hours)**

Thin Film Growth Techniques and Processes: Sputtering, Evaporation (Thermal, electronBeam), Pulse Laser Deposition (PLD), Chemical Vapor Deposition (CVD). Epitaxial Growth. Thermal Oxidation Process (Dry and Wet) Passivation. Metallization. Diffusion.

Unit III **(7 Hours)**

VLSI Processing: Clean Room Classification, Line width, Photolithography: Resolution and Process, Positive and Negative Shadow Masks, Photoresist, Step Coverage, Developer. Electron Beam Lithography. Etching: Wet Etching. Dry etching (RIE and DRIE). Basic Fabrication Process of R, C, P-N Junction diode, BJT, JFET, MESFET, MOS, NMOS, PMOS and CMOS technology. Wafer Bonding, Wafer Cutting, Wire bonding and Packaging issues (Qualitative idea).

Unit IV **(4 Hours)**

Micro Electro-Mechanical System (MEMS): Introduction to MEMS, Materials selection for MEMS Devices, Selection of Etchants, Surface and Bulk Micromachining, Sacrificial Subtractive Processes, Additive Processes, Cantilever, Membranes. General Idea MEMS based Pressure, Force, and Capacitance Transducers.

PRACTICAL COMPONENT: SEMICONDUCTOR DEVICES - FABRICATION AND APPLICATIONS
(Hours: 60)

At least 06 experiments from the following:

1. Fabrication of thin films via dip-coating technique, deposition of metal contacts through thermal evaporation and investigation of their current–voltage (I–V) characteristics.
2. Fabrication of thin films via spin-coating technique, deposition of metal contacts through thermal evaporation and investigation of their current–voltage (I–V) characteristics

3. Fabrication of p-n junction using either p or n type substrate along with appropriate semiconducting layer and study its current-voltage (I-V) Characteristics.
4. Generation of vacuum in small tubes (varying volumes) using a mechanical rotary pump and measurement of pressure using vacuum gauges.
5. Selective etching of Different Metallic thin films using suitable etchants of different concentrations.
6. Wet chemical etching of Si for Micro-Electro-Mechanical Systems (MEMS) applications using different concentrations of etchant.
7. Calibrate semiconductor type temperature sensor (AD590, LM 35, LM 75).
8. To measure the resistivity of a germanium (Ge) semiconductor crystal with temperature (up to 150 ^{o}C) by four-probe method.
9. Capacitance measurements of ceramics using LCR meter.
10. Capacitance measurements of dielectric thin film capacitor using LCR meter

<u>REFERENCES</u>

Essential Readings for the Theory Component

1. Physics of Semiconductor Devices, S. M. Sze. Wiley-Interscience.
2. Fundamentals of Semiconductor Fabrication, S.M. Sze and G. S. May, John-Wiley and Sons, Inc.
3. Introduction to Semiconductor materials and Devices, M. S. Tyagi, John Wiley & Sons VLSI Fabrication Principles (Si and GaAs), S. K. Gandhi, John Wiley & Sons, Inc.

Additional Readings for the Theory Component

Handbook of Thin Film Technology, Leon I. Maissel and Reinhard Glang.

References for the Practical Component

1. The science and Engineering of Microelectronics Fabrication, Stephen A. Champbell, 2010, Oxford University Press.
2. Introduction to Semiconductor Devices, Kelvin F.

B.Sc. Physical Sciences with Physics as one of the Core Disciplines

SKILL BASED COURSE – SBC 7-1: ARDUINO PROGRAMMING

Course Title and Code	Credits	Credit distribution of the course			Pre-requisite of the course
		Lecture	Tutorial	Practical	
Arduino Programming SBC 7-1	2	0	0	2	

COURSE OBJECTIVES

- To introduce students to the fundamentals of embedded systems using the Arduino platform.
- To develop programming skills in C/C++ for microcontroller-based applications.
- To foster logical thinking and problem-solving through real-world electronic projects.
- To lay the foundation for interfacing sensors and actuators using digital and analog I/O.

LEARNING OUTCOMES

- Explain the architecture and features of the Arduino Platform.
- Set up and use the Arduino IDE to write, debug using Serial Monitor, and upload code to an Arduino board.
- Write basic programs involving digital and analog I/O, loops, functions, and conditional statements.
- Implement simple tasks such as blinking LEDs, reading buttons, generating PWM signals, and reading analog voltages.
- Understand serial communication and use the Serial Monitor for debugging.
- Design small-scale automation and control programs using Arduino logic.

SYLLABUS OF SBC 7-1
(Hours: 60)

Unit I **(24 Hours)**

Introduction to Arduino
- Overview of Arduino and its applications.
- Understanding microcontrollers and development boards.

- Introduction to the Arduino IDE.
- Installing the Arduino IDE.
- Connecting Arduino to your computer.
- First program: Blink an LED (Hello World of Arduino).

Basic Electronic Components

- Basic concepts of electronic components- Resistors, capacitors, diodes, transistors, LEDs.
- Breadboards and prototyping techniques.
- Ohm's Law and calculating resistor values for LEDs.
- Controlling LEDs with Arduino.
- Switches and Buttons: Digital inputs and outputs. Using push buttons with Arduino.

Unit II **(36 Hours)**

Programming Fundamentals

- Arduino Programming Basics: Structure of an Arduino sketch (setup and loop functions), Variables, data types, and operators.
- Control Structures: Conditional statements (if, else, switch). Loops (for, while, do-while).
- Functions and Libraries: Writing and using functions. Introduction to Arduino libraries.
- Debugging and Troubleshooting: Common errors and debugging techniques. Serial communication (Serial Monitor) for debugging.

List of Experiments

1. Blink an LED. Also modify blink rate.
2. Button-Controlled LED. Turn an LED on/off using a push button.
3. Debounce a Button. Implement debounce to handle noisy button presses.
4. LED Fading to control LED brightness.
5. Potentiometer-Controlled LED. Adjust LED brightness using potentiometer and analog Read().
6. Serial Monitor Interaction. Display text and sensor readings on the Serial Monitor.
   16x2 LCD Display. Display "Hello, World!" and temperature data.

Project-based learning to be encouraged.

SUGGESTED READINGS

"Getting Started With Arduino" By Massimo Banzi and Michael Shiloh. Shroff/Maker Media; fourth edition (2022). ISBN-13 : 978-9391043858

B.Sc. Physical Sciences with Physics as one of the Core Disciplines

DISCIPLINE SPECIFIC CORE COURSE – DSC 8-1: ELECTROMAGNETIC THEORY

Course Title and Code	Credits	Credit distribution of the course			Pre-requisite of the course
		Lecture	Tutorial	Practical	
Electromagnetic Theory DSC 8-1	4	3	0	1	

COURSE OBJECTIVES

This core course develops further the concepts learnt in the electricity and magnetism course to understand the properties of electromagnetic waves in vacuum and different media.

LEARNING OUTCOMES

At the end of this course the student will be able to,

- Apply Maxwell's equations to deduce wave equation, electromagnetic field energy, momentum and angular momentum density
- Understand electromagnetic wave propagation in unbounded media: Vacuum, dielectric medium, conducting medium, plasma
- Understand electromagnetic wave propagation in bounded media: reflection and transmission coefficients at plane interface in bounded media
- Understand polarization of electromagnetic waves: Linear, circular and elliptical polarization. Production as well as detection of waves in laboratory
- Learn the features of planar optical wave guide
- In the laboratory course, the students will get an opportunity to perform experiments with polarimeter, Babinet compensator, ultrasonic grating and simple dipole antenna. Also, to study phenomena of interference, refraction, diffraction and polarization

SYLLABUS OF DSC 8
THEORY COMPONENT
(Hours: 45)

Unit I **(6 Hours)**

Maxwell's equations; Coulomb gauge and Lorentz gauge; Poynting's theorem and Poynting's vector; electromagnetic (em) energy density; physical concept of electromagnetic field energy density

Unit II **(19 Hours)**

EM wave propagation in unbounded media: Plane em waves through vacuum and isotropic dielectric medium: transverse nature, refractive index, dielectric constant, wave impedance. Plane em waves through conducting medium: relaxation time, skin depth, attenuation constant; Wave propagation through dilute plasma: electrical conductivity of ionized gases, plasma frequency, refractive index, skin depth.
EM waves in bounded media: Boundary conditions at a plane interface between two media; reflection and refraction of plane em waves at plane interface between two dielectric media - Laws of reflection and refraction; Fresnel's formulae for perpendicular and parallel polarization, Brewster's law; reflection and transmission coefficients; total internal reflection, evanescent waves; metallic reflection (normal incidence)

Unit III **(13 Hours)**

Polarization of EM waves: Propagation of em waves in an anisotropic media; symmetric nature of dielectric tensor; Fresnel's formula; uniaxial and biaxial crystals; light propagation in uniaxial crystal; double refraction; polarization by double refraction; Nicol prism; ordinary and extraordinary refractive indices; production and detection of plane, circular and elliptically polarized light; phase retardation plates: quarter wave and half wave plates

Unit IV **(7 Hours)**

Wave guides: Planar optical wave guides; planar dielectric wave guide ($-d/2 < x < d/2$); condition of continuity at interface; phase shift on total reflection; Eigenvalue equations; phase and group velocity of guided waves; field energy and power transmission (TE mode only).

PRACTICAL COMPONENT: ELECTROMAGNETIC THEORY
(Hours: 30)

- Mandatory sessions on the construction and use of specific measurement instruments and experimental apparatuses used in the lab, including necessary precautions.
- Mandatory sessions on the review of experimental data analysis, sources of error and their estimation in detail, writing of scientific laboratory reports including proper reporting of errors.
- Application to the specific experiments done in the lab.

At least six experiments to be performed from the following list:

7. To verify the law of Malus for plane polarized light.
8. To determine the specific rotation of sugar solution using polarimeter.
9. To analyse elliptically polarized light by using a Babinet's compensator.
10. To study the elliptical polarized light using Fresnel rhomb.
11. To determine the wavelength and velocity of ultrasonic waves in a liquid (Kerosene Oil, Xylene, etc.) by studying the diffraction through ultrasonic grating.

12. To study the reflection and refraction of microwaves
13. To study polarization and double slit interference in microwaves.
14. To determine the refractive index of liquid by total internal reflection using Wollaston's air-film.
15. To determine the refractive index of (1) glass and (2) a liquid by total internal reflection using a Gaussian eyepiece.
16. To verify the Stefan's law of radiation and to determine Stefan's constant.
17. To determine Boltzmann constant using V-I characteristics of PN junction diode.
18. To find numerical aperture of an optical fibre.
19. To use a prism shaped double refracting crystal to determine the refractive indices of the quartz/ calcite corresponding to ordinary and extra-ordinary rays.
20. To measure birefringence of Mica
21. To determine the dielectric constant of solids using microwaves

REFERENCES

Essential Readings for the Theory Component

1) Introduction to Electrodynamics, D. J. Griffiths, 3rd edition, 1998, Benjamin Cummings.
2) Electromagnetic Field and Waves, P. Lorrain and D. Corson, 2nd edition, 2003, CBS Publisher
3) Classical Electrodynamics, J. D. Jackson, 3rd edition, 2010, Wiley
4) Principle of Optics, M. Born and E. Wolf, 6th edition, 1980, Pergamon Press
5) Optics, A. Ghatak, 6th edition, 2017, McGraw-Hill Education, New Delhi

Additional Readings for the Theory Component

2) Electricity, Magnetism and Electromagnetic Theory, S. Mahajan, and S. R. Choudhary, 2017, TMH
3) Principles of Electromagnetic Theory, C. Jain, 2017, Narosa Publishing House
4) Elements of Electromagnetics, M. N. O. Sadiku, 2001, Oxford University Press.
5) Fundamentals of Electromagnetics, M. A. W. Miah, 1982, Tata McGraw Hill
6) Problems and solution in Electromagnetics, A. Ghatak, K. Thyagarajan and Ravi Varshney, 2015
7) Electromagnetic field Theory, R. S. Kshetrimayun, 2012, Cengage Learning
8) Engineering Electromagnetic, W. H. Hayt, 8th edition, 2012, McGraw Hill.
9) Electromagnetics, J. A. Edminster, Schaum Series, 2006, Tata McGraw Hill.
10) 2008+ Solved Problems in Electromagnetics, S. A. Nasar, 2001, SciTech

References for the Practical Component

1) Advanced Practical Physics for students, B. L. Flint and H. T. Worsnop, 1971, Asia Publishing House
2) Advanced level Physics Practicals, M. Nelson and J. M. Ogborn, 4th edition, reprinted 1985, Heinemann Educational Publisher

3) Electromagnetic Field Theory for Engineers & Physicists, G. Lehner, 2010, Springer
4) Practical Physics, G. L. Squires, 4th edition, 2015, Cambridge University Press
5) Engineering Practical Physics, S. Panigrahi and B. Mallick, 2015, Cengage Learning India Pvt. Ltd

B.Sc. Physical Sciences with Physics as one of the Core Disciplines

DISCIPLINE SPECIFIC ELECTIVE COURSE – DSE 8-1 : APPLIED OPTICS

Course Title and Code	Credits	Credit distribution of the course			Pre-requisite of the course
		Lecture	Tutorial	Practical	
Applied Optics DSE 8-1	4	2	0	2	

COURSE OBJECTIVES

This paper provides the conceptual understanding of various branches of modern optics to the students. This course introduces basic principles of LASER, Holography and signal transmission via optical fiber.

LEARNING OUTCOMES

At the end of this course, students will be able to

- Understand basic lasing mechanism qualitatively, types of lasers, characteristics of laser light and its application in developing LED, Holography.
- Gain concepts of Fourier optics and Fourier transform spectroscopy.
- Understand basic principle and theory of Holography.
- Grasp the idea of total internal reflection and learn the characteristics of optical fibers.

SYLLABUS OF DSE 8-1
THEORY COMPONENT
(Hours: 30)

Unit I **(8 Hours)**

Photo-sources and Detectors Lasers
Absorption process, Spontaneous and stimulated emission processes, Theory of laser action, Population of energy levels, Einstein's coefficients and optical amplification, properties of laser beam, Ruby laser, He-Ne laser and semiconductor lasers. Light Emitting Diode (LED) and photo-detectors.

Unit II **(7 Hours)**

Fourier Optics

Fourier Optics and Fourier Transform Spectroscopy (Qualitative explanation). Concept of Spatial frequency filtering, Fourier transforming property of a thin lens, Fourier Transform Spectroscopy (FTS): measuring emission and absorption spectra, with wide application in atmospheric remote sensing, NMR spectrometry, and forensic science.

Unit III

Holography Introduction **(7 Hours)**

Basic principle and theory: recording and reconstruction processes, Requirements of holography-coherence, etc. Types of holograms: The thick or volume hologram, Multiplex hologram, white light reflection hologram; application of holography in microscopy, interferometry, and character recognition.

Unit IV **(8 Hours)**

Photonics

Optical fibres: Total Internal Reflection, Basic characteristics of the optical fibre: Principle of light propagation through a fibre, the coherent bundle, The numerical aperture, Attenuation in optical fibre and attenuation limit; Single mode and multimode fibres, Fibre optic sensors: Fibre Bragg Grating.

<u>PRACTICAL COMPONENT: APPLIED OPTICS</u>
(Hours: 60)

College to set up at least 10 experiments from the listed experiments. *At least 6 experiments to be performed by students from amongst the experiments offered.*

Experiments on Lasers

1. To determine the grating radial spacing of the Compact Disc (CD) by reflection using He-Ne or solid-state laser.
2. To find the width of the wire or width of the slit using diffraction pattern obtained by a He-Ne or solid-state laser.
3. To find the polarization angle of laser light using polarizer and analyzer,
4. Thermal expansion of quartz using laser
5. To determine the wavelength and angular spread of laser light by using plane diffraction grating.

Experiments on Semiconductor Sources and Detectors

1. V-I characteristics of LED.
2. Study the characteristics of solid state laser.
3. Study the characteristics of LDR.
4. Characteristics of Photovoltaic Cell/ Photodiode.
5. Characteristics of IR sensor.

Experiments on Fourier Optics

1. Optical image addition/subtraction.
2. Optical image differentiation.
3. Fourier optical filtering.
4. Construction of an optical 4f system

Experiment on Fourier Transform Spectroscopy

To study the interference pattern from a Michelson interferometer as a function of mirror separation in the interferometer. The resulting interferogram is the Fourier transform of the power spectrum of the source. Analysis of experimental interferograms allows one to determine the transmission characteristics of several interference filters. Computer simulation can also be done.

Experiments on Holography and interferometry

1. Recording and reconstruction of holograms (Computer simulation can also be done).
2. To construct a Michelson interferometer or a Fabry Perot interferometer.
3. To determine the wavelength of sodium light by using Michelson's interferometer.
4. To measure the refractive index of air.

Experiments on Fibre Optics

1. To measure the numerical aperture of an optical fibre
2. To measure the near field intensity profile of a fibre and study its refractive index profile
3. To study the variation of the bending loss in a multimode fibre
4. To determine the power loss at a splice between two multimode fibre
5. To determine the mode field diameter (MFD) of fundamental mode in a single mode fibre by measurements of its far field Gaussian pattern

REFERENCES

1. Introduction to Fourier Optics, Joseph W. Goodman, The McGraw- Hill, 1996.
2. Introduction to Fiber Optics, A. Ghatak & K. Thyagarajan, Cambridge University Press.
3. Fibre optics through experiments, M. R. Shenoy, S. K. Khijwania, et.al. 2009, Viva Books
4. Optical Electronics, Ajoy Ghatak and K. Thyagarajan, 2011, Cambridge University Press
5. Optics, Karl Dieter Moller, Learning by computing with model examples, 2007, Springer.

B.Sc. Physical Sciences with Physics as one of the Core Disciplines

DISCIPLINE SPECIFIC ELECTIVE COURSE – DSE 8-2 : ATMOSPHERIC PHYSICS AND CLIMATE CHANGE

Course Title and Code	Credits	Credit distribution of the course			Pre-requisite of the course
		Lecture	Tutorial	Practical	
Atmospheric Physics and Climate Change DSE 8-2	4	3	0	1	

COURSE OBJECTIVES

This course familiarizes the students with the atmospheric processes, and vertical thermal and dynamical features in the lower and middle atmosphere. It enables to learn remote sensing techniques to explore atmospheric processes and helps to understand long term oscillations and fluid system dynamics which control climate change. Also, it delineates characteristics of pollutants and aerosols variability in the lower and middle atmosphere. Another important aspect would be how the different atmospheric and meteorological parameters are changing over a period of time from Climate change perspective.

LEARNING OUTCOMES

By successfully completing this course students will be able to,

- Have an overview of thermal structure of the Earth's atmosphere as well as various dynamical processes occurring in different layers of the atmosphere.
- Develop an understanding of remote sensing techniques such as radar, satellite, and lidar systems.
- Understand the origin of different atmospheric oscillations, which are prominent at different altitudes. In addition, understating will be improved on several features of low- and high-pressure systems and wind circulation.
- Atmospheric and Ocean interaction can be learnt how they influence each other on long term time scales connected with such as El Niño Southern Oscillations (ENSO)
- Climate Change can be understood by using long term atmospheric data (both observations and model) and further exploring and utilization of different numerical techniques for the fine and long-term temporal and regional to global scales.
- Develop the problem-solving skills using observations and conducting simulations. This would clarify the fundamental processes and modifications under different conditions.

SYLLABUS OF DSE 8-2
THEORY COMPONENT
(Hours: 45)

Unit I **(10 Hours)**

General features of Earth's atmosphere
Thermal structure of the Earth's Atmosphere, Composition of atmosphere, Hydrostatic equation, Potential temperature, Atmospheric Thermodynamics, Greenhouse effect, Local winds, monsoons, fogs, clouds, precipitation, Atmospheric boundary layer, Sea breeze and land breeze. Instruments for meteorological observations including RS/RW, meteorological processes and convective systems, fronts, Cyclones and anticyclones, thunderstorms. Dynamics of Particulate Matter (PM), pollutants and meteorological parameters diurnal, seasonal and annual variability. PM and their effect on human health.

Unit II **(13 Hours)**

Atmospheric Dynamics
Scale analysis, Fundamental forces, Basic conservation laws, The Vectorial form of the momentum equation in rotating coordinate system, scale analysis of equation of motion, Applications of the basic equations, Circulations and vorticity, Atmospheric oscillations, Quasi biennial oscillation, annual and semi-annual oscillations, Mesoscale and general circulations.
Atmospheric Waves
Surface water waves, wave dispersion, acoustic waves, buoyancy waves, propagation of atmospheric gravity waves (AGWs) in a nonhomogeneous medium, Lamb wave, Rossby waves and its propagation in three dimensions and in sheared flow, wave absorption, non-linear consideration.

Unit III **(7 Hours)**

Remote Sensing Techniques (Atmospheric Radar)
Radar equation and return signal, Signal processing and detection, Various type of atmospheric radars, Applications of radars to study atmospheric phenomena, Classification and properties of aerosols, Aerosol studies using Lidars.

Unit IV **(15 Hours)**

Climate Change
Historical trends of CO_2 and temperature, understanding on sea level rise. Thermodynamics in climatology, long term energy balance and cycles, and rudimentary introduction to climate change models. Physical processes of greenhouse gases warming the planet, Impact of climate change in extreme weather, regional case studies focus on India subcontinent, Climate policies and international agreement - UNFCCC, Kyoto Protocol, Paris Agreement, Role of COP meetings, Concept of Net-Zero Emission, and Climate Change and public health.

PRACTICAL COMPONENT: ATMOPHERIC PHYSICS AND CLIMATE CHANGE
(Hours: 30)

Atmospheric Physics

Scilab/Python/Matlab based simulations experiments based on Atmospheric Physics problems listed below.

At least 03 Experiments from the following should be conducted.

1. Numerical Simulation for atmospheric waves using dispersion relations for
    a. Atmospheric gravity waves (AGW)
    b. Kelvin waves
    c. Rossby waves, and
    d. mountain waves.
2. Processing of radar data a. VHF radar, b. X-band radar, and c. UHF radar,
3. Offline and online processing of LIDAR data.
4. Radiosonde data and its interpretation in terms of atmospheric parameters using vertical profiles in different regions of the globe. Suggested parameters calculations are (i) Brunt Vaisala frequency, (ii) potential temperature, (iii) pressure-height conversion, and (iv) thermal wind equation.
5. Handling of satellite data and plotting of atmospheric parameters using radio occultation technique

Climate Change

i. Time series analysis of temperature using long term data over metropolitan cities in India – an approach to understand the climate change.
ii. PM 2.5 measurement using compact instruments and experience with data from CPCB and DPCC to investigate the Climate Change.

Field visits to National centre for medium range weather forecasting, India meteorological departments, and ARIES Nainital to visualise onsite radiosonde balloon launch, simulation on computers and radar operations on real time basis.

REFERENCES

Essential Readings for the Theory Component

1. Fundamental of Atmospheric Physics, M.L Salby; Academic Press, Vol 61, 1996
2. The Physics of Atmosphere – John T. Houghton; Cambridge University press; 3 rd edn. 2002.
3. An Introduction to dynamic meteorology – James R Holton; Academic Press, 2004
4. Radar for meteorological and atmospheric observations – S Fukao and K Hamazu, Springer Japan, 2014

Additional Readings for the Theory Component

1. Stratosphere Troposphere Interactions - K Mohanakumar, Springer Netherlands, 2008.

2. Climate change in the Himalayas, Springer publication, by GB Pant, P Pradeep Kumar, J V Revadekar, Narendra Singh, 2018.
3. PM2.5 diminution and haze events over Delhi during the COVID-19 lockdown period: an interplay between the baseline pollution and meteorology, Nature- Scientific Reports, 10(13442). https://doi.org/10.1038/s41598- 020-70179-8., S. K. Dhaka, Chetna, V. Kumar, V. Panwar, A. P. Dimri, N. Singh, P. K. Patra, Y. Matsumi, M. Takigawa, and T. Nakayama (2020)
4. Gravity wave generation in the lower stratosphere due to passage of the typhoon 9426 (Orchid) observed by the MU radar at Shigaraki (34.85 N, 136.10 E), SK Dhaka, M Takahashi, Y. Shibagaki, MD Yamanaka, S Fukao, Journal of Geophysical Research: Atmosphere 108 (D19), 2003.
5. Indian MST radar observations of gravity wave activities associated with tropical convection, SK Dhaka, PK Devrajan, Y Shibagaki, RK Choudhary, S Fukao, Journal of Atmospheric and Solar-Terrestrial Physics 63 (15), 1631-1642.
6. Lidar and its applications, Application of Lidar to study atmospheric phenomenon. Data analysis tools and techniques (https://www.narl.gov.in)

References for the Practical Component

Data sources for radar, lidar, satellite and radiosondes

1. https://www.narl.gov.in
2. http://www.imd.gov.in
3. https://www.ncmrwf.gov.in/
4. https://www.aries.res.in/
5. http://www.rish.kyoto-u.ac.jp/ear/index-e.html

B.Sc. Physical Sciences with Physics as one of the Core Disciplines

DISCIPLINE SPECIFIC ELECTIVE COURSE – DSE 8-3 : ATOMIC AND MOLECULAR PHYSICS

Course Title and Code	Credits	Credit distribution of the course			Pre-requisite of the course
		Lecture	Tutorial	Practical	
Atomic and Molecular Physics DSE 8-3	4	3	1	0	

COURSE OBJECTIVES

This course introduces the basic concepts of atomic, molecular and nuclear physics to an undergraduate student. Advanced mathematics is avoided and the results of quantum mechanics are attempts to explain, or even to predict, the experimental observations of spectroscopy. The student will be able to visualize an atom or molecule as a physical entity rather than a series of mathematical equations.

LEARNING OUTCOMES

On successful completion of the module students should be able to elucidate the following main features.

- Stern-Gerlach experiment, electron spin, spin magnetic moments
- Space quantization and Zeeman effect
- Spectral notations for atomic and molecular states and corresponding term symbols
- Understanding of atomic spectra and molecular spectra
- Basic principle of Raman spectroscopy and Franck Condon principle
- To complete scientific potential lies on the way we are able to interpret the fundamental astrophysical and nuclear data. This acquired knowledge will be a common base for the areas of astrophysics, nuclear, medical, geology and other inter-disciplinary fields of Physics, Chemistry and Biology. Special skills required for the different fields will be enhanced.

SYLLABUS OF DSE 8-3
THEORY COMPONENT
(Hours: 45)

Unit I **(11 Hours)**

Atomic Physics
One-electron atoms: Degeneracy of energy levels and selection rules, modes of relaxation of an excited atomic state, line intensities and the lifetimes of excited states, line shapes and widths.
Fine structure of hydrogenic atoms: Shifting of energy levels, splitting of spectral lines, relativistic correction to kinetic energy, spin-orbit term, Darwin term, fine structure spectral lines, Lamb shift (qualitative idea).

Unit II **(12 Hours)**

Atoms in external magnetic fields: Larmor's theorem, Stern-Gerlach experiment, normal Zeeman effect, Paschen Back effect, and anomalous Zeeman effect, g-factors.
Two and multi-electron systems: Spin multiplicity, singlet and triplet states and selection rules in helium atom, central field approximation, Aufbau and Pauli exclusion principle, Slater determinant, LS and JJ coupling scheme (equivalent and non-equivalent electrons), term symbols and Hund's rule, Lande' interval rule.
Qualitative Discussion of Lamb shift and Auger effect.

Unit III **(11 Hours)**

Molecular Physics
Electronic states of diatomic molecules: Linear combination of atomic orbitals (LCAO), bonding and antibonding orbitals; 'gerade', 'ungerade', molecular orbitals and the ground state electronic configurations for homo and hetero-nuclear diatomic molecules, classification of molecular excited states of diatomic molecule, Vector representation of Orbital and electron spin angular momenta in a diatomic molecule, The Born-Oppenheimer approximation, Concept of Potential energy curve for a diatomic molecule, Morse potential. The Franck-Condon principle

Unit IV **(11 Hours)**

Molecular Spectra of diatomic molecule: Rotational Spectra (rigid and non-rigid rotor), Vibrational Spectra (harmonic and anharmonic), Vibration-Rotation Spectrum of a diatomic molecule, Isotope effect, Intensity of spectral lines
Raman Effect: Classical Theory (with derivation) of Raman effect, pure rotational Raman Lines, Stoke's and Anti-Stoke's Lines, comparison with Rayleigh scattering
Idea of spin resonance spectroscopy (Nuclear Magnetic Resonance, Electron Spin Resonance) with few examples, estimation of magnetic field of the Sun.

REFERENCES

Essential Readings

1. Physics of Atoms and Molecules, B. H. Bransden and C. J. Jochain, 2nd edition, Pearson
2. Fundamentals of Molecular Spectroscopy, C. N. Banwell and E. M. McCash, 1994, Tata McGraw – Hill
3. Atomic physics, J. B. Rajam and foreword by Louis De Broglie, 2010, S. Chand and Co.
4. Atoms, Molecules and Photons, W. Demtroder, 2nd edition, 2010, Springer
5. Atomic, Nuclear and. Particle Physics. Compiled by. The Physics Coaching Class. University of science and Technology of China, edited By Yung-Kuo Lim. World scientific.
6. Atomic Physics, S. N. Ghoshal, 2019, S. Chand Publication
7. Introduction to Spectroscopy, D. L. Pavia, G. M. Lampman, G. A. Kriz and J. R. Vyvyan, 5th edition, 2014, Brookes/Cole

Additional Readings

1. Basic Atomic and Molecular Spectroscopy, J. M. Hollas, Royal Society of Chemistry
2. Molecular Spectra and Molecular Structure, G. Herzberg
3. Introduction to elementary particles, D. J Griffiths, 2008, Wiley
4. Atomic and molecular Physics, R. Kumar, 2013, Campus Book Int.
5. The Fundamentals of Atomic and Molecular Physics, Undergraduate Lecture Notes in Physics, 2013, Springer

B.Sc. Physical Sciences with Physics as one of the Core Disciplines

DISCIPLINE SPECIFIC ELECTIVE COURSE – DSE 8-4: DIGITAL SIGNAL PROCESSING

Course Title and Code	Credits	Credit distribution of the course			Pre-requisite of the course
		Lecture	Tutorial	Practical	
Digital Signal Processing DSE 8-4	4	2	0	2	

COURSE OBJECTIVES

- This paper describes the discrete-time signals and systems, Fourier Transform Representation of Aperiodic Discrete-Time Signals.
- This paper also highlights the concept of filters and realization of Digital Filters.
- At the end of the syllabus, students will develop an understanding of Discrete and fast Fourier Transform.

LEARNING OUTCOMES

At the end of this course, students will be able to develop following learning outcomes:

- Students will learn basic discrete-time signal and system types, convolution sum, impulse and frequency response concepts for linear time-invariant (LTI) systems.
- The student will be in position to understand use of different transforms and analyze the discrete time signals and systems. They will learn to analyze a digital system using z-transforms and discrete time Fourier transforms, region of convergence concepts, their properties and perform simple transform calculations.
- The student will realize the use of LTI filters for filtering different real world signals. The concept of transfer Function and difference-Equation System will be introduced. Also, they will learn to solve Difference Equations.
- Students will develop an ability to analyze DSP systems like linear-phase, FIR, IIR, All-pass, averaging and notch Filter etc.
- Students will be able to understand the discrete Fourier transform (DFT) and realize its implementation using FFT techniques.
- Students will be able to learn the realization of digital filters, their structures, along with their advantages and disadvantages. They will be able to design and understand different types of digital filters such as finite & infinite impulse response filters for various applications.

SYLLABUS OF DSE 8-4
THEORY COMPONENT
(Hours: 30)

Unit I **(7 Hours)**

Discrete-Time Signals and Systems: Classification of Signals, Transformations of the Independent Variable, Periodic and Aperiodic Signals, Energy and Power Signals, Even and Odd Signals, Discrete-Time Systems, System Properties. Impulse Response, Convolution Sum; Graphical and Analytical Method, Properties of Convolution (General Idea); Sum Property System Response to Periodic Inputs, Relationship Between LTI System Properties and the Impulse Response.

Unit II **(9 Hours)**

Discrete-Time Fourier Transform: Fourier Transform Representation of Aperiodic Discrete-Time Signals, Periodicity of DTFT, Properties; Linearity; Time Shifting; Frequency Shifting; Differencing in Time Domain; Differentiation in Frequency Domain; Convolution Property. The z-Transform: Bilateral (Two-Sided) z-Transform, Inverse z- Transform, Relationship Between z-Transform and Discrete-Time Fourier Transform, z-plane, Region-of- Convergence; Differentiation in the z-Domain; Power Series Expansion Method (General Idea). Transfer Function and Difference-Equation System.

Unit III **(10 Hours)**

Filter Concepts: Phase Delay and Group delay, Zero-Phase Filter, Linear-Phase Filter, Simple FIR Digital Filters (only qualitative treatment).
Discrete Fourier Transform: Frequency Domain Sampling (Sampling of DTFT), Discrete Fourier Transform (DFT) and its Inverse, DFT as a Linear transformation, Properties; Periodicity; Linearity; Circular Time Shifting; Circular Frequency Shifting; Circular Time Reversal; Multiplication Property; Parseval’s Relation (general idea), Linear Convolution Using the DFT (Linear Convolution Using Circular Convolution).

Unit IV **(4 Hours)**

Realization of Digital Filters: FIR Filter structures; Direct-Form; Cascade-Form
Finite Impulse Response Digital Filter: Advantages and Disadvantages of Digital Filters, Types of Digital Filters: FIR Filters.

PRACTICAL COMPONENT: DIGITAL SIGNAL PROCESSING

(Hours: 60)

Sessions on the review of experimental data analysis, sources of error and their estimation in detail, writing of scientific laboratory reports including proper reporting of errors and application to the specific experiments done in the lab.

At least 06 experiments from the following using Scilab/Matlab/Python.

1. Write a program to generate and plot the following sequences: (a) Unit sample sequence $\delta(n)$, (b) unit step sequence *u(n)*, (c) ramp sequence *r(n)*, (d) real valued exponential sequence $x(n) = (0.8)^n u(n)$ for $0 \le n \le 50$.
2. Write a program to compute the convolution sum of a rectangle signal (or gate function) with itself for N = 5

$$\mathrm{x(n)} = \mathrm{rect}\left(\frac{\mathrm{n}}{2\mathrm{N}}\right) = \prod \left(\frac{\mathrm{n}}{2\mathrm{N}}\right) = \{1 \quad -\mathrm{N} \le \mathrm{n} \le \mathrm{N} \ 0 \qquad \text{otherwise}$$

3. An LTI system is specified by the difference equation: y(n)=0.8y(n-1)+x(n)
   (a) Determine $\mathrm{H(e^{iw})}$
   (b) Calculate and plot the steady state response y(n) to $\mathrm{x(n)} =$cos cos $(0.5\pi\mathrm{n})\ \mathrm{u(n)}$
4. Given a casual system y(n)=0.9y(n-1)+x(n)
   (a) Find H(z) and sketch its pole-zero plot
   (b) Plot the frequency response $|H(e^{jw})|$ and $\angle H(e^{jw})$
5. Design a digital filter to eliminate the lower frequency sinusoid of *x(t)=sin7t+sin200t*. The sampling frequency is 500 Hz. Plot its pole zero diagram, magnitude response, input and output of the filter.
6. Let *x(n)* be a 4-point sequence:
   $x(n) = \{1,1,1,1\} = \{1 \ \ 0 \le n \le 3 \ 0 \ \ otherwise$
   ↑

   Compute the DTFT $X(e^{jw})$ and plot its magnitude
   (a) Compute and plot the 4 point DFT of *x(n)*
   (b) Compute and plot the 8 point DFT of *x(n)* (by appending 4 zeros)
   (c) Compute and plot the 16 point DFT of *x(n)* (by appending 12 zeros)
7. Let *x(n)* and *h(n)* be the two 4-point sequences,
   x(n)={1,2,2,1}   *h(n)={1,-1,-1,1}*
   ↑   ↑

   Write a program to compute their linear convolution using circular convolution.
8. Using a rectangular window, design a FIR low-pass filter with a pass-band gain of unity, cut off frequency of 1000 Hz and working at a sampling frequency of 5 KHz. Take the length of the impulse response as 17.

9. Design an FIR filter to meet the following specifications:

Passband edge F_p=2 KHz
Stopband edge F_s=5 KHz
Passband attenuation A_p=2 dB
Stopband attenuation A_s=42 dB
Sampling frequency F_{sf}=20 KHz

10. The frequency response of a linear phase digital differentiator is given by

$$H_d(e^{jw}) = jwe^{-j\tau w} \ |w| \leq \pi$$

Using a Hamming window of length M = 21, design a digital FIR differentiator. Plot the amplitude response

REFERENCES

Essential Readings for the Theory Component

1. Digital Signal Processing, Tarun Kumar Rawat, 2015, Oxford University Press, India
2. Digital Signal Processing, S. K. Mitra, McGraw Hill, India.
3. Principles of Signal Processing and Linear Systems, B.P. Lathi, 2009, 1st Edn. Oxford University Press.
1. Fundamentals of signals and systems, P.D. Cha and J.I. Molinder, 2007, Cambridge University Press.
2. Digital Signal Processing Principles Algorithm & Applications, J.G. Proakis and D.G. Manolakis, 2007, 4th Edn., Prentice Hall.

Additional Readings for the Theory Component

1. Digital Signal Processing, A. Anand Kumar, 2nd Edition, 2016, PHI learning Private Limited.
2. Digital Signal Processing, Paulo S.R. Diniz, Eduardo A.B. da Silva, Sergio L. Netto, 2nd Edition, 2017, Cambridge University Press.

References for the Practical Component

1. A Guide to MATLAB, B.R. Hunt, R.L. Lipsman, J.M. Rosenberg, 2014, 3rd Edn., Cambridge University Press.
2. Fundamentals of Digital Signal processing using MATLAB, R.J. Schilling and S.L. Harris, 2005, Cengage Learning.
3. Getting started with MATLAB, Rudra Pratap, 2010, Oxford University Press.

B.Sc. Physical Sciences with Physics as one of the Core Disciplines

DISCIPLINE SPECIFIC ELECTIVE COURSE – DSE 8-5 : NONLINEAR DYNAMICS

Course Title and Code	Credits	Credit distribution of the course			Pre-requisite of the course
		Lecture	Tutorial	Practical	
Nonlinear Dynamics DSE 8-5	4	3	0	1	

COURSE OBJECTIVES

This course introduces the main topics of low-dimensional nonlinear systems, with applications to a wide variety of disciplines, including physics, engineering, mathematics, chemistry, and biology. This course begins with the first order dynamical system and the idea of phase space, flows and trajectories and ends with the elementary fluid dynamics. Students will also appreciate the introduction to chaos and fractals.

LEARNING OUTCOMES

Upon successful course completion, a student will be able to:

- Demonstrate understanding of the concepts that underlay the study of dynamical systems.
- Understand fractals as self-similar structures.
- Learn various forms of dynamics and different routes to chaos.
- Understand basic Physics of fluids and its dynamics theoretically and experimentally and by computational simulations
- In the Lab course, students will be able to perform Simulations/Lab experiments on: coupled Oscillators, Simulation of Simple Population, Predator-Prey Dynamics, Simple genetic circuits, rate equations for some simple chemical reactions, Fractal Formation in Deterministic Fractals, Fluid Flow Models.

<u>SYLLABUS OF DSE 8-5</u>
<u>THEORY COMPONENT</u>
(Hours: 45)

Unit I **(15 Hours)**

Introduction to Dynamical systems: Definition of a continuous first order dynamical system. The idea of phase space, flows and trajectories. Simple mechanical systems as first order dynamical systems: simple and damped harmonic oscillator. Sketching flows and trajectories in phase space. Fixed points, attractors, stability of fixed points, basin of attraction, notion of qualitative analysis of dynamical systems. Examples of dynamical systems – Population models e.g. exponential growth and decay, logistic growth, predator- prey dynamics. Rate equations for chemical reactions e.g. auto catalysis, bi-stability.

Unit II **(15 Hours)**

Introduction to Chaos and Fractals: Chaos in nonlinear equations - Logistic map and Lorenz equations: Dynamics from time series. Parameter dependence- steady, periodic and chaotic states. Cobweb iteration. Fixed points. Defining chaos- a periodic, bounded, deterministic and sensitive dependence on initial conditions. Period- Doubling route to chaos.
Self-similarity and fractal geometry: Fractals in nature - trees, coastlines, earthquakes, etc. Need for fractal dimension to describe self-similar structure. Deterministic fractal vs. self-similar fractal structure.

Unit III **(8 Hours)**

Elementary Fluid Dynamics: Importance of fluids: Fluids in the pure sciences, fluids in technology. Study of fluids: Theoretical approach, experimental fluid dynamics, computational fluid dynamics. Basic physics of fluids: The continuum hypothesis-concept of fluid element or fluid parcel; Definition of a fluid- shear stress; Fluid properties-viscosity, thermal conductivity, mass diffusivity, other fluid properties and equation of state

Unit IV **(7 Hours)**

Flow phenomena
Flow dimensionality, steady and unsteady flows, uniform and non-uniform flows, viscous and inviscid flows, incompressible and compressible flows, laminar and turbulent flows, rotational and irrotational flows, separated and unseparated flows. Flow visualization - streamlines, pathlines, streaklines.

PRACTICAL COMPONENT: NONLINEAR DYNAMICS
(Hours: 30)

Computing and visualizing trajectories using software such as Scilab, Maple, Octave, XPPAUT based on Applied Dynamics problems.
At least 06 experiments from the following:

1. To determine the coupling coefficient of coupled pendulums.
2. To determine the coupling coefficient of coupled oscillators.
3. To determine the coupling and damping coefficient of damped coupled oscillator.
4. To study population models e.g. exponential growth and decay, logistic growth,
5. predator-prey dynamics.
6. To study rate equations for chemical reactions e.g. auto catalysis, bistability.
   (i) To study examples from game theory.
   (ii) To study period doubling route to chaos in logistic map.
   (iii)To study various attractors of Lorenz equations.
   (iv) Computational visualization of fractal formations of Deterministic fractal.
   (v) Computational visualization of fractal formations of self-similar fractal.
   (vi) Computational visualization of fractal formations of Fractals in nature – trees, coastlines, earthquakes.
   (vii) Computational Flow visualization - streamlines, pathlines, streaklines.

REFERENCES

1. Nonlinear Dynamics and Chaos, Steven H. Strogatz, Levant Books, Kolkata, 2007
2. Understanding Nonlinear Dynamics, Daniel Kaplan and Leon Glass, Springer.
3. An Introduction to Fluid Dynamics, G.K.Batchelor, Cambridge Univ. Press, 2002
4. Simulation of ODE/PDE Models with MATLAB®, OCTAVE and SCILAB: Scientific and Engineering Applications: A. Vande Wouwer, P. Saucez, C. V. Fernández. 2014 Springer

B.Sc. Physical Sciences with Physics as one of the Core Disciplines

DISCIPLINE SPECIFIC ELECTIVE COURSE – DSE 8-6 : NUCLEAR AND PARTICLE PHYSICS

Course Title and Code	Credits	Credit distribution of the course			Pre-requisite of the course
		Lecture	Tutorial	Practical	
Nuclear and Particle Physics DSE 8-6	4	3	1	0	

COURSE OBJECTIVES

The objective of the course is to impart the understanding of the sub atomic particles and their properties. It will emphasize to gain knowledge about the different nuclear techniques and their applications in different branches Physics and societal application. The course will focus on the developments of problem-based skills.

LEARNING OUTCOMES

- To be able to understand the basic properties of nuclei: Nuclear charge and mass density, size, magnetic and electric moments
- To appreciate the formulations and contrasts between different nuclear models such as Liquid drop model, Fermi gas model and Shell Model and evidences in support.
- Familiarization with different types of nuclear reactions, Q- values, compound and direct reactions.
- To know about energy losses due to ionizing radiations, energy losses of electrons, gamma ray interactions through matter and neutron interaction with matter.
- To understand classification of fundamental forces based on their range, time-scale and mediator mass.
- To understand Scattering cross-sections of 2 to 2 processes and their inherent symmetries.
- Angular and energy distributions for three body decay process.
- Discrete symmetries of nature and associated conservation laws and Colour triplet

SYLLABUS OF DSE 8-6
THEORY COMPONENT
(Hours: 45)

Unit I **(15 Hours)**

General Properties of Nuclei and Nuclear Models: Constituents of nucleus and their Intrinsic properties. Fermi gas model (degenerate fermion gas, nuclear symmetry potential in Fermi gas). Single Particle Shell Model (Concept of mean field and spin orbit coupling), Estimation of Spin parity and electromagnetic moments for ground state configuration for even- even, even -odd and odd-odd nuclei. Basic concept of Collective Model and deformed shell model.

Unit II **(10 Hours)**

Nuclear Reactions: Types of Reactions, Units of related physical quantities, Conservation Laws, Kinematics of reactions, Q-value, Reaction rate, Reaction cross section, Concept of compound and direct reaction, Coulomb scattering (Rutherford scattering).

Unit III **(8 Hours)**

Interaction of Nuclear Radiation with matter: Interaction of radiation for light ions (electrons) and heavy charge particles, neutron and photons with matter. Energy loss due to ionization (Bethe-Block formula), for both light and heavy-ions, Cerenkov radiation. Gamma ray interaction with matter. Neutron interaction with matter.

Unit IV **(12 Hours)**

Particle Physics: Overview of Particle spectrum and their interactions in the Standard Model. Range, time-scale and relative strength of interactions. Interactions at a distance mediated by virtual particles (Exchange Force).

Requirement of High Energy Colliders to probe the constituents of nucleon, Linear and circular colliders, Inelastic collisions at Hadron colliders. Brief idea about Large Hadron Collider experiment and Indian ALICE and CMS and collaborations.

Kinematics for $2 \rightarrow 2$ scattering processes and Crossing symmetries of scattering amplitudes. Angular and energy distributions of decaying particles in $1 \rightarrow 3$ decay processes (muon decay / beta decay).

Lepton and Baryon quantum numbers. Isospin, Strangeness and Hypercharge. Gell-Mann-Nishijima formula. Parity and Charge conjugation of a particle state. Time Reversal and General CPT theorem.

Valence quark model of Murray Gell-Mann and Yuval Ne'eman, current and constituent masses of quarks, flavor symmetry Isospin triplets, Baryon octet and decuplet, Meson octet. Antisymmetric Δ^{++} state and necessity for color quantum number. Evidence for color triplet quarks from $\mathbf{e^+e^-}$ annihilation experiment.

REFERENCES

Essential Readings

For Nuclear Physics

1. Basic ideas and concepts in Nuclear Physics: An introductory approach by K Heyde, third edition, IOP Publication, 1999.
2. Introductory Nuclear Physics by K S Krane, Wiley-India Publication, 2008.
3. Nuclear Physics by S N Ghoshal, First edition, S. Chand Publication, 2010.
4. Nuclear Physics: principles and applications by J Lilley, Wiley Publication, 2006.
5. Concepts of Nuclear Physics by B L Cohen, Tata McGraw Hill Publication, 1974.
6. Radiation detection and measurement, G F Knoll, John Wiley & Sons, 2010.

For Particle Physics

7. Modern Particle Physics by Mark Thompson, Cambridge University Press, 2013.
8. Particles and Nuclei: An Introduction to the Physical Concepts by Bogdan Povh, Klaus Rith, Christoph Scholz, Frank Zetsche, Werner Rodejohann, Springer-Verlag 2015.
9. An Introductory Course of Particle Physics, Palash B. Pal (CRC Press, 2015)
10. Introduction to High Energy Physics by D H Perkins, 4^{th} edition, Cambridge University Press, 2000.
11. Introduction to elementary particles by D J Griffiths, Wiley, 2008.
12. Quarks & Leptons, F. Halzen and A. D. Martin, John Wiley, 1984.

References for Tutorial

13. Problems and Solutions in Nuclear and Particle Physics by Sergio Petreta, Springer, 2019.
14. Schaum's Outline of Modern Physics, McGraw-Hill, 1999.
15. Schaum's Outline of College Physics, by E. Hecht, 11th edition, McGraw Hill, 2009.
16. Problems and Solutions on Atomic, Nuclear and Particle Physics by Yung-Kuo Lim, World Scientific, 2000.
17. Nuclear Physics "Problem-based Approach" Including MATLAB by Hari M. Aggarwal, PHI Learning Pvt. Ltd. (2016).

B.Sc. Physical Sciences with Physics as one of the Core Disciplines

DISCIPLINE SPECIFIC ELECTIVE COURSE – DSE 8-7 : PLASMA PHYSICS

Course Title and Code	Credits	Credit distribution of the course			Pre-requisite of the course
		Lecture	Tutorial	Practical	
Plasma Physics DSE 8-7	4	3	1	0	

COURSE OBJECTIVES

This course presents the characteristic plasma properties and theoretical approaches to plasma physics. It treats single charged-particle motion in electromagnetic fields, collisions, electrical conductivity and diffusion, and plasma waves. Applications to controlled thermonuclear fusion, plasma processing, and astrophysical plasmas will serve to illustrate when and where the various theories are applicable.

LEARNING OUTCOMES

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

- define, using fundamental plasma parameters, under what conditions an ionised gas consisting of charged particles (electrons and ions) can be treated as a plasma.
- know various applications of plasma physics.
- determine the drift velocities of charged particles moving in electric and magnetic fields that are either uniform or vary slowly in space and time.
- distinguish the single particle approach, fluid approach to describe different plasma phenomena and formulate the conditions for a plasma to be in a state of perfect thermodynamic equilibrium.
- apply the conservation laws and Maxwell's equations to describe dynamical processes like wave propagation in a plasma.

SYLLABUS OF DSE 8-7
THEORY COMPONENT
(Hours: 45)

Unit I **(12 Hours)**

Introduction to plasma: Basics of gas dynamics, occurrence of plasma in nature, concept of temperature and density of plasma, Saha's equation, quasineutrality in plasma, collective behaviour, Debye shielding, Microscopic Properties (resistivity and conductivity).

Unit II **(8 Hours)**

Plasma applications and measurement: Gas discharge, industrial plasma, ionosphere plasma, solar plasma, plasma processing of materials, laser ablation, laser-driven fusion, magnetic fusion, plasma propulsion. Basics of Plasma production in laboratory and diagnostics

Unit III **(13 Hours)**

Particle confinement: Single particle motion in the presence of uniform and non-uniform electric and magnetic field, Grad-B drift, curvature drift, polarization drift, Magnetic mirrors and concept of earth magnetic mirror, Basic concept of controlled thermonuclear fusion.

Unit IV **(12 Hours)**

Fluid description of plasma: Set of fluid equations of plasmas, diamagnetic drift of plasma, plasma approximation, waves in cold plasmas, plasma oscillations, electron plasma wave, ion acoustic wave, electromagnetic wave in unmagnetized plasma.

REFERENCES

1. Introduction to Plasma Physics and Controlled Fusion by F. F. Chen (Third Edition 2016).
2. The Physics of Plasmas, by T. J. M. Boyd and J. J. Sanderson. Cambridge University Press, 2003.
3. Introduction to Plasma Physics, R.J. Goldston and P. H. Rutherford (IOP, 1995).
4. Fundamentals of Plasma Physics -J. A. Bittencourt, Springer, New York, NY (Third edition).
5. The physics of fluids and plasmas: an introduction for astrophysicists – Arnab Rai Choudhuri, Cambridge University Press (1998)
6. Principles of Plasma Physics, N.A. Krall and A.W. Trivelpiece, Mc Graw Hill (1973).
7. Principles of Plasma Discharges and Materials Processing (Second Edition, 2005) by Lieberman, Lichtenberg.

B.Sc. Physical Sciences with Physics as one of the Core Disciplines

DISCIPLINE SPECIFIC ELECTIVE COURSE – DSE 8-8: SENSORS AND DITECTORS

Course Title and Code	Credits	Credit distribution of the course			Pre-requisite of the course
		Lecture	Tutorial	Practical	
Sensors and Detectors DSE 8-8	4	3	0	1	

COURSE OBJECTIVES

To make students familiar with the constructions and working principle of different types of sensors and transducers. To make students aware about the measuring instruments and the methods of measurement and the use of different transducers.

LEARNING OUTCOMES

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

- Use concepts in common methods for converting a physical parameter into an electrical quantity.
- Classify and explain with examples of transducers, including those for measurement of temperature, strain, motion, position and light.
- Choose proper sensor comparing different standards and guidelines to make sensitive measurements of physical parameters like pressure, flow, acceleration, etc.
- Predict correctly the expected performance of various sensors.
- Locate different type of sensors used in real life applications and paraphrase their importance.
- Set up testing strategies to evaluate performance characteristics of different types of sensors and transducers and develop professional skills in acquiring and applying the knowledge outside the classroom through design of a real-life instrumentation system.

SYLLABUS OF DSE 8-8
THEORY COMPONENT
(Hours: 45)

Unit I **(13 Hours)**

Transducers, Classification of transducers on different basis, Types of transducers (Basic idea of Mechanical, resistive, capacitive, inductive, piezoelectric, optical and digital).
Sensor, Components of sensor, Direct and complex sensor (Basic idea)
Distinction between Sensor and Transducer, Characteristics of Transducers/Sensor: Static characteristics and static calibration (Calibration accuracy and component error), Dynamic characteristics.
Inductive sensor: Variable Inductance Sensors, Plunger type displacement sensor, Variable Gap Sensor, LVDT: Construction, working, output characteristics. Idea of RVDT (Qualitative).
Capacitive sensors: Variable distance-parallel plate type, variable area- parallel plate (serrated plate/teeth type), variable dielectric constant type; Sensitivity of capacitive sensors, Stretched diaphragm type

Unit II **(9 Hours)**

Magnetic Sensors: Magnetoresistive Sensors and Hall effect sensor (performance and characteristics).
Temperature sensor: RTD (construction, working and temperature coefficient), thermistor, categories of thermistor (PTC and NTC: material, shape, ranges, RT curve and accuracy specification), Thermo emf sensor (thermoelectricity generation, thermos-emf measurement, Thermocouples (construction, characteristics), and Pyroelectric sensors (pyroelectric effect and output voltage-temperature relationship).

Unit III **(13 Hours)**

Pressure sensors: Direct versus indirect pressure measurement, Different types of gauges and their working range, Mechanical gauges (McLeod Gauge), Thermal Conductivity Gauges (Thermocouple and Pirani gauges) and Ionization gauges (hot & cold cathode), advantages and limitations of various types of gauges, Gauge calibration (Static: Manometric method and dead-beat tester, dynamic calibration).
Radiation Sensors: Basic Characteristics (Concept of Work Function, Spectral Sensitivity, Spectral threshold, Quantum yield, time lag, linearity, Status and dynamic response), Types of Photodetectors: Photoemissive Cell, Photo Multiplier, Photo conductive Cell (LDR), Photovoltaic cells, photodiodes. Detection of Nuclear Radiation: Qualitative treatment of Geiger Muller counters and Scintillation detectors.

Unit IV **(10 Hours)**

Applications of Sensors and detectors: Basic principles of Remote sensing, Introduction to LiDAR (principles, applications and benefits), Types of LiDAR (air-borne and ground based) Applications of motion sensors in accelerometers and gyroscopes (qualitative analysis of working principle).
Biomedical Sensor: Electrochemical sensor (electrochemical cell, cell potential, three electrodes system, working principle).

PRACTICAL COMPONENT: SENSORS AND DETECTORS
(Hours: 30)

At least 5 experiments to be done from the list below:

1. Characteristics of LDR as a function of distance from light source.
2. Light characteristics of Photodiode.
3. Measurement of Strain using Strain Gauge.
4. To study the characteristics of a Linear Variable Differential Transformer (LVDT).
5. To study the characteristics of a Resistance Temperature Device (RTD).
6. To study the frequency response of a loudspeaker.
7. Determine characteristics of an Infrared (IR) emitter-receiver module.
8. Create vacuum in a small chamber using a mechanical (rotary) pump and/or secondary pump and measure the chamber pressure using a pressure gauge – Pirani and/or CC gauge.
9. Measurement of thermos-emf in thermopile and to calculate the Seebeck coefficient.
10. Study the pyroelectric effect and generation of induced voltage with temperature change.

REFERENCES

Essential Readings for the Theory Component

1. Experimental Methods for Engineers, J.P. Holman, McGraw Hill
2. Introduction to Measurements and Instrumentation, A.K. Ghosh, PHI Learning Pvt. Ltd.
3. 3.Transducers and Instrumentation, D.V.S. Murty, 2nd Edition, PHI Learning Pvt. Ltd.
4. Instrumentation Devices and Systems, C.S. Rangan, G.R. Sarma, V.S.V. Mani, Tata
5. McGraw Hill
6. Electronic circuits: Handbook of design & applications, U.Tietze, Ch.Schenk, Springer
7. Electronic Instrumentation by H. S. Kalsi (Mc Graw Hill Publisher)
8. Sensors and Transducers, D Patranabis, PHI Learning Pvt. Ltd.
9. An Introduction to Sensors and Instrumentations, Sobnath Singh, Narosa
10. Handbook of Modern Sensors, Jacob Fraden, Springer
11. Handbook of Thion film Technology, Maissel and Glang, Tata McGraw Hill
12. Instrumentation, Measurement and Analysis, Nakra and Chaudhry, McGraw Hill

Additional Readings for the Theory Component

1. Radiation detection and measurement, G.F. Knoll, Wiley
2. Measurement, Instrumentation and Experiment Design in Physics & Engineering, M.Sayer and A. Mansingh, PHI

References for the Practical Component

1. Electronic circuits: Handbook of design and applications, U. Tietze and C. Schenk, Springer
2. Basic Electronics: A text lab manual, P. B. Zbar, A. P. Malvino, M. A. Miller, McGraw

B.Sc. Physical Sciences with Physics as one of the Core Disciplines

SKILL BASED COURSE – SBC 8-1: INTERFACING WITH ARDUINO

Course Title and Code	Credits	Credit distribution of the course			Pre-requisite of the course
		Lecture	Tutorial	Practical	
Interfacing with Arduino SBC 8-1	2	0	0	2	SBC 7-1: Arduino Programming

COURSE OBJECTIVES

- Explain the architecture and features of the Arduino Platform.
- Set up and use the Arduino IDE to write, debug, and upload code to an Arduino board.
- Write basic programs involving digital and analog I/O, loops, functions, and conditional statements.
- Implement simple tasks such as blinking LEDs, reading buttons, generating PWM signals, and reading analog voltages.
- Understand serial communication and use the Serial Monitor for debugging.
- Design small-scale automation and control programs using Arduino logic.

LEARNING OUTCOMES

- Identify and describe the working principles of common sensors (e.g., temperature, light, distance) and actuators (e.g., motors, buzzers).
- Interface sensors (LDR, DHT11, ultrasonic, IR, etc.) with Arduino and acquire data.
- Control actuators (relays, DC motors, stepper motors, servos, buzzers) using digital output and PWM.
- Design simple projects such as automatic lighting systems, object detection alarms, or temperature monitors.
- Implement basic feedback and control systems (e.g., temperature-based fan control).
- Troubleshoot common hardware and communication issues in Arduino circuits.

SYLLABUS OF SBC 8-1
(Hours: 60)

Apart from common experiments for all students on the listed topics, project-based learning (group activities) to be encouraged.

Unit I **(24 Hours)**

Interfacing with Sensors and Actuators

- Working with Sensors: Introduction to sensors (temperature, humidity, light, magnetic field etc.). Reading analog values.
- Analog and Digital Inputs/Outputs: Analog vs. Digital signals. Working with potentiometers, photoresistors, and thermistors.
- Interfacing with Motors: Controlling DC motors. Introduction to servos and stepper motors.
- Using Displays and Keypads: Interfacing with 7-segment displays and LCDs. Using keypads for input.
- Sound and Audio Output: Working with buzzers and speakers. Generating sound with Arduino.

Unit II **(36 Hours)**

Communication Protocols and Advanced Topics.

- Serial Communication: Understanding UART and Serial Communication. Communication between Arduino and computer.
- I2C and SPI Communication: Introduction to I2C and SPI protocols. Interfacing with external modules (e.g., sensors, displays).
- Wireless Communication: Introduction to wireless modules (Bluetooth, Wi-Fi). Simple projects using wireless communication.
- Data Logging: Reading and storing data from sensors. SD card modules and data logging projects.
- Introduction to IoT with Arduino: Basics of the Internet of Things (IoT). Simple IoT project: Sending data to a web server.
- Planning and designing your project.

SUGGESTED READINGS

"Getting Started With Arduino" By Massimo Banzi and Michael Shiloh. Shroff/Maker Media; fourth edition (2022). ISBN-13 : 978-9391043858

B.Sc. Physical Sciences with Physics as one of the Core Disciplines

SKILL BASED COURSE – SBC 8-2: WEATHER FORECASTING

Course Title and Code	Credits	Credit distribution of the course			Pre-requisite of the course
		Lecture	Tutorial	Practical	
Weather forecasting SBC 8-2	2	1	0	1	

COURSE OBJECTIVES

The aim of this course is not just to impart theoretical knowledge to the students but to enable them to develop an awareness and understanding regarding the causes and effects of different weather phenomenon and basic forecasting techniques.

LEARNING OUTCOMES

The student will gain the following:

- Acquire basic knowledge of the elements of the atmosphere, its composition at various heights, variation of pressure and temperature with height.
- Learn basic techniques to measure temperature and its relation with cyclones and anti-cyclones.
- Knowledge of simple techniques to measure wind speed and its directions, humidity and rainfall.
- Understanding of absorption, emission and scattering of radiations in atmosphere; Radiation laws.
- Knowledge of global wind systems, jet streams, local thunderstorms, tropical cyclones, tornadoes and hurricanes.
- Knowledge of climate and its classification. Understanding various causes of climate change like global warming, air pollution, aerosols, ozone depletion, acid rain.
- Develop skills needed for weather forecasting, mathematical simulations, weather forecasting methods, types of weather forecasting, role of satellite observations in weather forecasting, weather maps etc. Uncertainties in predicting weather based on statistical analysis.
- Develop ability to do weather forecasts using input data.
- In the laboratory course, students should be able to learn: Principle of the working of a weather Station, Study of Synoptic charts and weather reports, Processing and analysis of weather data, Reading of Pressure charts, Surface charts, Wind charts and their analysis.

SYLLABUS OF SBC 8-2
THEORY COMPONENT
(Hours: 15)

Unit -1 **(8 Periods)**

Introduction to atmosphere: Elementary idea of atmosphere: physical structure and composition; compositional layering of the atmosphere; variation of pressure and temperature with height; air temperature; requirements to measure air temperature; temperature sensors: types; atmospheric pressure: its measurement
Measuring the weather: Wind; forces acting to produce wind; wind speed direction: units, its direction; measuring wind speed and direction; humidity, clouds and rainfall, radiation: absorption, emission and scattering in atmosphere; radiation laws.

Unit-2 **(7 Periods)**

Weather systems: Global wind systems; air masses and fronts: classifications; jet streams; local thunderstorms; tropical cyclones: classification; tornadoes; hurricanes.
Climate and Climate Change: Climate: its classification; causes of climate change; global warming and its outcomes; air pollution and its measurement, particulate matters PM 2.5, PM 10. Health hazards due to high concentration of PM2.5; aerosols, ozone depletion.
Basics of weather forecasting: Weather forecasting: analysis and its historical background; need of measuring weather; types of weather forecasting; weather forecasting methods; criteria of choosing weather station; basics of choosing site and exposure; satellites observations in weather forecasting; weather maps; uncertainty and predictability; probability forecasts.

PRACTICAL COMPONENT: WEATHER FORECASTING
(Hours: 30)

Demonstrations and Experiments:
1. Study of synoptic charts & weather reports, working principle of weather station.
2. Processing and analysis of weather data:
   (a) To calculate the sunniest time of the year.
   (b) To study the variation of rainfall amount and intensity in different seasons.
   (c) To examine the maximum and minimum temperature throughout the year.
   (d) To study the relative humidity of the day and seasons and the entire year.
   (e) Development and movement of low and high Pressure system over Indian/global region.
3. Exercises in chart reading: Plotting of constant pressure charts, surfaces charts, upper wind charts and its analysis.
4. Formats and elements in different types of weather forecasts/ warning (both aviation and non-aviation).
5. Simulation of weather system

6. Field visits to India Meteorological department and National center for medium range weather forecasting

REFERENCES

Essential Readings

1. Aviation Meteorology, I.C. Joshi, 3rd edition 2014, Himalayan Books
2. The weather Observers Hand book, Stephen Burt, 2012, Cambridge University Press.
3. Meteorology, S.R. Ghadekar, 2001, Agromet Publishers, Nagpur.
4. Text Book of Agro meteorology, S.R. Ghadekar, 2005,Agromet Publishers, Nagpur.
5. Atmosphere and Ocean, John G. Harvey, 1995, The Artemis Press.

Additional Reading:

1. PM2.5 diminution and haze events over Delhi during the COVID-19 lockdown period: an interplay between the baseline pollution and meteorology, Nature- Scientific Reports, 10(13442). https://doi.org/10.1038/s41598- 020-70179-8., S. K. Dhaka, Chetna, V. Kumar, V. Panwar, A. P. Dimri, N. Singh, P. K. Patra, Y. Matsumi, M. Takigawa, and T. Nakayama (2020)
2. Chapter 1 - Composition and thermal structure of the earth's atmosphere, Atmospheric Remote Sensing, Principles and Applications, Earth Observation, 2023, Pages 1-18, https://doi.org/10.1016/B978-0-323-99262-6.00023-7. SK Dhaka and Vinay Kumar.
3. Climatic trends in temperature, relative humidity, and wind speed over Indian landmass and isle in Andaman Nicobar and Lakshadweep during 1981-2021, MAPAN-Journal of Metrology Society of India, (2024), DOI: 10.1007/s12647-024-00743-4, Shristy Malik, A.S. Rao, S K. Dhaka.
4. Decoding temporal patterns and trends of PM10 pollution over Delhi: A multi-year analysis (2015–2022). Environmental Monitoring and Assessment, 196(6), 500. https://doi.org/10.1007/s10661-024-12638-7, Chetna, Dhaka, S. K., Walker, S.-E., Rawat, V., & Singh, N. (2024).